TECHNICAL REPORT 3

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Embassy Suites Hotel, Springfield Virginia

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Executive Summery

The Embassy Suites Hotels is a 7 story all-suite hotel located in Springfield Virginia. Situated a few miles away from downtown Washington D.C., Embassy suites contains 219 guestrooms and a host of amenities like a pool and bar areas. The building will also contain many retail stores located on the lower lever. The building stands at 91feet 10 inches and is approximately 185,000 square feet. The building floor system contains an 8 inch cast in place reinforced slab connect to mostly 14"x 30" reinforced concrete columns. The columns run between the floors at a story height of approximately nine feet. The typical story height is 9 feet except for the ground storefront level and the roof level, having heights of 18 feet and 10 feet respectively. The foundation system contains a mud mat system due to soil differentials around the site. Aside from the mud mat system, some areas of the Embassy Suites foundation contain a typical strip footing and slab on grade system. The lateral and gravity load system are integrated and consist of reinforced concrete moment frames.

Technical Report 3 delves deeper into explanations highlighted in Technical Report 1 that evaluated the existing conditions and structural components of the Embassy Suites Hotel. This was performed in order to develop a further understanding of the structural system of the building and how the building will behave and respond to a combination of loading conditions. Lateral forces due to wind and seismic were found using Analytical Procedure and Equivalent Lateral Force Procedure that are put forth in ASCE 7-05.

Additionally, a series of 2D frames where modeled to see how lateral forces are applied to the building and distributed to the lateral force resting elements. Rigidity factors and drift values due to direct shear and torsion shear effects from wind and seismic loads were found and confirmed using hand calculation. These effects showed how the frames would respond to different loadings. Also, a spot check was performed on an interior column to check adequacy.

In analyzing the structural systems, all existing structural members are sound and properly designed. Values for maximum drift were found and compared to ASCE specifications for drift limits. All frames drift values were established to have met the code requirements. Furthermore the check for the 14" x 30" interior column was confirmed for adequacy with the combination of loads applied to it.

Introduction: Embassy Suites Hotel

Figure: Site Map. (Photo taken from Google Earth)

The Embassy Suites Hotels is the newest, 7 story, luxury, hotel to become part of the Miller Global, LLC family. Along with Miller Global, the owner the collaborative construction team on this venture include, Cooper Carry, architect; SK & A Structural Engineers, PLLC , structural designers; Balfour Beatty Construction, construction manager; Jordan and Skala, MEP firm; Christopher Consultants, LTD, civil engineering firm. The site is located at the junction of I-95 and Fairfax County Parkway. The location lies in the Springfield region of Fairfax County, Virginia. The site is approximately 16 miles away from the heart of downtown Washington, D.C... Patrons will also be in close proximity to both the Fort Belvoir Main Army Post and the National Geospatial-Intelligence Agency (NGA) facility. The construction delivery method was design –bid - build. Construction began in November 2011 and will be completed July 13th 2013.

Figure: **Facade. (Photo taken from Miller Global, LLC website)**

Upon its completion, this 31.5 million, 185,000 square foot, hotel will feature many amenities. These include a large open air atrium and spacious two room suites. The hotel will serve as a model for comfort and convenience. The building's architecture boasts long flowing curved lines that give it immense visual appeal and a unique flow. The hotel's ground floor will contain a 1300 square foot pool area, a fitness center along with multiple meeting areas, a bar, a lounge and over 1400 square feet of retail space.

The ground level and upper floors store front materials will be made up of manufactured masonry (adhered concrete stone veneer). It is comprised of boral cultured stone country ledge stone along with architectural adhered precast concrete panels. It also contains 1" insulated glass windows with aluminum frames and automatic entrances. The upper levels the exterior façade will feature an exterior insulation finish system (EIFS).

This report will be describing the various structural elements and systems in place at the Embassy Suite Hotel project and how the building will respond to lateral forces. To learn how the multiple structural systems work as a part of a sound, cohesive building, one must delve into explanations of the foundation design, floor, lateral, and gravity load resisting systems design.

Structural Systems

Existing Foundation

Prior to construction, subsurface exploration and geotechnical engineering analysis were conducted on the future Embassy Suites Hotel site and was completed in January11, 2011 by ECS Mid- Atlantic, LLC. The report indicates a number of test borings were performed on 3 separate occasions. The test borings were drilled at depths ranging from 2.5' to 79' to determine the soil composition in different areas of the site. ECS Mid- Atlantics results showed fill soil material was found in ten boring locations around the site. The fill material was composed of

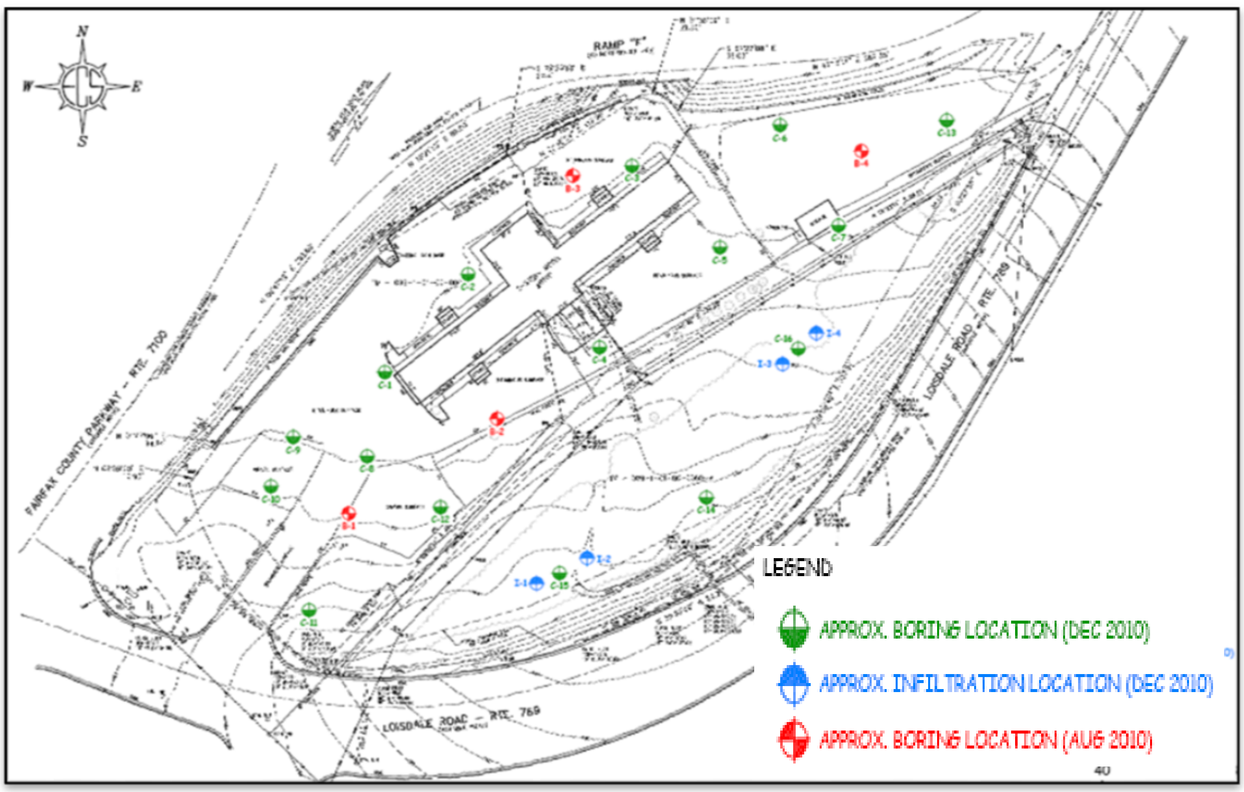


Figure: Core Boring Locations

silty sand and clay from depths of 6.5' to 8.5' below the ground surface. Further down the borings indicated the existence of natural soils that were mainly composed of clayey sand, silt and fat clay. A weather rock material was found at 77' to 78.6'and ground water was encountered at of 18.5' to 65'.

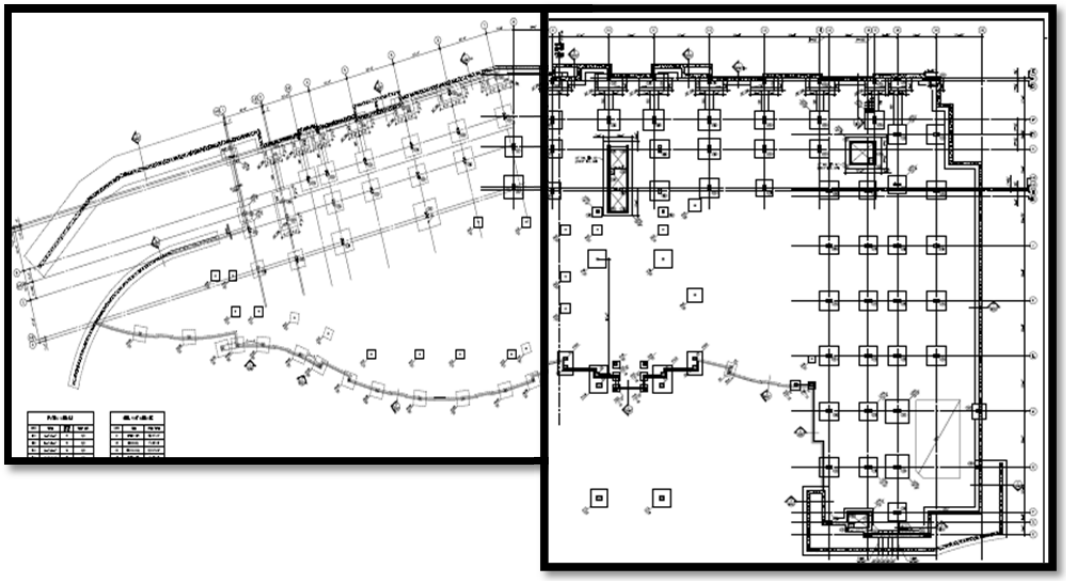


Figure: Foundation Plan

Due to the variability in soil composition, the project team had to employ a partial mud matt system to equalize the soil capacity around the site in some areas. A mud matt system is a thin layer of lean concrete mix (in this case 2000 psi) placed over the existing soil below and allows a stable base for construction.

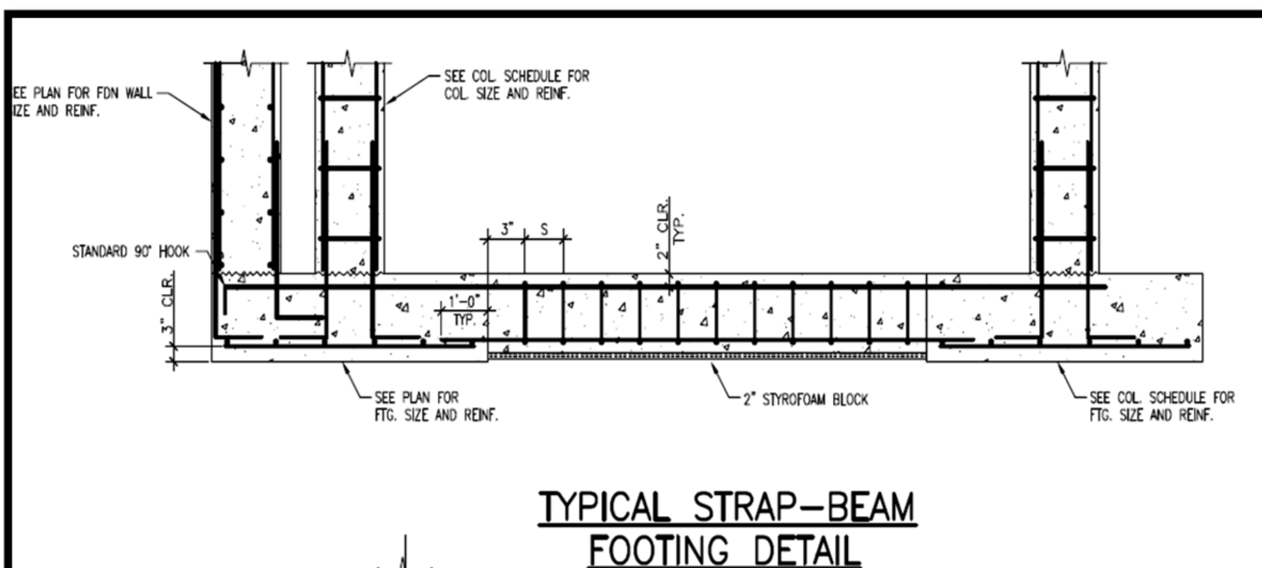
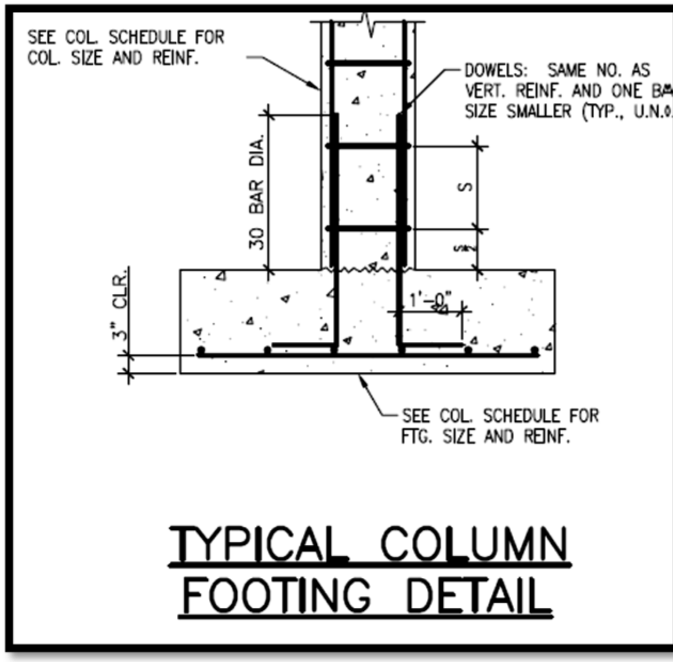


Figure: Strap Beam Detail



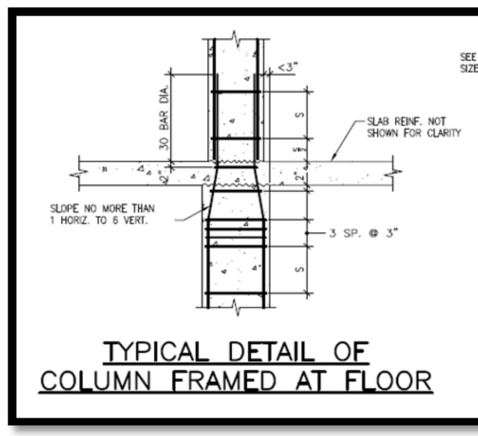
The spread footings were designed to have an allowable bearing capacity 6000 psi. The size of footings range from 3' by 3' to 12' by 8' and extend 2' below the slab on grade. To tie the footings together, longitudinally placed strap beams ranging from 36 width x 24 depths to 42 width x 24 depth beams were used. A strap beam is a structural element used to connect to isolated footings together. These beams help distribute the building load to the footings and eventually the ground. The beams range in size and have varied vertical and horizontal reinforcing.

The typical slab on grade is a minimum of 5 inches in depth and sits on 4 inches of washed crushed stone. The capacity of the slab is 3500 psi for the interior portions and 5000 psi for exterior slab conditions. The slab contains 6x6 – W 2.0 x W2.0 welded wire fabric and has number 4 reinforcing steel bars spaced 12 inches on center each way.

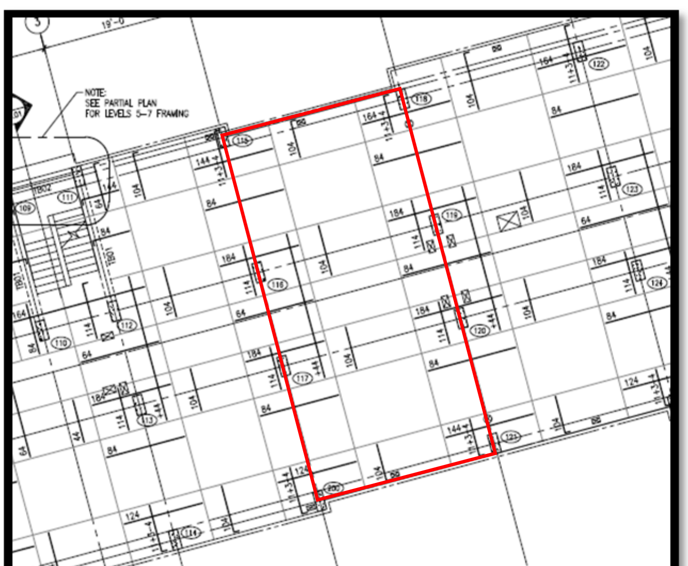
Floor System

The Embassy Suites Hotel is made up of a typical flat slab construction. The two way slab thickness is 8 inch and the compressive strength of the normal weight concrete is 5000 psi. The slab reinforcing includes number 4 reinforcing bars spaced at 10 inches on center, either way and run the full length from column to column. The floor system also uses drop panel system around one of the interior columns to protect against punching shear. Punching shear is a failure mechanism were the slab separates from the column due to concentrated shear force. Drop panels are 3.5 inches thick (total slab thickness around column on typical floor is 11.5 inches) and extend 5 feet from either side of the columns.

Framing System



In the image below, a typical framing plan section is shown for floors of the Embassy Suites Hotel (Floors 3 to 7). A typical bay size is 23’ by 18’ for floors containing the guest suites. The columns chosen in for the framing plan were almost all 14” x 30” rectangular reinforced concrete columns. The majority of the columns have a minimum compressive strength of 6,000psi. There are no beams running in between the interior and exterior columns. The only reinforced beams found are located in stairwell openings and elevator shafts.



Due to the increased load on the second floor, large concrete transfer girders had to be used to accommodate for the fitness and pool area. Level 2 also contains HSS columns along with a variety of wide flange shape beams. These are located in the section of the hotel where future retail stores will be housed.

Lateral System

To resist lateral forces due to wind and seismic loads the structural engineers employed reinforced concrete moment frames moment frames. The concrete moment frames are the main lateral force resisting system in the building. The lower storefront levels have welded steel moment connections as shown in welded moment detail. The moment connections were designed to develop the full capacity of the member. The connections use high strength ¾ or 7/8 inch ASTM A325 or A490 threaded bolts. The bolts connect the ¼ x 1 inch plates to the beams were the plates are butt and penetrate welded.

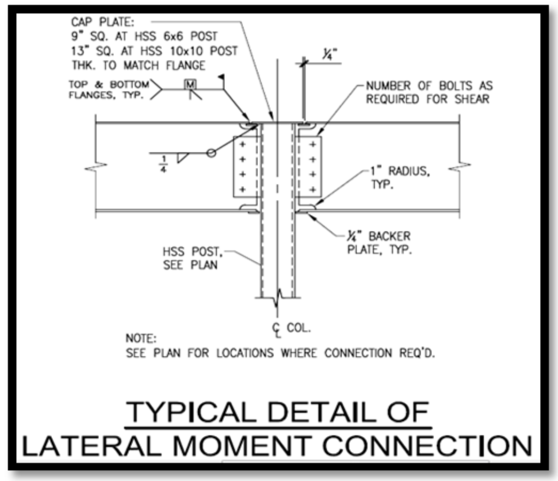


Figure: Welded Moment Connection

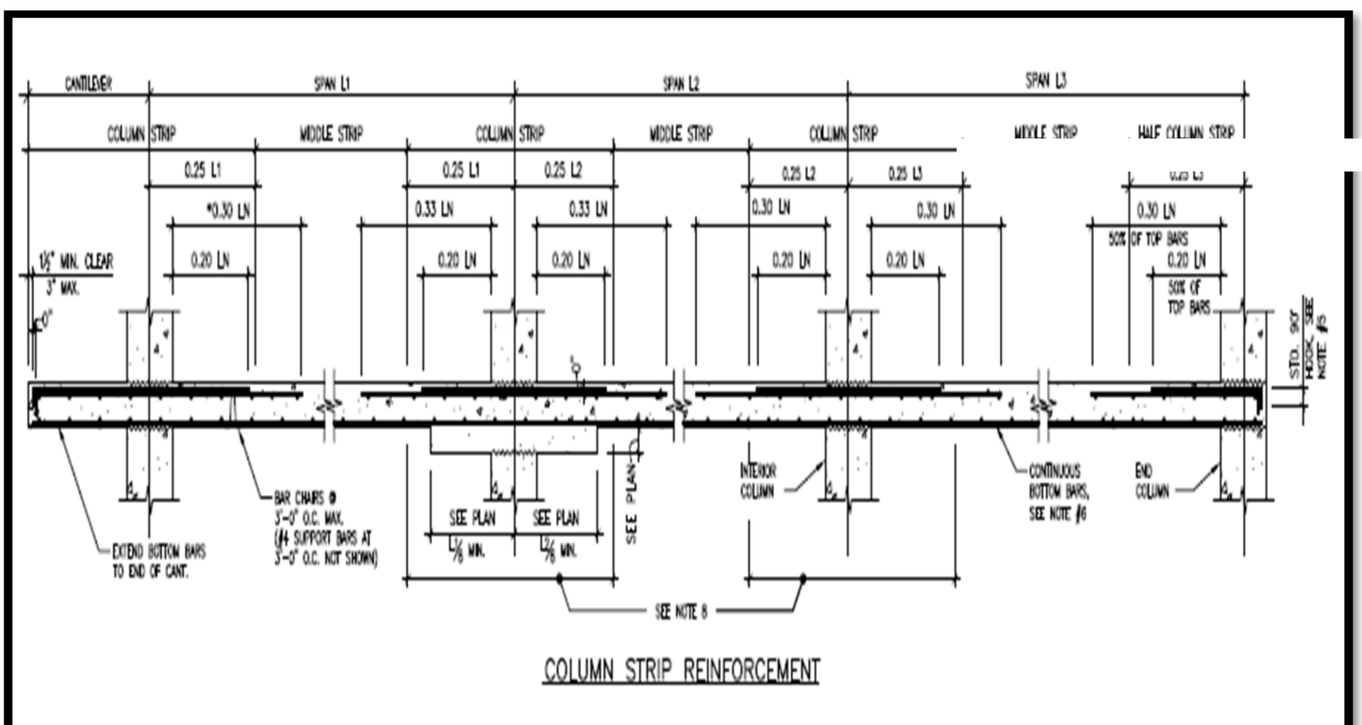


Figure: Main Lateral Force Resisting System

Roofing System

The high level roofing system consist of 3.25 inch light weight concrete slab. This slab has a compressive strength of 3,500 psi. The lower level roof (top of retail space) is made of 1.5 inch deep 20 gauge Type B cold formed metal deck. The roof deck systems are supported by wide flange beams, concrete reinforced beams varying in size and open web steel joists. The lower level roof system is comprised of a thermoplastic membrane fully adhered with heat welded seams and vapor retarder over a metal deck. Part of the lower level roof (top of part of the second floor) contains a green roof system that includes a pre-vegetated 50 percent extensive and a 50 percent intensive system that is placed upon a protective mat.

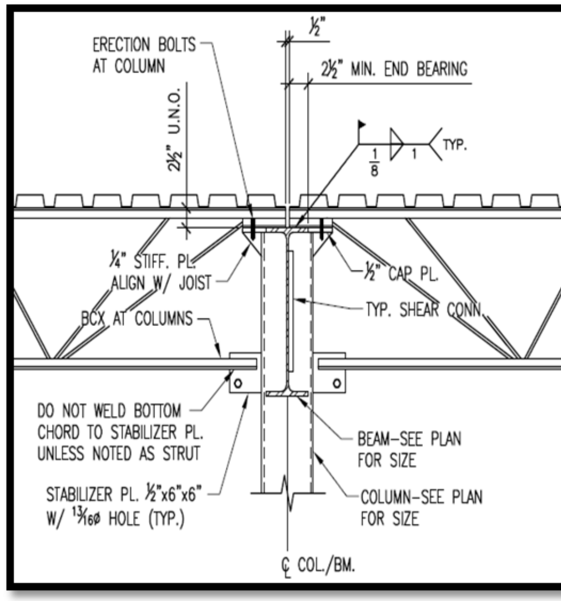


Figure 1: Lower Roof System Connection

Codes and Requirements

Listed are the codes and specifactions used in the design of the Embassy sites hotel project and ones used for analysis

- 2009 Virginia Construction Code (IBC 2009) with the Virginia Statewide Building Code
- 2009 Virginia Mechanical Code (IMC 2009)
- 2008 International Electric Code
- 2009 International Pluming Code (IPC 2009)
- 2009 Virginia Fire Prevention Code (IFC 2009) with the Statewide Fire Prevention Code
- American Society of Civil Engineers (ASCE 7- 05)
- Publication #4 "Standard Recommended Practice for Concrete Formwork" (ACI 347)
- American Concrete Institute Specifications for Reinforced Cast-In-Place Concrete (ACI 318-08)
- American Concrete Institute Specifications for Structural Concrete (ACI 301)
- American Institute of Steel Construction (AISC 325 -11)
- American Iron and Steel Institute Specification for the Design of Light Gage Cold Formed Structural Steel Members (A.I.S.I)
- Steel Deck Institute Design Specifications (S.D.I)

Codes Used in Analysis

ASCE 7-05, Minimum Design Loads for Buildings

ACI 318-08, Building Code Requirements for Structural Concrete

International Building Code (IBC), 2009

Materials

Listed below in the tables are the materials used in the constriction of the hotel project that include material weight and strength.

Concrete		
Element	Weight	Strength (psi)
Footings	Normal	4000
Grade Beams	Normal	4000
Retaining Wall	Normal	4000
Retaining Wall Footing	Normal	4000
Interior Slab-On-Grade	Normal	3500
Exterior Slab-On-Grade	Normal	5000
Formed Slabs	Normal	5000
Formed Beams	Normal	5000
Columns	Normal	6000
Foundation Walls	Normal	4000
CMU Grout	Normal	2500
All Other	Normal	3000

Table: Concrete Material Summery

Steel		
Element	Standard	Grade
Reinforced Bars	ASTM 615	60
Welded Wire Reinforcement	ASTM 185	N/A
Pre-stressed Steel Wire	ASTM 416	N/A
Wide Flange Shapes (Beams, Girders, Columns etc.)	ASTM A992	50
Stiffener Plates	ASTM A572	50
Hollow Structural Sections	ASTM 500	B
Steel Pipe	ASTM A53	B
Angles, Channels, S-Shapes etc.	ASTM A36	36
Nuts, Bolts	ASTM A325, A490	N/A
Misc. Steel	ASTM A36	36

Table: Steel Material Summery

Gravity Loads

Dead and Live Loads

In this section, gravity loads (dead, live, and applicable) are presented. These loads are compared to actual building load calculations used in Embassy Suites Hotel. Assumptions for superimposed dead load are offered in Tables 3 to 5.

Live Load

Live Load		
Element	Design Live Load (psf)	Code Minimums
Corridors	40	40
Mechanical Rooms	150	150
Partitions	15	15
Elevator Machine Room	125	125
Stairs and Exit Ways	125	125
Slab on Grade	125	125
Balconies	125	125

Table: Live Load Values

Dead Load

Dead Load		
Element	Design Dead Load (psf)	Assumption
MEP	-	5
	-	

Table: Dead Load Values

Other Applicable Load		
Load Type	Load	Code Minimums
Roof Live	30	30
Concentrated Roof Load	300lb	300lb
Roof Rain Load	30	30
Snow Drift Load	20	20
Snow Load	20	20
Rain Water Load	125	125
Ponding Load	125	125
Sliding Snow Load	-	10

Table: Other Applicable Load Values

Lateral Loads

Wind Analysis

The wind analysis performed on the Embassy Suites Hotel was carried out in accordance with Chapter 6 of ASCE 7-05, *Wind Loads.* Due to the fact, that overall building height of the hotel exceeds 60 feet, it is necessary to use the Analytical Method of analysis. The values used in this analytical procedure can be found in Tables 6 - 8.Appendix C holds detailed wind analysis procedure. The wind directions are highlighted below.

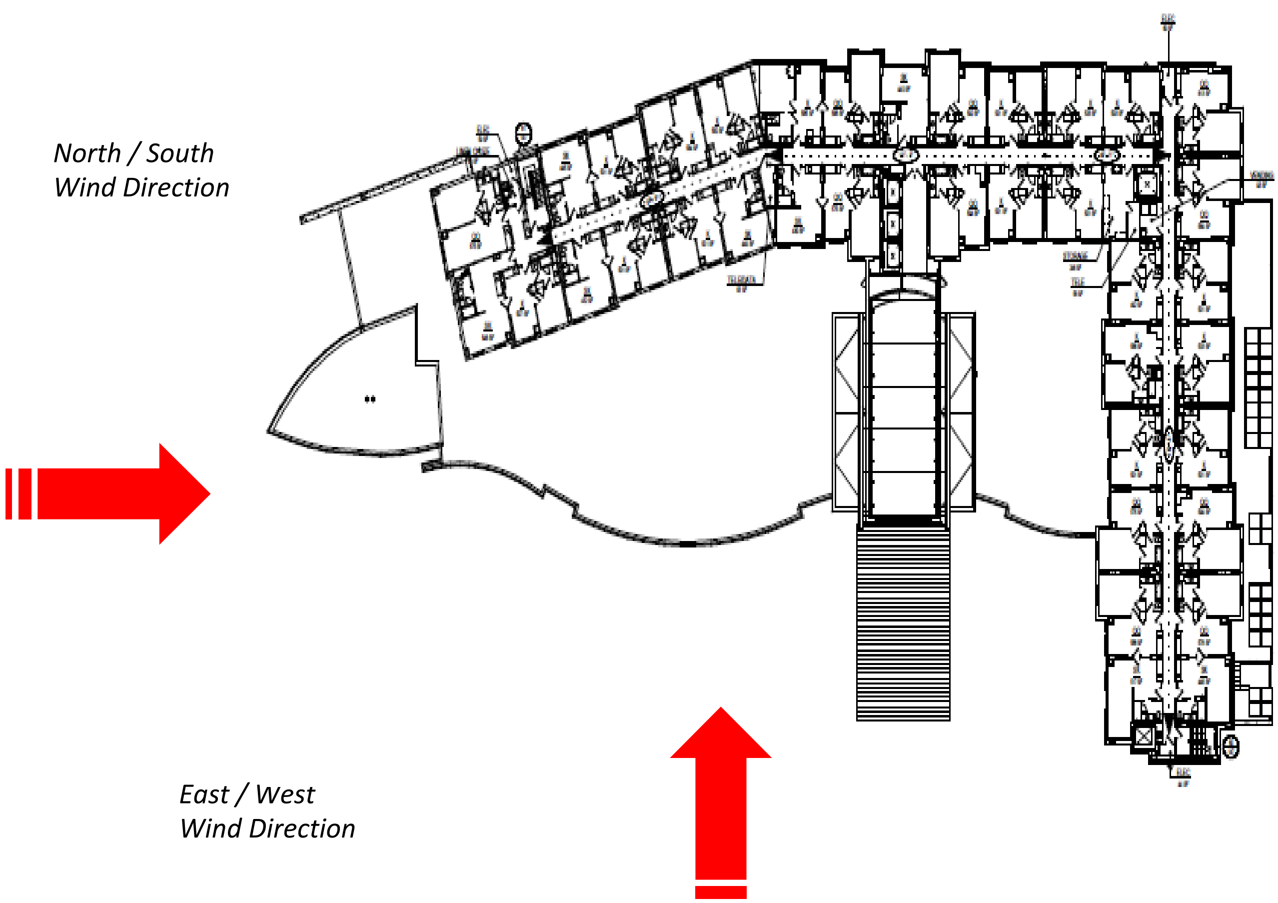


Figure: North/ South and East / West Wind Direction

Wind Analysis Data			
Element	**Symbol**	**Value**	**ASCE7-05 Reference**
Basic Speed	V	90 mph	Figure 1
Directional Factor	Kd	0.85	Table 6-4
Importance Factor 1.0	I	1.0	Table 6-1
Occupancy Category		II	Table 1-1
Exposure Category B		B	Section 6.5.6.3
Enclosure Classification		Enclosed, Partially Enclosed	Section 6.5.9
Topographic Factor	Kzt	1.0	Section 6.5.7.2
Velocity Pressure Exposure Coefficient Evaluated @ Height Z	Kz	Varies	Table 6-3
Velocity Pressure @ Height Z	qz	Varies	Equation 6-15
Velocity Pressure @ Mean Roof Height	qh	.938	Equation 6-15
Gust Effect Factor	G		Section 6.5.8.1
Product of Internal Pressure Coefficient & Gust Effect Factor	GCpi	+/- 0.18, +/-.55	Figure 6-5
External Pressure Coefficient (Windward) (East /West Direction)	Cp	.8	Figure 6-6
External Pressure Coefficient (Leeward) (East /West Direction)	Cp	-.5	Figure 6-6
External Pressure Coefficient (Windward) (North /South Direction)	Cp	.8	Figure 6-6
External Pressure Coefficient (Leeward) (North /South Direction)	Cp	-.362	Figure 6-6
External Pressure Coefficient (Windward) (East /West Direction, Penthouse Roof)	Cp	-.5	Figure 6-6
External Pressure Coefficient (Leeward) (East /West Direction, Penthouse Roof)	Cp	-.18	Figure 6-6
External Pressure Coefficient (Windward) (North /South Direction, Penthouse Roof)	Cp	.51	Figure 6-8
External Pressure Coefficient (Leeward) (North /South Direction Penthouse Roof)	Cp	-.5	Figure 6-8
External Pressure Coefficient (Center Panel) (North /South Direction Penthouse Roof)	Cp	-1.14	Figure 6-8

Table: Wind Analysis Variables

The East/ West direction wind pressures were calculated in the analysis and presented in table (below). The wind hitting the East/ West facade had a greater impact due to it having more contact with the building. The contact length along the wall was taken as 326.4 feet. The first floor of the Embassy Suites Hotel is partially located underground, having the east face exposed (Store Front). Having the west face of the first level underground will not cause a wind load blockage and any effects of a blockage can be neglected in the analysis. Values in table may vary from actual values used in design of building. The windward and leeward pressures at all levels can be located in building elevation figure on the next page (Figure 12). Additionally, a load diagram of story shear is also provided in Figure 12 located on the following page.

East / West Direction										
					Wind Pressure (psf)					
Level	Height Above Ground (ft.)	Story Height (ft.)	Kz	qz	Windward [pz]	Leeward [ph]	Total Pressure (psf)	Force of Windward Pressure	Force of Total Pressure	Sum Total Story Shear
Top Penthouse Roof	91.833		0.965	17.009	1.864	-11.623	13.487	878	6353	6.35
Roof	74.000	10.375	0.906	15.969	13.835	-10.002	23.837	46849	80721	87.07
Seventh	63.625	9.125	0.864	15.229	13.331	-10.002	23.333	39706	69494	156.57
Sixth	54.500	9.125	0.828	14.594	12.900	-10.002	22.902	38420	68210	224.78
Fifth	45.375	9.125	0.787	13.871	12.408	-10.002	22.41	36957	66745	291.52
Fourth	36.250	9.125	0.738	13.008	11.821	-10.002	21.823	35208	64997	356.52
Third	27.125	9.125	0.677	11.933	11.090	-10.002	21.092	33030	62820	419.34
Second	18.000	18	0.600	10.575	10.167	-10.002	20.169	59734	118495	537.84
First	0.000	0	0.000	0.000	0.000	0.000	0	0.000	0	0

Table: East / West Wind Values

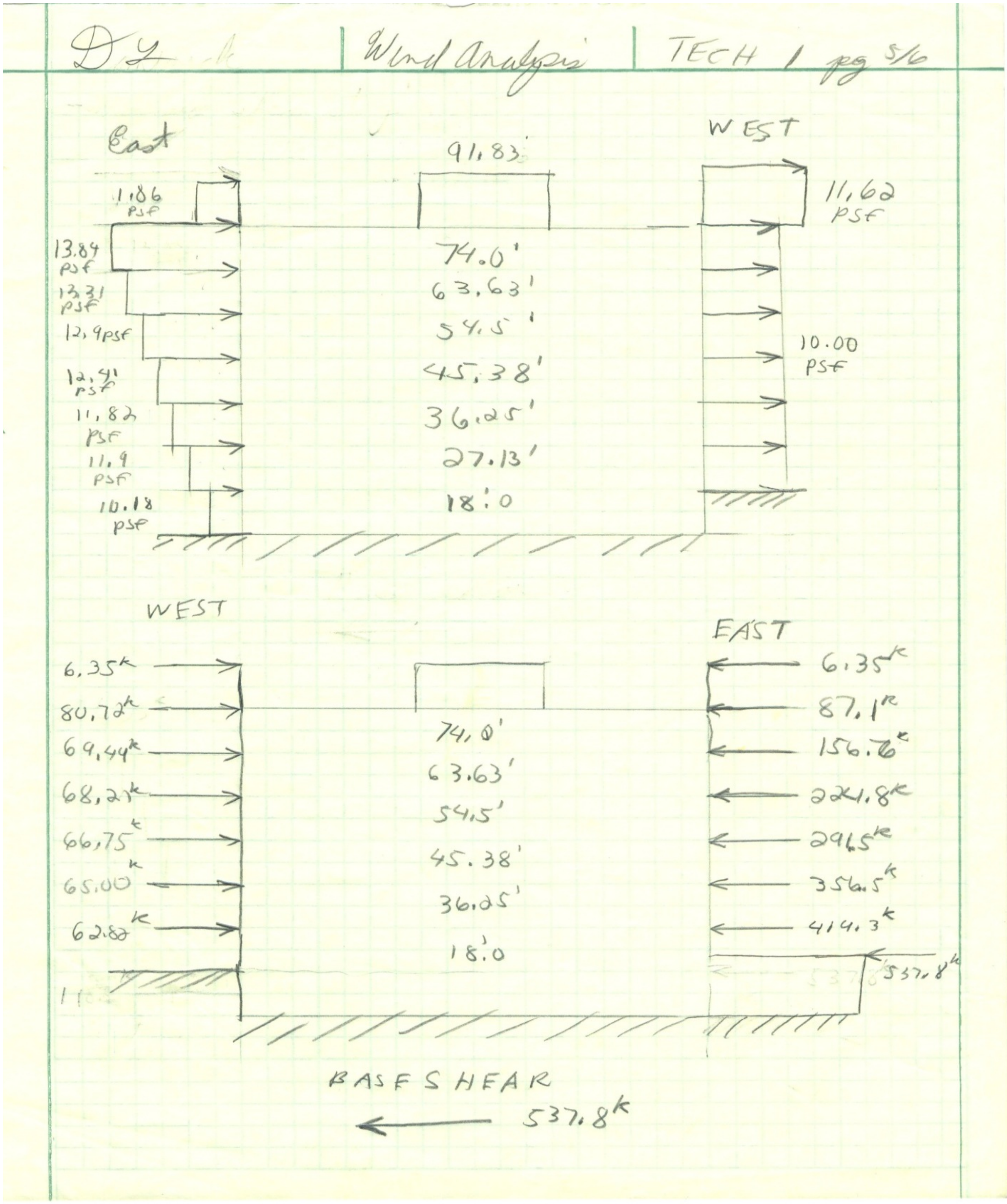


Figure: 12 East / West Wind Pressure and Story Shear

The North/ South direction wind pressures were calculated in the analysis and presented in table (below). The contact length along the wall was taken as 192.8 feet. In analyzing the wind along the North/ South facade the penthouse roof level had to be analyzed was arched roof, hence making the results for windward and leeward pressures different from the main flat roof level. Variables in table may vary from actual values used in design of building. The windward and leeward pressures at all levels can be located in building elevation figure on the next page. (Figure 13). Additionally, a load diagram of story shear is also provided in Figure 13 located on the following page.

North/ South Wind Direction										
					Wind Pressure (psf)					
Level	Height Above Ground (ft.)	Story Height (ft.)	Kz	qz	Windward [pz]	Leeward [ph]	Total Pressure (psf)	Force of Windward Pressure	Force of total Pressure	Sum Total Story Shear
Center Arched Roof	91.833	4.041	0.97	17.09	n/a	n/a	25.575	n/a	5572	5.57
Quarter Arched roof	87.792	13.792	0.953	16.797	16.232	-16.120	32.352	12100	24100	29.67
Roof	74.000	10.375	0.906	15.969	13.835	-8.063	21.898	27678	43810	73.48
Seventh	63.625	9.125	0.864	15.229	13.331	-8.063	21.394	23458	37645	111.12
Sixth	54.500	9.125	0.828	14.594	12.900	-8.063	20.963	22699	36887	148.01
Fifth	45.375	9.125	0.787	13.871	12.408	-8.063	20.471	21834	36021	184.03
Fourth	36.250	9.125	0.738	13.008	11.821	-8.063	19.884	20801	34988	219.02
Third	27.125	9.125	0.677	11.933	11.090	-8.063	19.153	19514	33702	252.72
Second	18.000	9.125	0.600	10.575	10.167	-8.063	18.23	17890	32078	284.80
First	0.000	18	0.000	0.000	0.000	-8.063	0.000	0.000	0	0.000

Table 8: North / South Wind Values

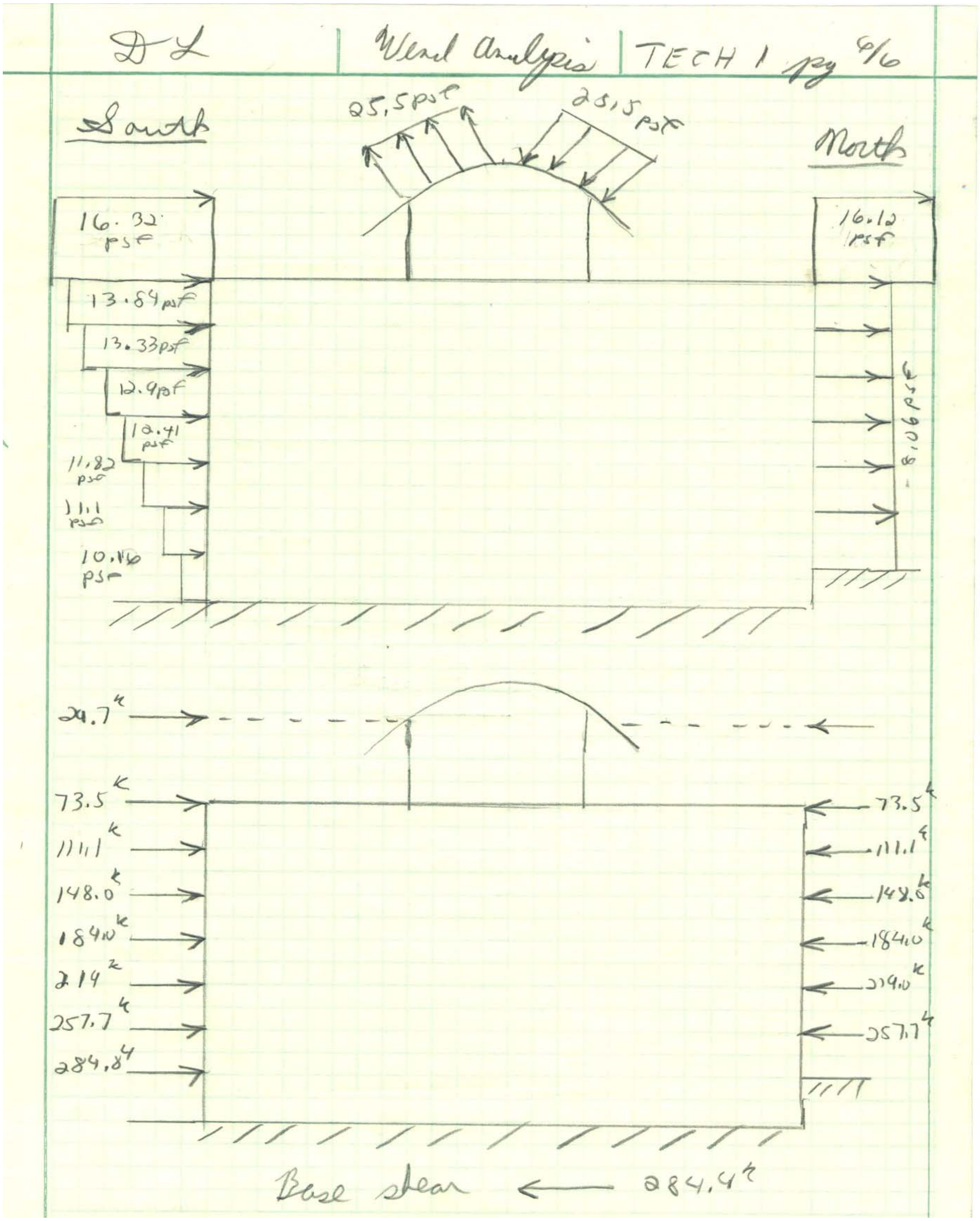


Figure: 13 North / South Wind Pressure and Story Shear

Seismic Analysis

Chapters 11 and 12 of ASCE 7-05 were used in the analysis of the seismic loads on The Embassy Suites Hotel. The hotel was designed to withstand the effects of seismic loads having the seismic design class designation B from section 1613.5.6 of the IBC 2009 and a site class designation of D from section 1613.5.2 of the IBC 2009. Seismic Design values are listed in Table 9 and 10. Seismic Design values and base shear calculation may differ from actual design values used in the design of The Embassy suites due to the use of different assumed dead loads per floor. It is important to mention the the assumed base level for calculating the building load was taken at level 2 to giving the total height above grade to be 56 feet. See Appendix D for detailed calculations of shears and gravity loads.

Seismic Analysis Data			
Element	Symbol		ASCE 70-5 References
Site Class		D	Table 20.3-1
Occupancy Category		II	Table 1-1
Importance Factor		1	Table 11.5-1
Structural System		Ordinary Reinforced Concrete Moment Frames	Table 12.2-1
Spectral Response Acceleration, short	Ss	0.155	USGS
Spectral Response Acceleration	S1	0.051	USGS
Site Coefficient	Fa	1.6	Table 11.4-1
Site Coefficient	Fv	2.4	Table 11.4-2
MCE Spectral Response Acceleration	Sms	0.248	Eq. 11.4-1
MCE Spectral Response Acceleration	Sm1	0.122	Eq. 11.4-2
Design Spectral Acceleration	Sds	0.165	Eq. 11.4-3
Design Spectral Acceleration	Sd1	0.081	Eq. 11.4-4
Seismic Design Category	Sdc	B	Table 11.6-2
Response Modification Coefficient	R	3	Table 12.212
Approximate Period Parameter	Ct	.016	Table 12.8-2
Building Height (above grade)	hn	56 feet	
Approximate Period Parameter	x	.9	Table 12.8-2
Approximate Fundamental Period	Ta	.599	Table 12.8-7
Long Period Transition Period	TL	8 s	Figure 22-15
Seismic Response Coefficient	Cs	0.055	Eq. 12.8-2
Structural Period Exponent	k	1.0	Eq. 12.8-3

Table: Seismic Analysis Variables

Base Shear							
Story	Floor Area	Story Ht.	Story Weight	wxhx	Cvx	Lateral Force Fx (k)	Story Shear Vx
2	23,907	0	735	0	0	0	-
3	23,946	9.125	3249.7	29609	.2258	75	781
4	23,899	9.125	3244.8	29609	.2258	176.3	781
5	23,899	9.125	3244.8	29609	.2258	176.3	603.9
6	23,899	9.125	3244.8	29609	.2258	176.3	427.6
7	23,899	9.125	3244.8	29656	.2262	176.3	251.3
Roof	23,899	10.375	3249.7	12639	.096	176.7	75

Table: Base Shear Values

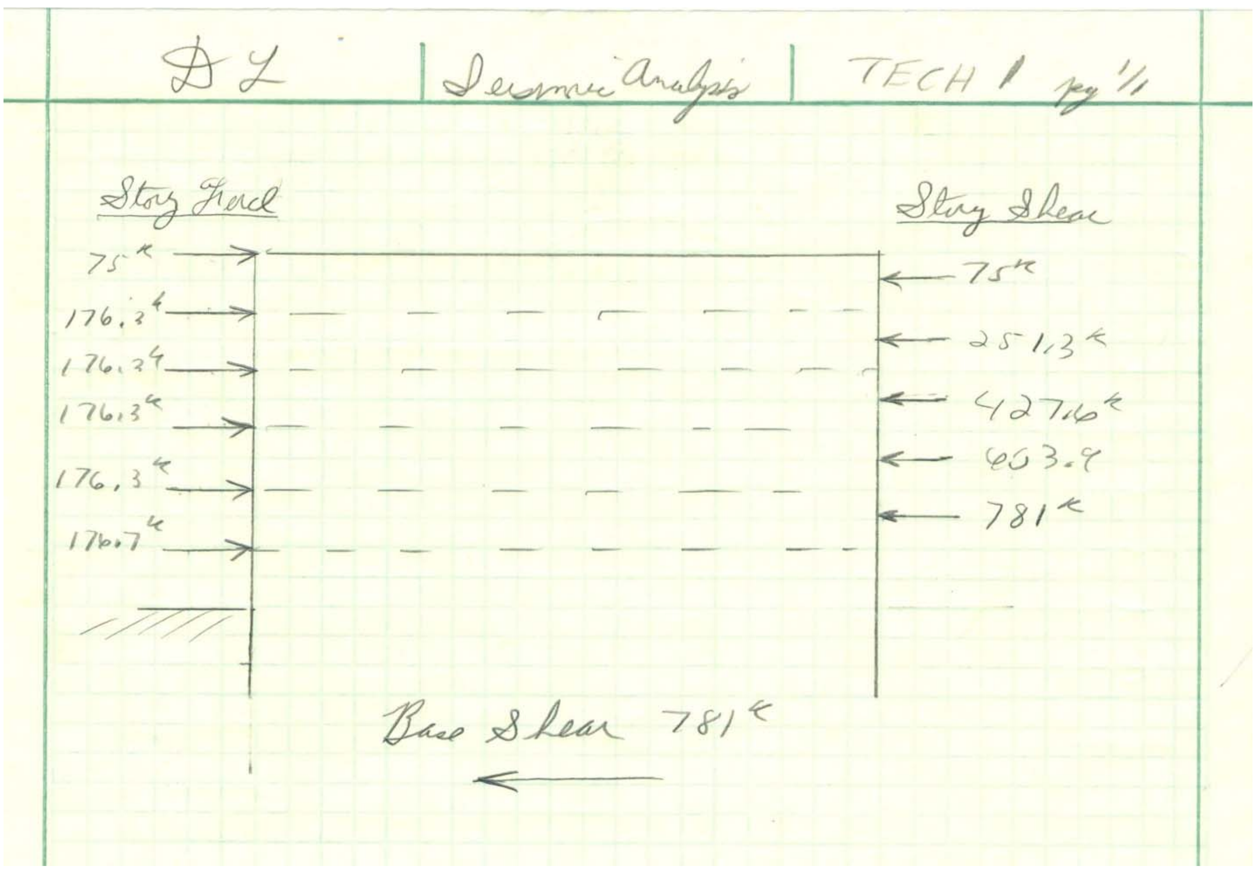


Figure: Seismic Story Force and Story Shear

Spot Checks

To gain a better understanding of the structural elements used in the design of the Embassy Suites Hotel a number of spot checks were performed on typical floor levels. The spot checks performed consisted of an interior and exterior column and a two way slab analysis. Gravity load calculation results may vary due to different assumptions of dead loads and the fact that lateral loads were not taken into account. Detailed spot checks are available in Appendix E. Spot check locations are indicated in figure.

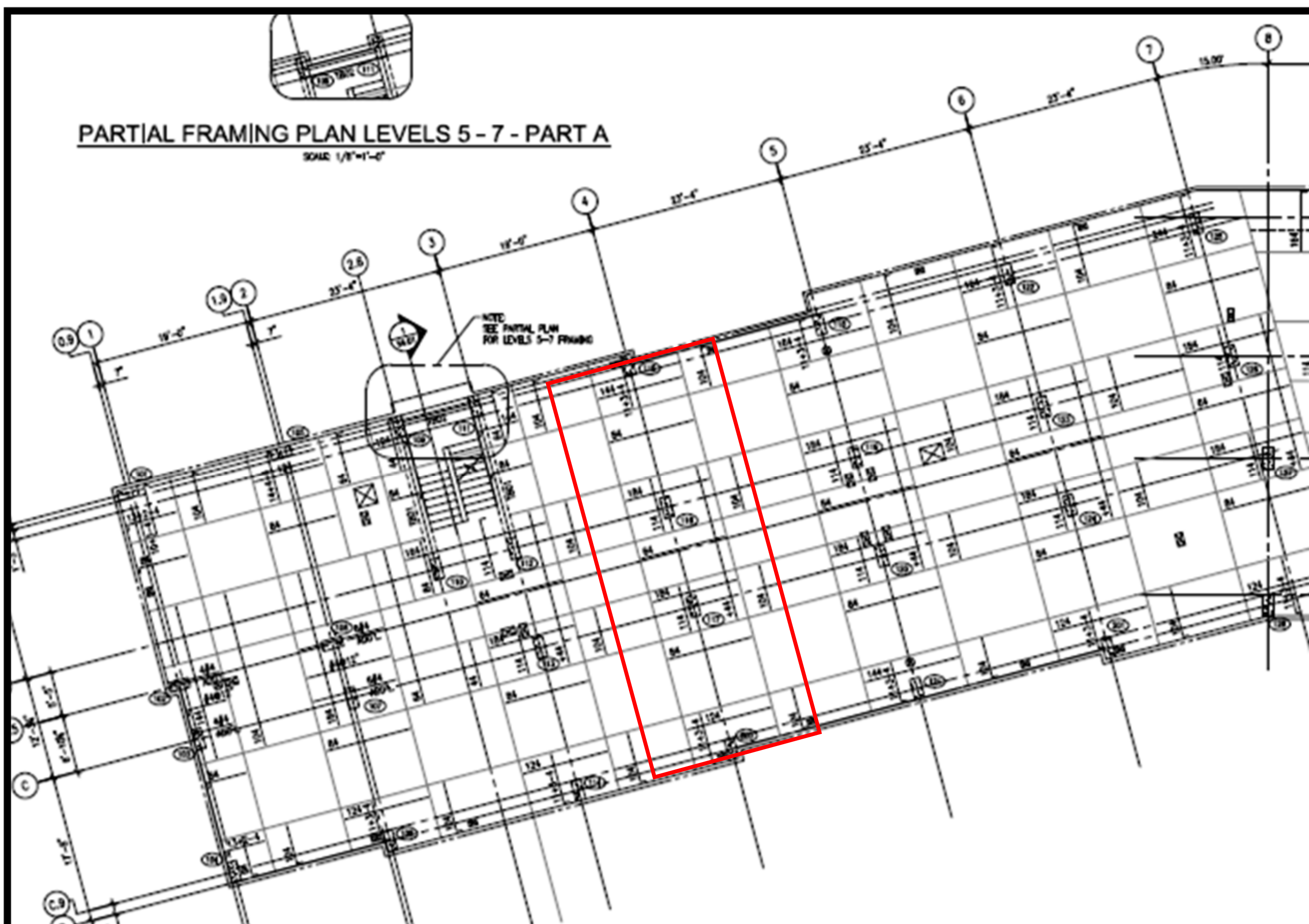


Figure: Spot Check Locations

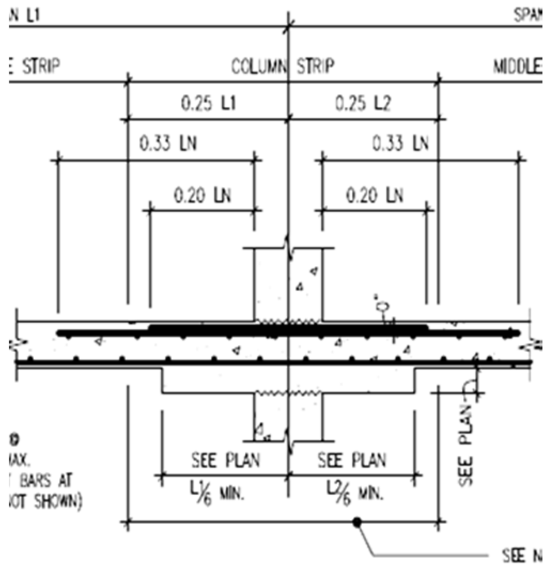


Figure: Slab section with drop panel

A two way slab analysis was performed between column line 5. The ultimate moment was computed due to loads listed in seismic analysis. The analysis for flexure consisted of checking if the slab could resist the moments distributed to its column and middle strips by seeing if adequate reinforcing and compressive strength of the concrete was available using parameters outlined by the Direct Design Method in chapter 13 ACI 318-08. Additionally a punching shear check was performed to see if the slab had enough strength resist localized shear forces.

The results of the direct design method analytical procedure showed that the slab was adequate to carry and transfer moment. Detailed calculations of spot checks are available in Appendix E.

Computer Modeling

To better understand how the Embassy Suites building responds to lateral forces, a series of 2D frames where analyzed and modeled in a computer program called STAAD Pro. The frames analyzed were one 3 bay frame and one 8 bay frame orientated to resist forces in the east and west directions. Additionally, one 3 bay frame and one 15 bay frame were analyzed to determine how the frame would respond to forces orientated in the north and south directions

The computer analysis was used to determine:

- Distribution factors for lateral loads (k-values)
- The distribution of loads to each of the buildings moment frames at their respective story level
- The controlling load combination and factors that was the most critical in determining the design

Lateral Load Distribution

Stiffness Factors (K-Values)

According to ACI 318-11 section 8.8.2 the lateral deflection of a structure computed using load combinations can differ greatly form ones obtained in linear analysis. This is why in section 10.10.4.1 of the code it is required to take a percentage of the gross section properties of members in a structure to determine a reduced stiffness of structural members under different load conditions.

Reduced values were put into the STAAD Pro models to obtain stiffness factors. 70% of the depth of the column was taken and 25% of the tributary width of the flat plate slab was used for inputs while computing the k values for the 3, 8 and 15 bays frames respectively.

Additionally, an assumption was made for the support condition at the bases of each of the frames. Due to the fact that the Embassy Suites Hotel project has spread footing and grade beams at its primary foundation system and that the soil bearing capacity was not uniform around the site, the base support conditions were modeled as pin connections.

The orientation of each frame on a coordinate axis can be show in the figure below.This orientation was chosen maximum lateral load resistance because the more stiffness an element has the great its resistance to lateral forces.

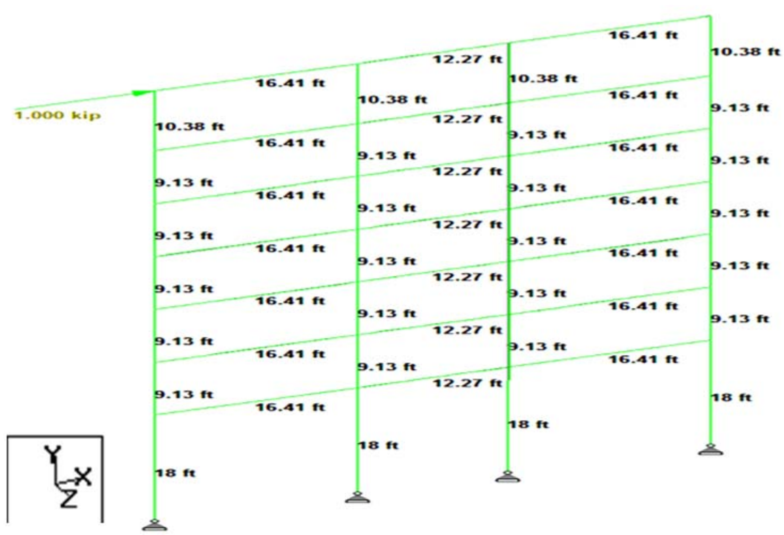


Figure: 3 Bay Frame with 1 kip load applied at Top

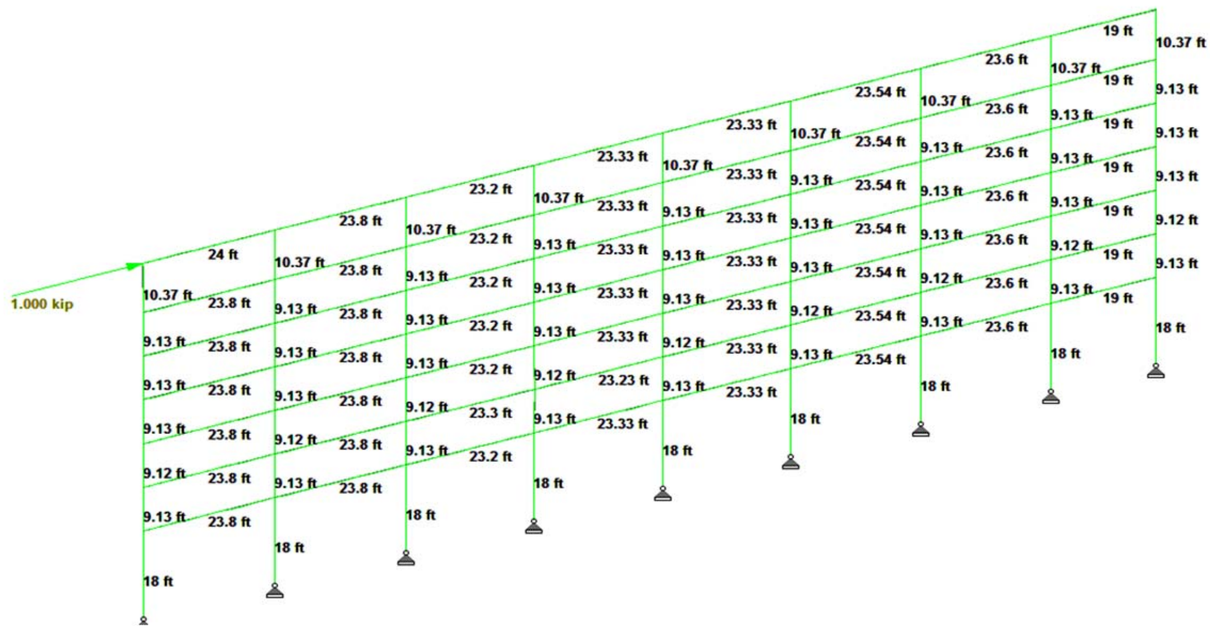


Figure: 8 Bay Frame with 1 kip load applied at Top

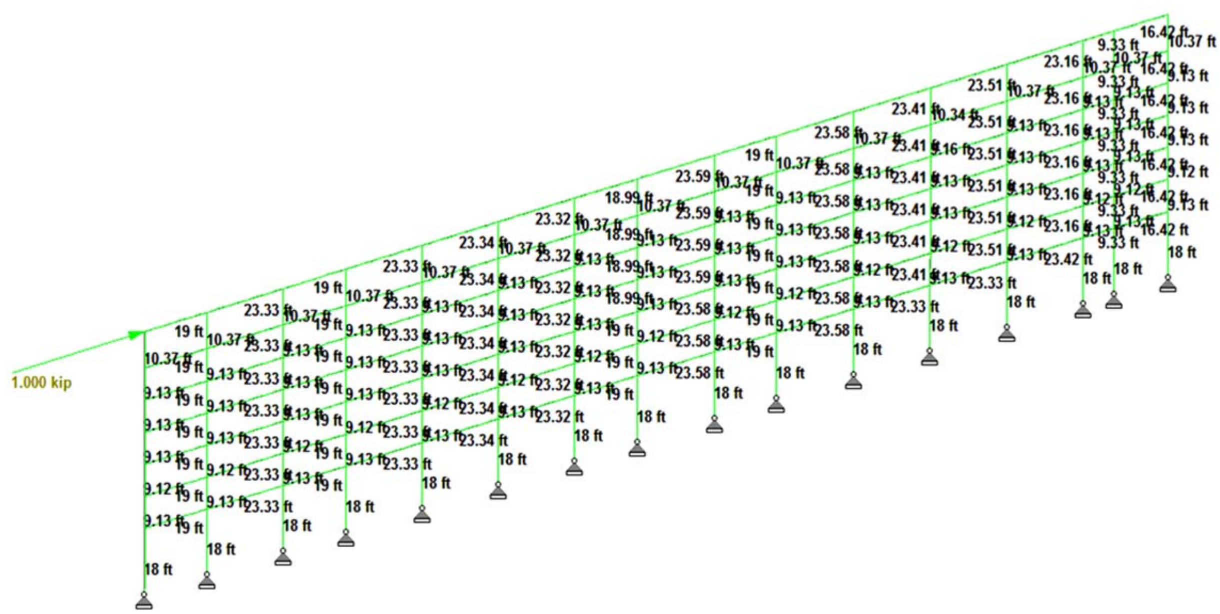


Figure: 15 Bay Frame with 1 kip load applied at Top

To determine the story stiffness due to a unit load a 1 kip force was applied at the top of each of the moment frames to obtain a displacement. The formula K = P/ delta , was used where P is the 1 kip unit load applied to the top of the frame and delta is the displacement of the frame at its respective story level in inches due to the unit load. K – value calculations can be found in Appendix

Center of Rigidity and Center of Mass

Center of Rigidity

The center of rigidity is defined the stiffness centroid in a structure. A reverence point was chosen in the south west corner of the building to find distances in the x and y directions. A more simplified L- shape layout of the floors was chosen for ease of calculation to determine the distances to each moment frame.

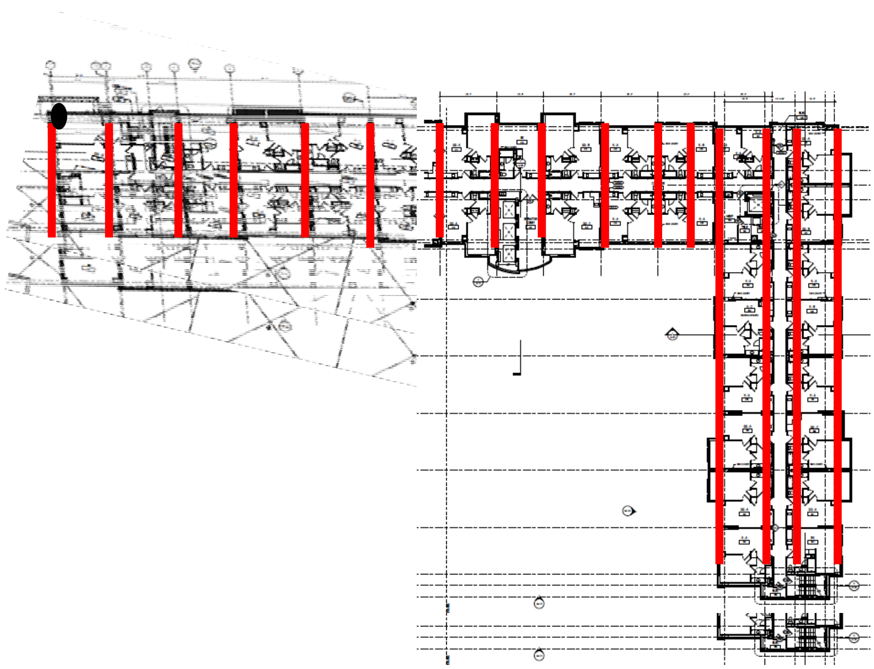


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Figure: Reference Point for calculation of Center of Rigidity (x – direction component); Frames Resisting Lateral Load due to Force in East /West direction (red)

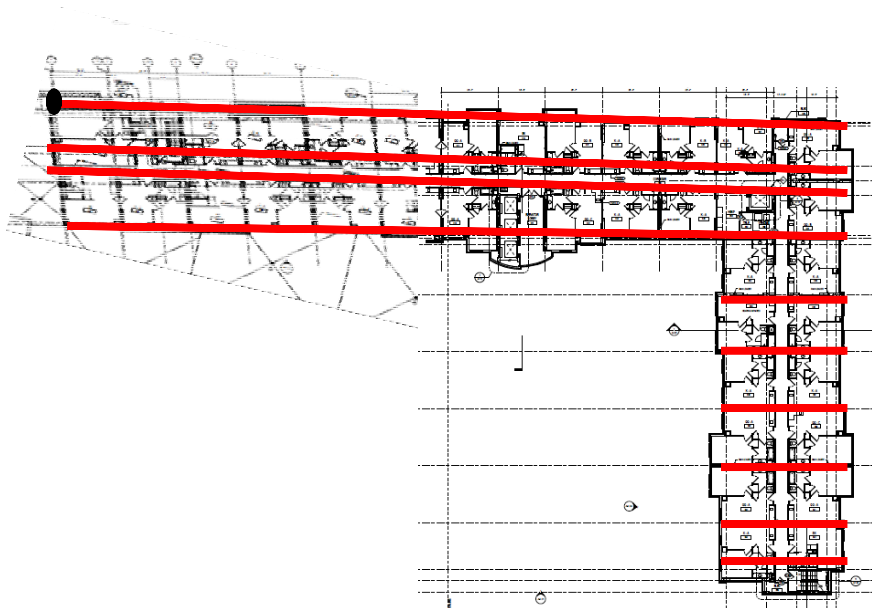


Figure: Reference Point for calculation of Center of Rigidity (y – direction component); Frames Resisting Lateral Load due to Force in North / South direction (red)

The formulas used to calculate the center of rigidity are as follows:

$$\frac{\sum kix}{\sum ki}$$

$$\frac{\sum kiy}{\sum k}$$

The center of rigidity is found by the multiplying the sum of each element stiffness by its location from the reference point and dividing it by the total amount of frame stiffness in that direction.

Center of Mass

The center of mass is defined as the mass centroid in a structure. A reverence point was chosen in the south west corner of the building to find distances in the x and y directions. A more simplified L- shape layout of the floors was chosen for ease of calculation to determine the distances to each moment frame.

The formulas used to calculate the center of mass are as follows:

$$\frac{A_1x_1 + A_2x_2}{A_1 + A_2}$$

$$\frac{A_1y_1 + A_2y_2}{A_1 + A_2}$$

The center of mass is found breaking the building down into area shapes. The sum of the area of a shape is multiplied by its location from the reference point to the middle of that shape and dividing it by the total sum of the areas of the respective shapes.

Detailed calculations of the center of mass and center of rigidity can be found in Appendix

Torsion

Torsional effects in a build structure are caused when the center of rigidity and the center of mass are offset causing s twisting moment that is subjected to the lateral force resisting systems. This is especially prevalent for L- shaped structures. These effects have to be accounted for in the design of the lateral systems. To gain a better understand of torsion and how it is distributed to a building one must look at individual frames in respective direction due to wind and seismic loads.

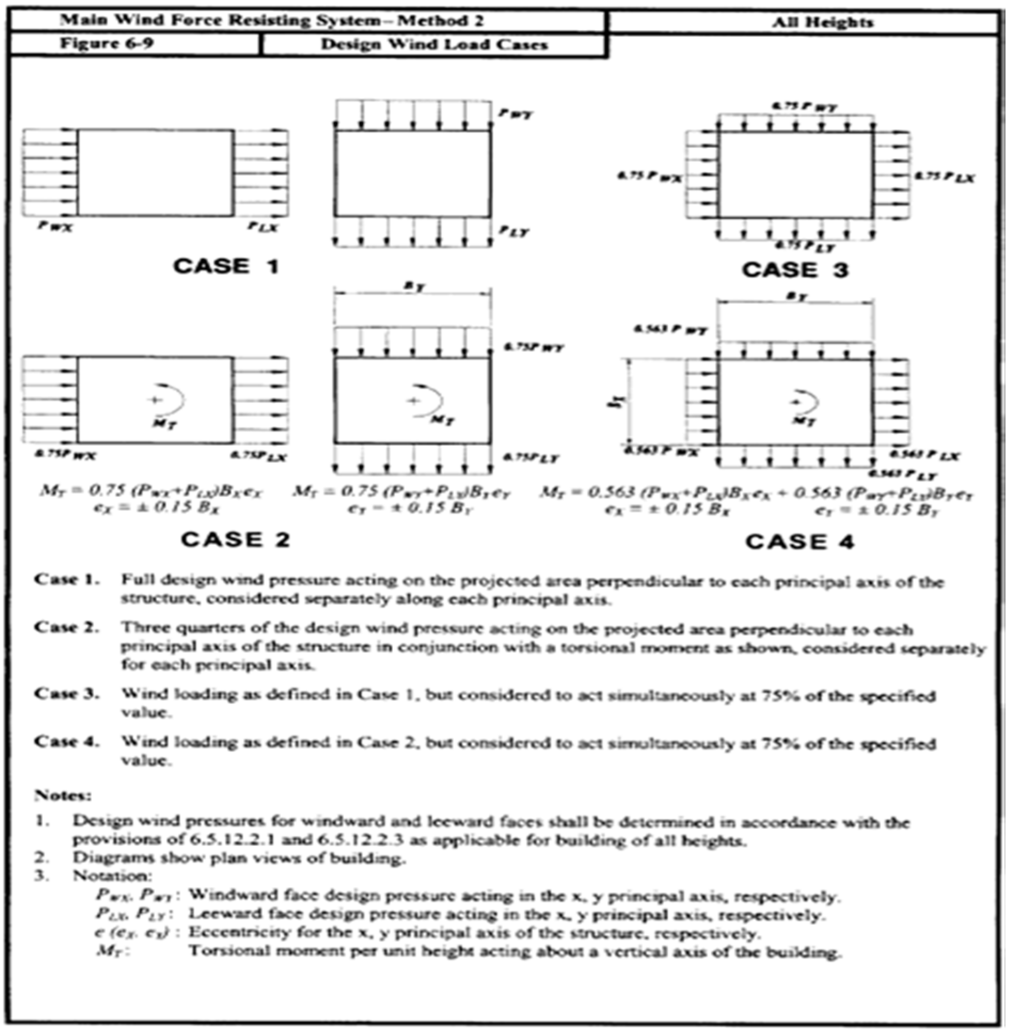


Figure: ASCE Design Wind Load Cases

Torsional Shear: Wind Loading

In ASCE 7-05, figure 6-9 highlights 4 different wind load cases on a building. For this report it will be assumed that the wind load will act at the center of pressure of the building and only considering Case 1. In the table below is an example calculation of the forces distributed torsional shears to the frames on level 7 due to wind loadings in the east / east and north / south directions.

Case 1 E / W Wind									
Level 7									
Floor	Frame	Ki	di	di^2	Kidi^2	Kidi	M(k-ft)	∑ Kidi^2	Fi
7th	Frame 1	7	-175	30625	214375.00	-1225	1525.2	1305555.22	-1.43
7th	Frame 2	7	-156	24336	170352.00	-1092	1525.2	1305555.22	-1.28
7th	Frame 3	7	-132.67	17601.3289	123209.30	-928.69	1525.2	1305555.22	-1.08
7th	Frame 4	7	-113.67	12920.8689	90446.08	-795.69	1525.2	1305555.22	-0.93
7th	Frame 5	7	-90.34	8161.3156	57129.21	-632.38	1525.2	1305555.22	-0.74
7th	Frame 6	7	-67.01	4490.3401	31432.38	-469.07	1525.2	1305555.22	-0.55
7th	Frame 7	7	-43.8	1918.44	13429.08	-306.6	1525.2	1305555.22	-0.36
7th	Frame 8	7	-24.68	609.1024	4263.72	-172.76	1525.2	1305555.22	-0.20
7th	Frame 9	7	-1.1	1.21	8.47	-7.7	1525.2	1305555.22	-0.01
7th	Frame 10	7	17.2	295.84	2070.88	120.4	1525.2	1305555.22	0.14
7th	Frame 11	7	41.48	1720.5904	12044.13	290.36	1525.2	1305555.22	0.34
7th	Frame 12	7	64.81	4200.3361	29402.35	453.67	1525.2	1305555.22	0.53
7th	Frame 13	10.4	88.14	7768.6596	80794.06	916.656	1525.2	1305555.22	1.07
7th	Frame 14	10.4	111.5	12432.25	129295.40	1159.6	1525.2	1305555.22	1.35
7th	Frame 15	10.4	120.8	14592.64	151763.46	1256.32	1525.2	1305555.22	1.47
7th	Frame 16	10.4	137.12	18801.8944	195539.70	1426.048	1525.2	1305555.22	1.67

Table: Calculation of Torsional Forces for E/W Wind 7th Floor

Case 1 N/S Wind									
Level 7									
Floor	Frame	Ki	di	di^2	Kidi^2	Kidi	M(k-ft)	∑ Kidi^2	Fi
7th	Frame 1	20.8	-58.9	3469.21	72159.57	-1225.12	1649.4	395321.17	-5.11
7th	Frame 2	20.8	-41.23	1699.913	35358.19	-857.584	1649.4	395321.17	-3.58
7th	Frame 3	20.8	-29	841	17492.80	-603.2	1649.4	395321.17	-2.52
7th	Frame 4	20.8	-11.33	128.3689	2670.07	-235.664	1649.4	395321.17	-0.98
7th	Frame 5	7	11.8	139.24	974.68	82.6	1649.4	395321.17	0.34
7th	Frame 6	7	35.2	1239.04	8673.28	246.4	1649.4	395321.17	1.03
7th	Frame 7	7	58.5	3422.25	23955.75	409.5	1649.4	395321.17	1.71
7th	Frame 8	7	82.1	6740.41	47182.87	574.7	1649.4	395321.17	2.40
7th	Frame 9	7	105.68	11168.26	78177.84	739.76	1649.4	395321.17	3.09
7th	Frame 10	7	124.6	15525.16	108676.12	872.2	1649.4	395321.17	3.64

Table: Calculation of Torsional Forces for N/S Wind 7th Floor

Ki : Load Stiffness Factor per Story

di: Distance to Center of Rigidity

M: Moment caused by eccentric load (Story Force x eccentricity)

Fi: Torsional Force in each frame

Direct Shear: Wind Loading

In the table below are the direct shear forces distributed to each frame due to east / west and north /south wind loadings respectively. The direct shear of each frame was calculated by taking the stiffness factor for that frame over the sum of the stiffness factors in the direction of the force multiplied by the story force. The formula is as follows:

$$\frac{\sum ki}{\sum K} * \text{P}$$

Floor	Story Pressure	Wind Direction	K - 3 Bay	K- 8 Bay	Total k	% P to 3 Bay Frame	% P to 8 Bay Frame	P to 3 Bay	P to 8 Bay
7th	80.72	E/W	7	10.4	125.7	0.0557	0.0829	4.5	6.7
6th	69.49	E/W	7.5	11.4	135.0	0.0553	0.0842	3.8	5.8
5th	68.21	E/W	8.0	12.3	145.4	0.0550	0.0849	3.8	5.8
4th	66.75	E/W	8.6	13.3	156.8	0.0550	0.0850	3.7	5.7
3rd	65.00	E/W	9.3	14.9	170.8	0.0542	0.0874	3.5	5.7
2nd	62.82	E/W	10.2	16.9	190.2	0.0536	0.0891	3.4	5.6
1st	118.50	E/W	11.9	20.8	226.2	0.0526	0.0921	6.2	10.9
Floor	**Story Pressure**	**Wind Direction**	**K - 3 Bay**	**K- 15 Bay**	**Total k**	**% P to 3 Bay Frame**	**% P to 15 Bay Frame**	**P to 3 Bay**	**P to 15 Bay**
7th	43.81	N/S	7	20.8	125.3	0.0559	0.1662	2.4	7.3
6th	37.64	N/S	7.5	22.7	135.7	0.0550	0.1675	2.1	6.3
5th	36.89	N/S	8.0	24.4	145.6	0.0550	0.1676	2.0	6.2
4th	36.02	N/S	8.6	26.3	157.0	0.0549	0.1676	2.0	6.0
3rd	34.99	N/S	9.3	29.4	173.2	0.0535	0.1698	1.9	5.9
2nd	33.70	N/S	10.2	33.3	194.6	0.0524	0.1713	1.8	5.8
	32.08								

Table: Calculation of Direct Shear Forces for N/S and E/W Wind

Torsional Shear: Seismic Loading

In the table below is an example calculation of the forces distributed torsional shears to the frames on level 7 due to seismic loadings in the east / west and north / south directions. It is important to note that the seismic story force acts at the center of mass and the eccentricity of the moment is from the center of mass to the center of rigidity. Even though seismic loads are not directional in nature and are applied to the whole building at once, it is important it to examine it in this manner to determine controlling load cases.

Seismic Loading									
Level 7									
Floor	Frame	Ki	di	di^2	Kidi^2	Kidi	M(k-ft)	∑ Kidi^2	Fi
7th	Frame 1	7	-198.2	39283.24	274982.68	-1387.4	1740	1374127.59	-1.76
7th	Frame 2	7	-179.2	32112.64	224788.48	-1254.4	1740	1374127.59	-1.59
7th	Frame 3	7	-155.87	24295.46	170068.20	-1091.09	1740	1374127.59	-1.38
7th	Frame 4	7	-136.87	18733.4	131133.78	-958.09	1740	1374127.59	-1.21
7th	Frame 5	7	-113.87	12966.38	90764.64	-797.09	1740	1374127.59	-1.01
7th	Frame 6	7	-90.21	8137.844	56964.91	-631.47	1740	1374127.59	-0.80
7th	Frame 7	7	-67	4489	31423.00	-469	1740	1374127.59	-0.59
7th	Frame 8	7	-47.88	2292.494	16047.46	-335.16	1740	1374127.59	-0.42
7th	Frame 9	7	-24.3	590.49	4133.43	-170.1	1740	1374127.59	-0.22
7th	Frame 10	7	-5.2	27.04	189.28	-36.4	1740	1374127.59	-0.05
7th	Frame 11	7	18.28	334.1584	2339.11	127.96	1740	1374127.59	0.16
7th	Frame 12	7	41.61	1731.392	12119.74	291.27	1740	1374127.59	0.37
7th	Frame 13	10.4	64.94	4217.204	43858.92	675.376	1740	1374127.59	0.86
7th	Frame 14	10.4	88.3	7796.89	81087.66	918.32	1740	1374127.59	1.16
7th	Frame 15	10.4	97.6	9525.76	99067.90	1015.04	1740	1374127.59	1.29
7th	Frame 16	10.4	114	12996	135158.40	1185.6	1740	1374127.59	1.50

Table: Calculation of Torsional Shear Forces for Seismic

Seismic Loading N/S Direction									
Level 7									
Floor	Frame	Ki	di	di^2	Kidi^2	Kidi	M(k-ft)	∑ Kidi^2	Fi
7th	Frame 1	20.8	-50.1	2510.01	52208.21	-1042.08	660	405041.7	-1.70
7th	Frame 2	20.8	-32.43	1051.705	21875.46	-674.544	660	405041.7	-1.10
7th	Frame 3	20.8	-20.2	408.04	8487.23	-420.16	660	405041.7	-0.68
7th	Frame 4	20.8	-2.53	6.4009	133.14	-52.624	660	405041.7	-0.09
7th	Frame 5	7	20.6	424.36	2970.52	144.2	660	405041.7	0.23
7th	Frame 6	7	44	1936	13552.00	308	660	405041.7	0.50
7th	Frame 7	7	67.3	4529.29	31705.03	471.1	660	405041.7	0.77
7th	Frame 8	7	90.87	8257.357	57801.50	636.09	660	405041.7	1.04
7th	Frame 9	7	114.48	13105.67	91739.69	801.36	660	405041.7	1.31
7th	Frame 10	7	133.4	17795.56	124568.92	933.8	660	405041.7	1.52

Table: Calculation of Direct Shear Forces for Seismic

Direct Shear: Seismic Loading

In the table below is an example calculation of the forces distributed direct shears to the frames on level 7 due to wind loadings in the east / west and north / south directions.

Floor	Story Pressure	Direction	K - 3 Bay	K- 8 Bay	Total k	% P to 3 Bay Frame	% P to 8 Bay Frame	P to 3 Bay	P to 8 Bay
7th	75.00	E/W	7	10.4	125.7	0.0557	0.0829	4.2	6.2
6th	176.30	E/W	7.5	11.4	135.0	0.0553	0.0842	9.7	14.8
5th	176.30	E/W	8.0	12.3	145.4	0.0550	0.0849	9.7	15.0
4th	176.30	E/W	8.6	13.3	156.8	0.0550	0.0850	9.7	15.0
3rd	176.60	E/W	9.3	14.9	170.8	0.0542	0.0874	9.6	15.4
2nd		E/W	10.2	16.9	190.2	0.0536	0.0891	0.0	0.0
1st		E/W	11.9	20.8	226.2	0.0526	0.0921	0.0	0.0
Floor	**Story Pressure**	**Direction**	**K - 3 Bay**	**K- 15 Bay**	**Total k**	**% P to 3 Bay Frame**	**% P to 15 Bay Frame**	**P to 3 Bay**	**P to 15 Bay**
7th	75.00	N/S	7	20.8	125.3	0.0559	0.1662	4.2	12.5
6th	176.30	N/S	7.5	22.7	135.7	0.0550	0.1675	9.7	29.5
5th	176.30	N/S	8.0	24.4	145.6	0.0550	0.1676	9.7	29.5
4th	176.30	N/S	8.6	26.3	157.0	0.0549	0.1676	9.7	29.6
3rd	176.60	N/S	9.3	29.4	173.2	0.0535	0.1698	9.4	30.0
2nd		N/S	10.2	33.3	194.6	0.0524	0.1713	0.0	0.0

Table: Calculation of Torsional Shear Forces for Seismic

Load Combinations

A series of basic load combinations where taken into consideration when analyzing values that were to determine drift and total forces applied to individual frames. The typical controlling load combination for this design is highlighted in red. The ASCE 7-10 load combinations are as follows:

2.3.2 Basic Combinations

Structures, components, and foundations designed so that their design strength equals o exceeds the effects of the factored loads in th following combinations:

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

Where:

D = Dead load.

E = Combined effect of horizontal and vertical earthquake induced forces

L = Live load, except roof live load, including any permitted live load reduction.

L r = Roof live load including any permitted live load reduction.

R = Rain load.

S = Snow load.

W = Load due to wind pressure.

Story Drift and Lateral Displacement

A series of 2D Frames were modeled with STAAD Pro using values calculated in direct and torsional shear analysis to analysis the maximum drift for both wind and seismic loads. A 3 and 8 bay frames were models with load orientated in the east and west direction and a 3 and 15 Bay frame in the north and south direction. These frames considered the maximum percentage of load when they were modeled to get to address the possibility of the largest drift. The image shows the location of the frames in the building.

The deflections for wind were compared to a limit of L/ 600 as a conservative assumption outlined in ASCE 7-05 Appendix C. For Seismic loads the maximum drift was compared to .02 times the height of the frame are which specified in ASCE 7-05 table 12.12-1.

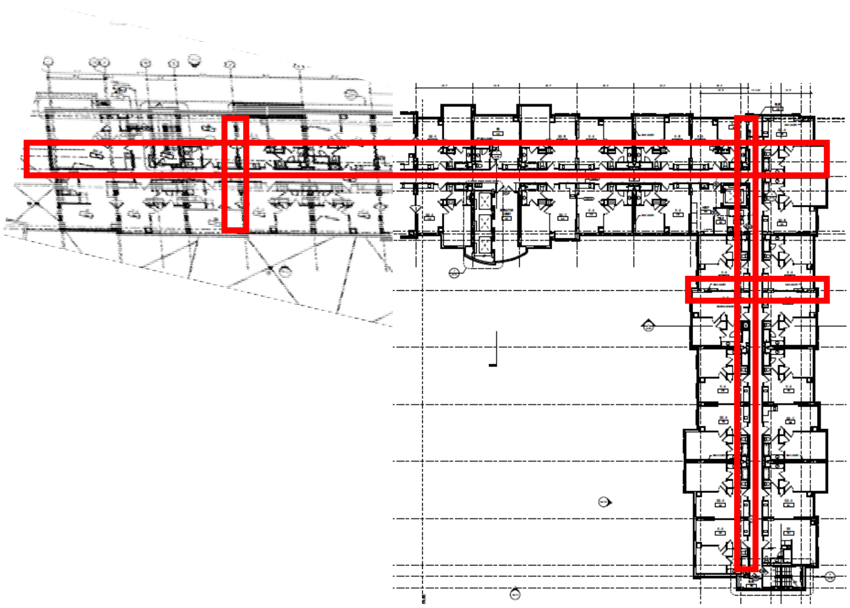


Figure: Frames Analyzed for Drift

Before the frames could be modeled, the total story forces for each frame had to be calculated. These tables show the maximum lateral forces due to wind and seismic applied to each story of the building frames modeled in STAAD Pro.

Lateral Wind Force E/W Direction						
Level	P to 3 Bay (Direct Force)	P to 8 Bay (Direct Force)	Frame 5 (Torsion Force)	Frame 15 (Torsion Force)	Total Lateral (K)	
7th	4.50	6.69	-0.74	1.47	3.76	8.16
6th	3.84	5.85	-0.63	1.28	3.21	7.13
5th	3.75	5.79	-0.62	1.26	3.14	7.06
4th	3.67	5.68	-0.60	1.24	3.07	6.92
3rd	3.52	5.68	-0.58	1.23	2.95	6.91
2nd	3.37	5.60	-0.55	1.21	2.82	6.81

Table: Calculation of Total Forces applied to Frames for Wind

Lateral Wind Force N/S Direction						
Level	P to 15 Bay (Direct Force)	P to 3 Bay (Direct Force)	Frame 2 (Torsion Force)	Frame 6 (Torsion Force)	Total Lateral (K)	
7th	7.28	2.45	-3.58	1.03	3.70	3.47
6th	6.30	2.07	-3.11	0.88	3.20	2.95
5th	6.18	2.03	-3.07	0.86	3.11	2.89
4th	6.04	1.98	-3.00	0.84	3.04	2.81
3rd	5.94	1.87	-2.98	0.80	2.96	2.68
2nd	5.77	1.77	-2.93	0.77	2.84	2.53

Table: Calculation of Total Forces applied to Frames for Wind

Lateral Seismic Force E/W Direction						
Level	P to 3 Bay (Direct Force)	P to 8 Bay (Direct Force)	Frame 5 (Torsion Force)	Frame 15 (Torsion Force)	Total Lateral (K)	
7th	4.18	6.22	-1.01	1.29	3.17	7.50
6th	9.75	14.84	-2.36	3.07	7.39	17.91
5th	9.70	14.97	-2.35	3.10	7.35	18.07
4th	9.69	14.99	-0.76	1.00	8.94	16.00
3rd	9.57	15.43	-0.73	1.00	8.85	16.43

Table: Calculation of Total Forces applied to Frames for Seismic

Lateral Seismic Force N/S Direction						
Level	P to 15 Bay (Direct Force)	P to 3 Bay (Direct Force)	Frame 2 (Torsion Force)	Frame 6 (Torsion Force)	Total Lateral (K)	
7th	12.47	4.19	-1.10	0.50	11.37	4.69
6th	29.53	9.70	-2.45	1.10	27.08	10.79
5th	29.54	9.69	-2.41	1.07	27.13	10.76
4th	29.55	9.68	-2.36	1.05	27.20	10.73
3rd	29.99	9.44	-2.34	1.01	27.64	10.45

Table: Calculation of Total Forces applied to Frames for Seismic

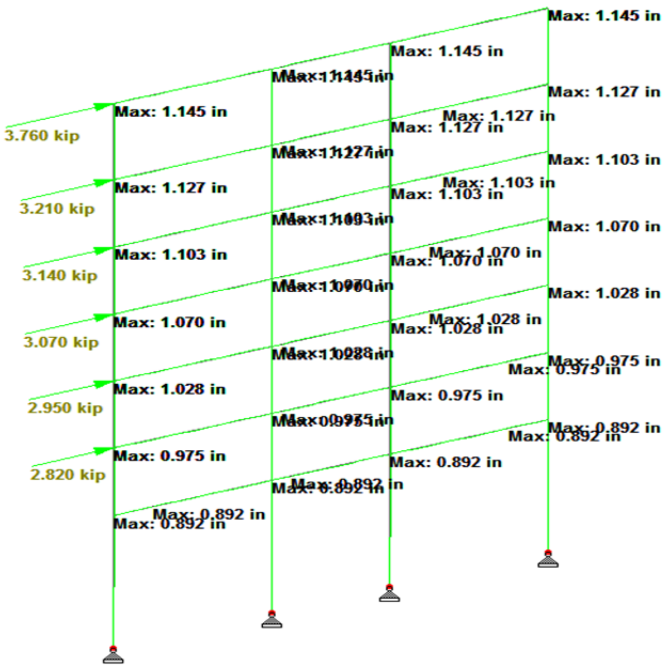


Figure: Drift Analysis 3 Bay Frame Wind E/ W Direction

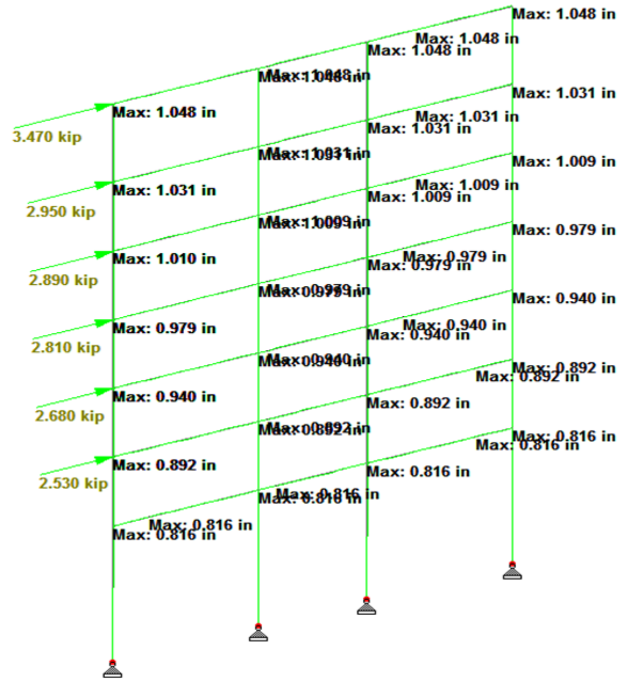


Figure: Drift Analysis 3 Bay Frame Wind N/S Direction

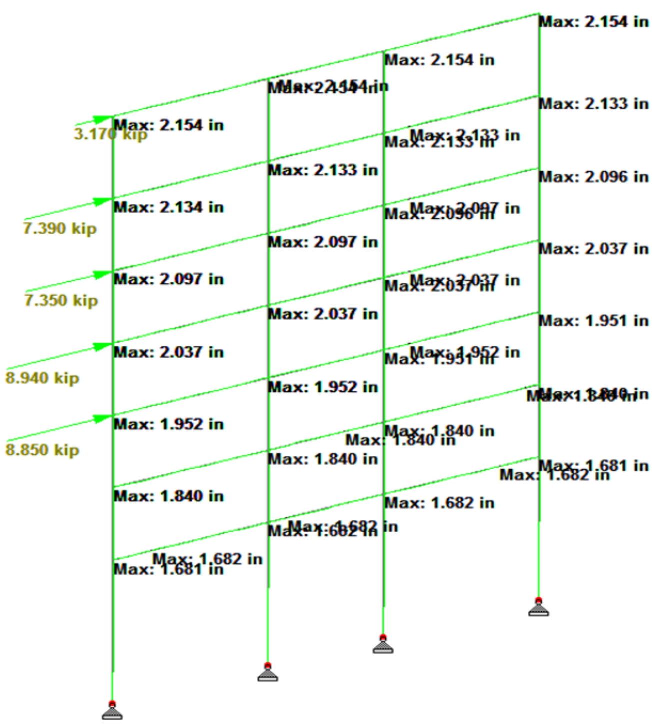


Figure: Drift Analysis 3 Bay Frame Seismic E/ W Direction

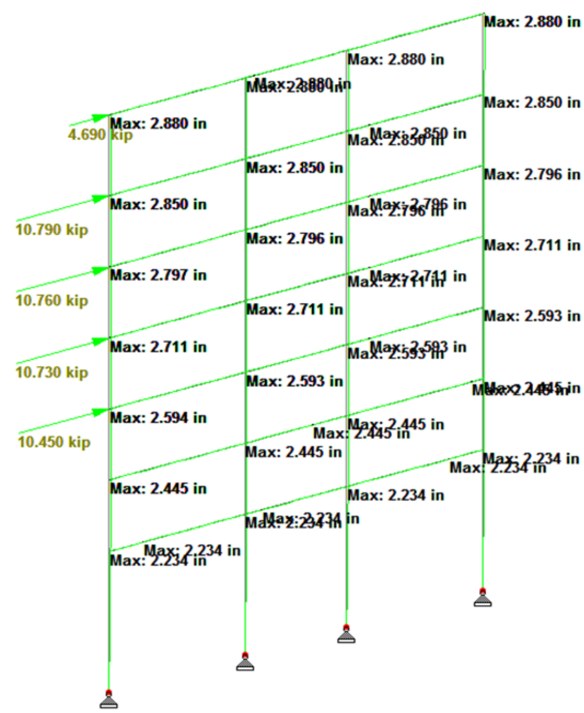


Figure: Drift Analysis 3 Bay Frame Wind N/S Direction

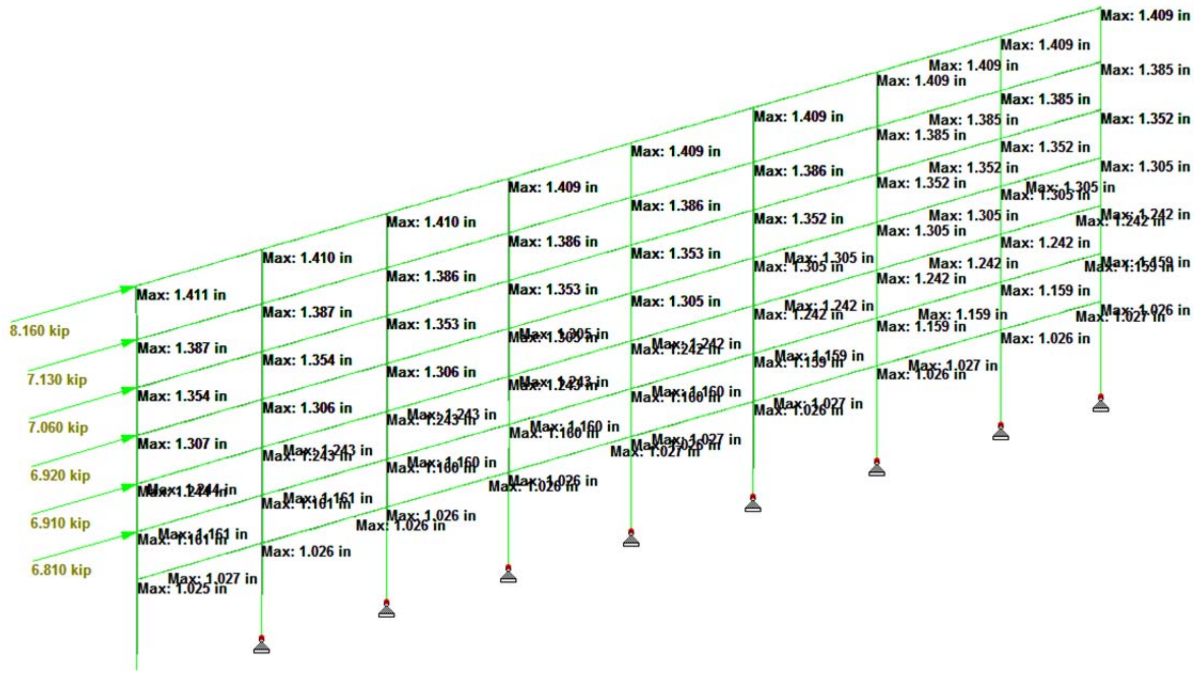


Figure: Drift Analysis 8 Bay Frame Wind E/ W Direction

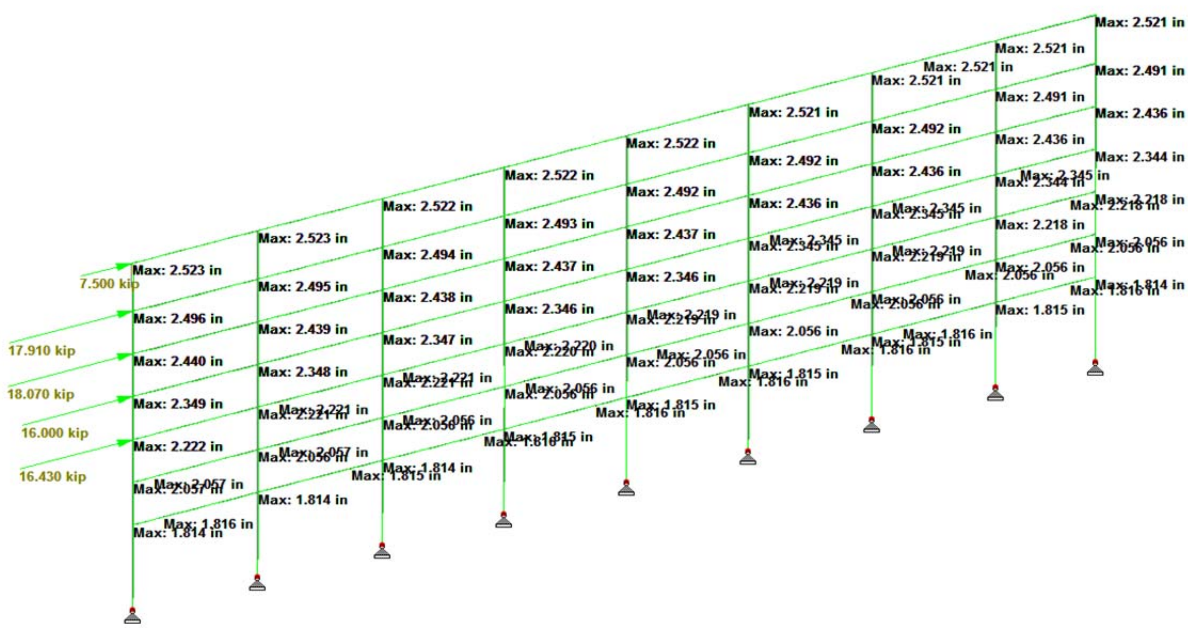


Figure: Drift Analysis 8 Bay Frame Seismic E/ W Direction

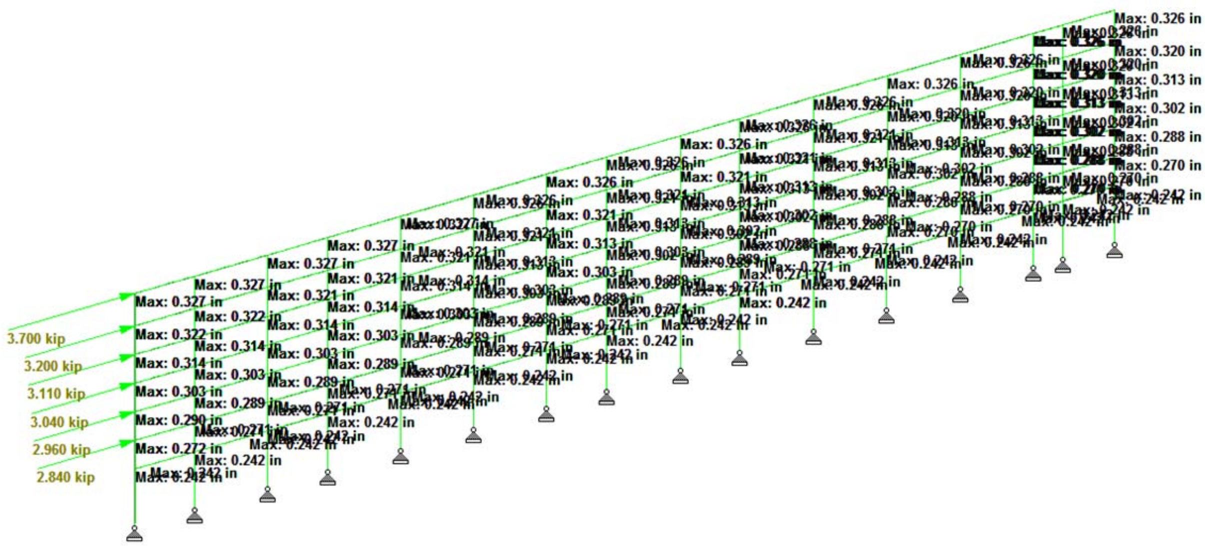


Figure: Drift Analysis 15 Bay Frame Wind N/S Direction

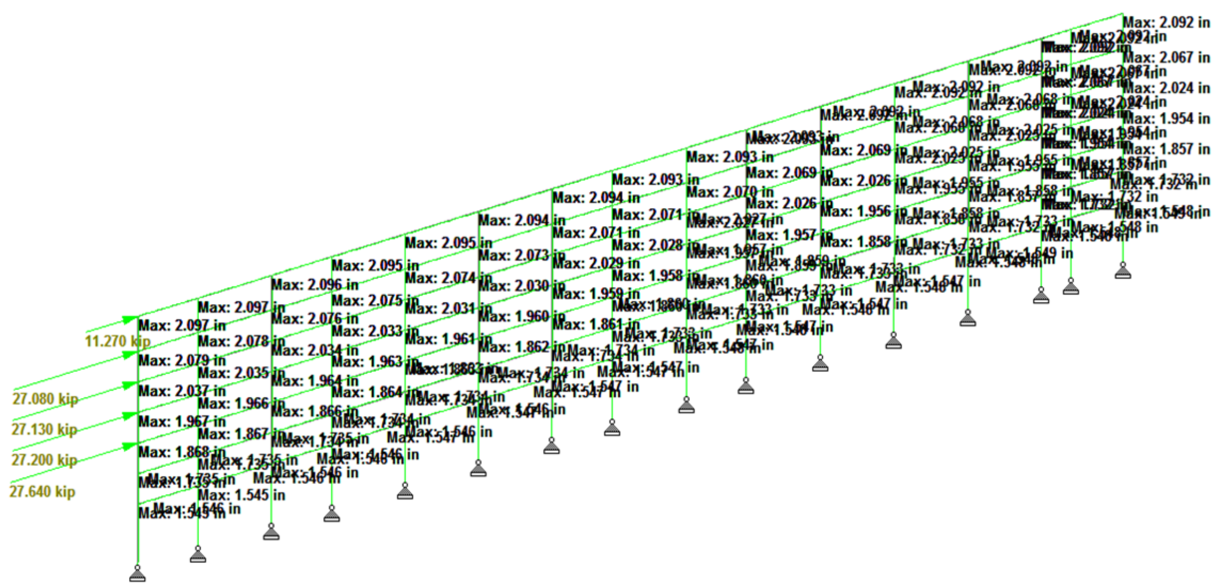


Figure: Drift Analysis 15 Bay Frame Seismic N/ S Direction

The table shown compares the drift at the top of each frame to the drift limits allowed for wind and seismic loads put forth in ASCE 7-10.

Drift Summary				
Direction	Lateral Force	Frame	Maximum Drift (in)	Drift Limit (in)
E/W	Wind	3 Bay	1.14	1.48
E/W	Wind	8 Bay	1.41	1.48
N/S	Wind	3 Bay	1.04	1.48
N/S	Wind	15 Bay	0.322	1.48
E/W	Seismic	3 Bay	2.154	17.76
E/W	Seismic	8 Bay	2.52	17.76
N/S	Seismic	3 Bay	2.88	17.76
N/S	Seismic	15 Bay	2.09	17.76

Table: Drift Values

Frame Spot Check

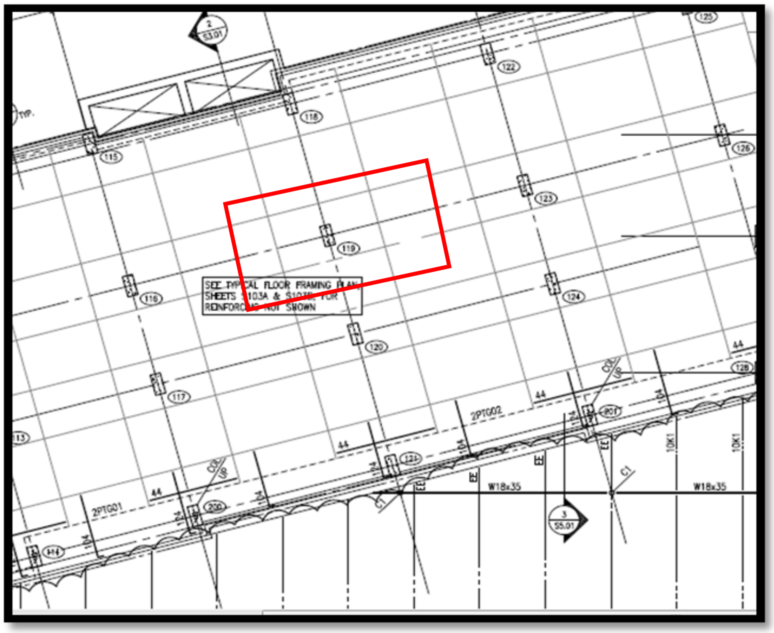


Figure: Column #119 Location

A column check was performed for an interior a 14" x 30" column in a 3 bay frame positioned on the 2nd floor of the Embassy Suites Hotel project along column line 5. This was considered a typical column in the structure. Column number 119 was analysis was performed with axial and bending affects applied with the lateral loads being from the east / west wind direction.

To develop an interaction diagram the CRSI Design Handbook was used. The interaction diagram values and the calculated values for Pu and Mu were compared with Pu and Mu falling in the limits of the diagram.

The analysis results showed that the column was adequate for the design. Detailed calculation can be found in Appendix

Conclusion

By analyzing the lateral systems and the effects of lateral forces on individual frames throughout the building of the Embassy Suites Hotel one gains a better understanding of how multiple structural elements work together as a part of a lateral force resisting systems and how the building responds to these loads. In analyzing multiple load combinations, comparing story drift to code limitations and checking members for adequacy it shows how the building performs due to wind, seismic, and gravity loads. It was found that the design of the Embassy Suites Hotel was developed according to code standards and can resist the loads that will be applied.

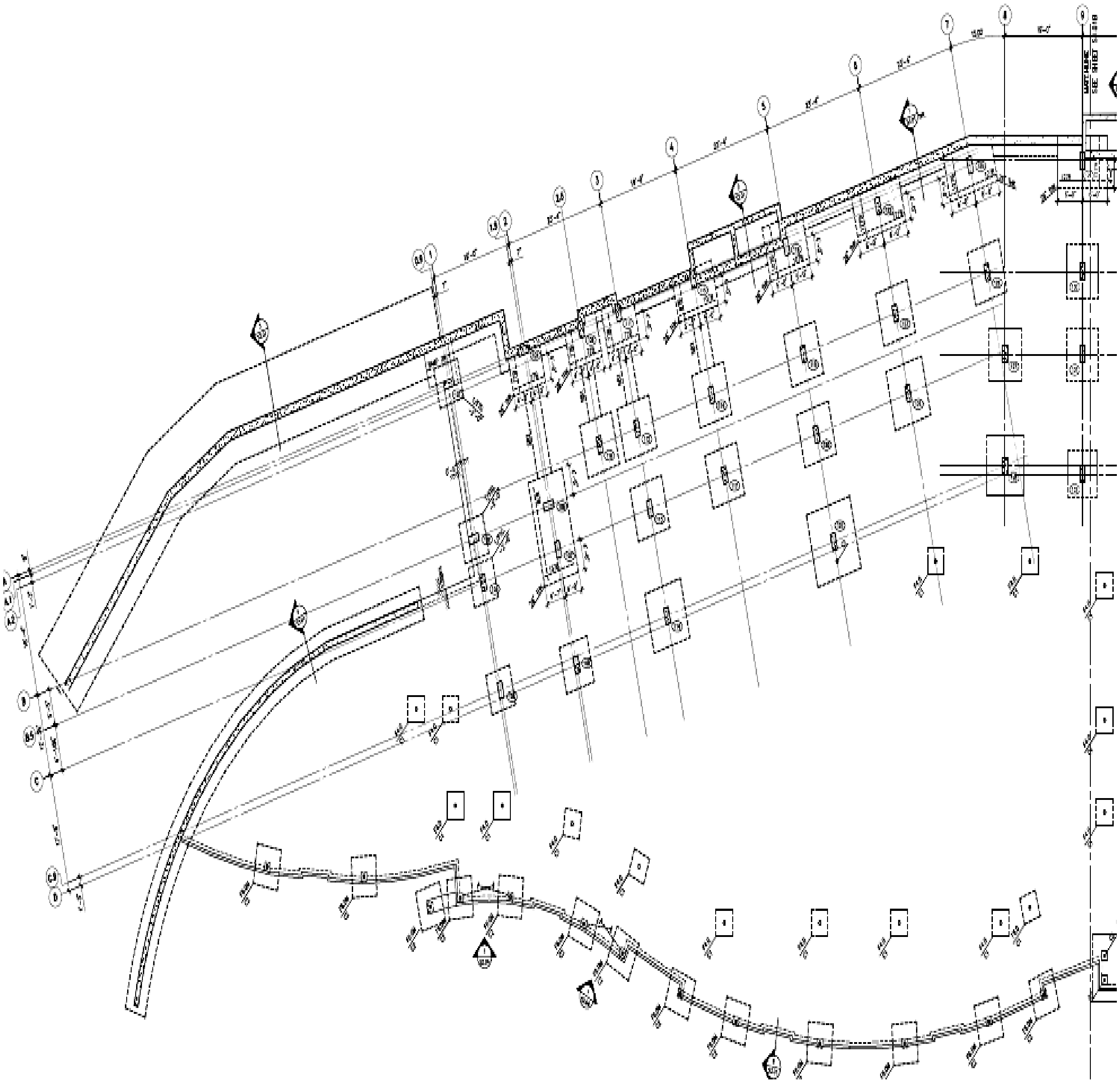
In the wind and seismic analysis forces acting on the faces of the building were found using Analytical Procedure and Equivalent Lateral Force Procedure put forth in ASCE 7-05. In examining the load combinations it was found that the pressures due to wind would control the design for the lateral systems when the various ASCE load combinations were applied.

A series of 2D computer models were developed to analyze maximum drift due to the combination direct and torsional forces acting on 3 types of frames in the building. The total drift at the top of the frames was found to be adequate and met all code standards. Due to the L-Shape configuration further research into torsional effects caused by a will be investigated following the proposal to ensure stability.

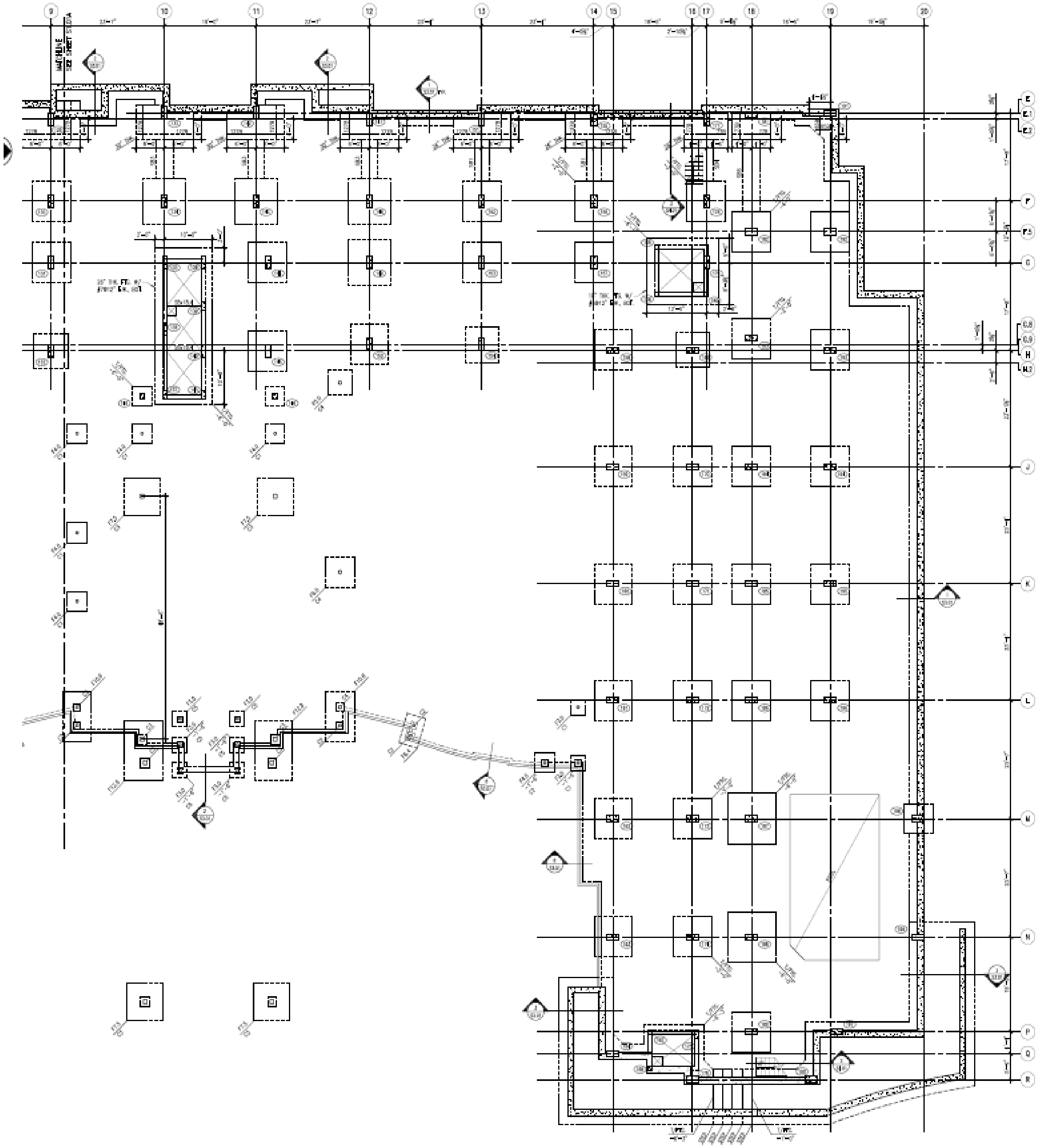
The main structural components of the load resisting systems include reinforced concrete moment frames, contained flat slab construction and reinforced concrete 14 x 30 columns located throughout the building. The columns that are a part of this moment frame system are designed due the combination of lateral and gravity loads that can cause different loading effects on the particular members. The slab of lateral system has found to require top reinforcing bars in the columns trip to prevent the failure mechanism known as punching shear.

To check the adequacy of frame components, a 14” x 30” interior tied column with 8 vertical reinforcing bars spot check was performed on the second floor. Using an interaction diagram the column was found to be adequate for the combination of loads that will be applied to it.

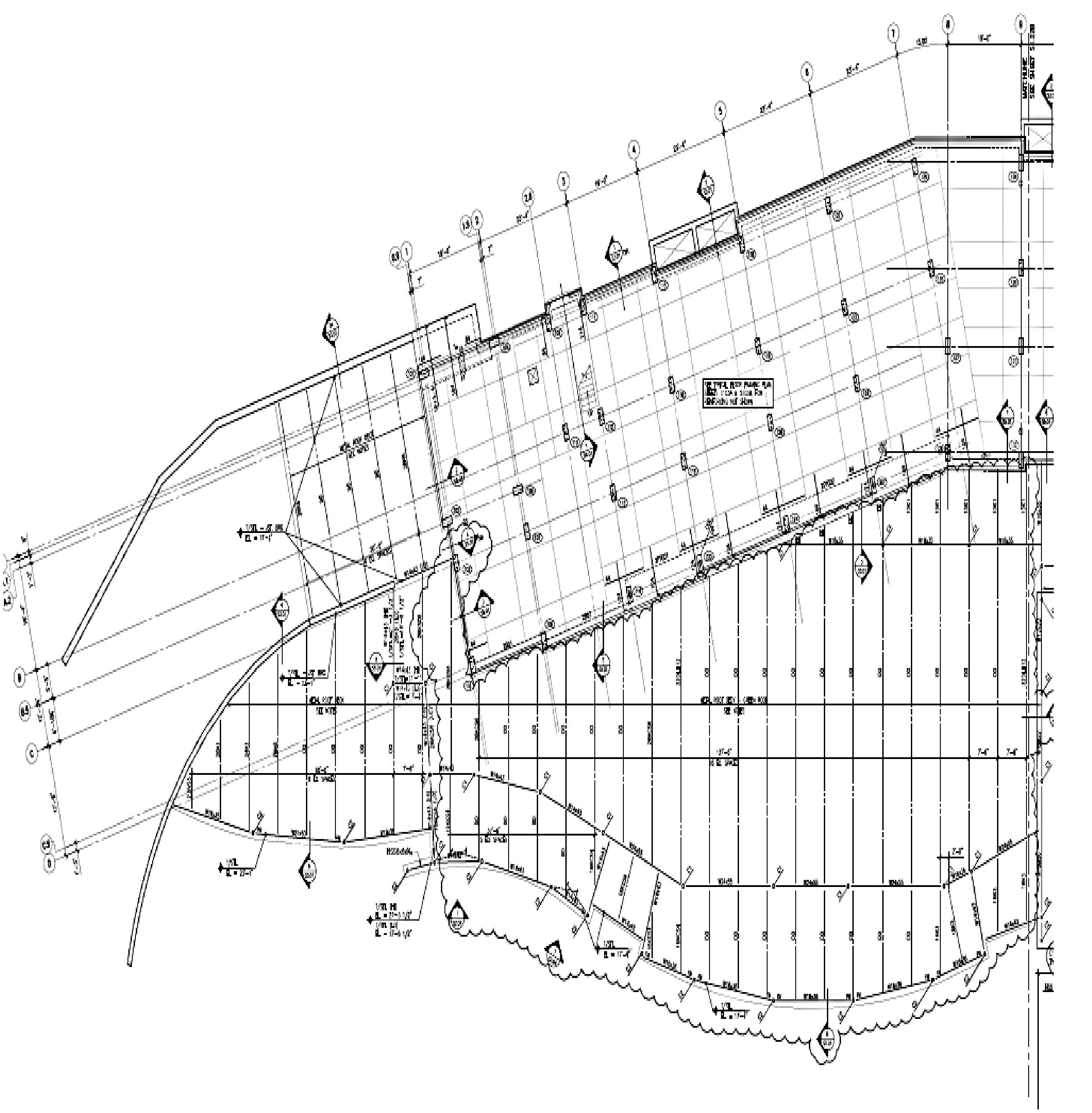
Appendix A: Plans



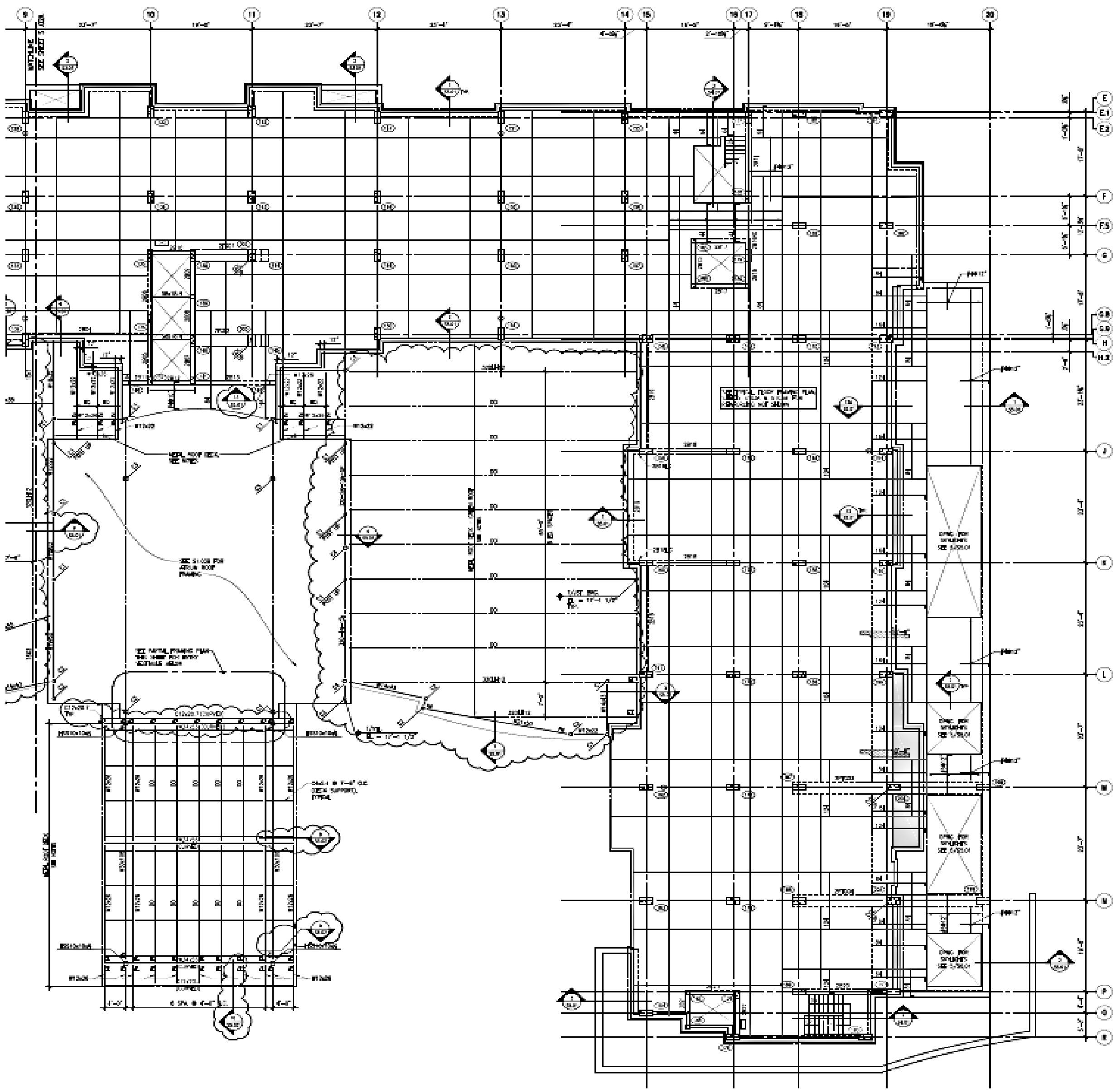
Foundation Plan A



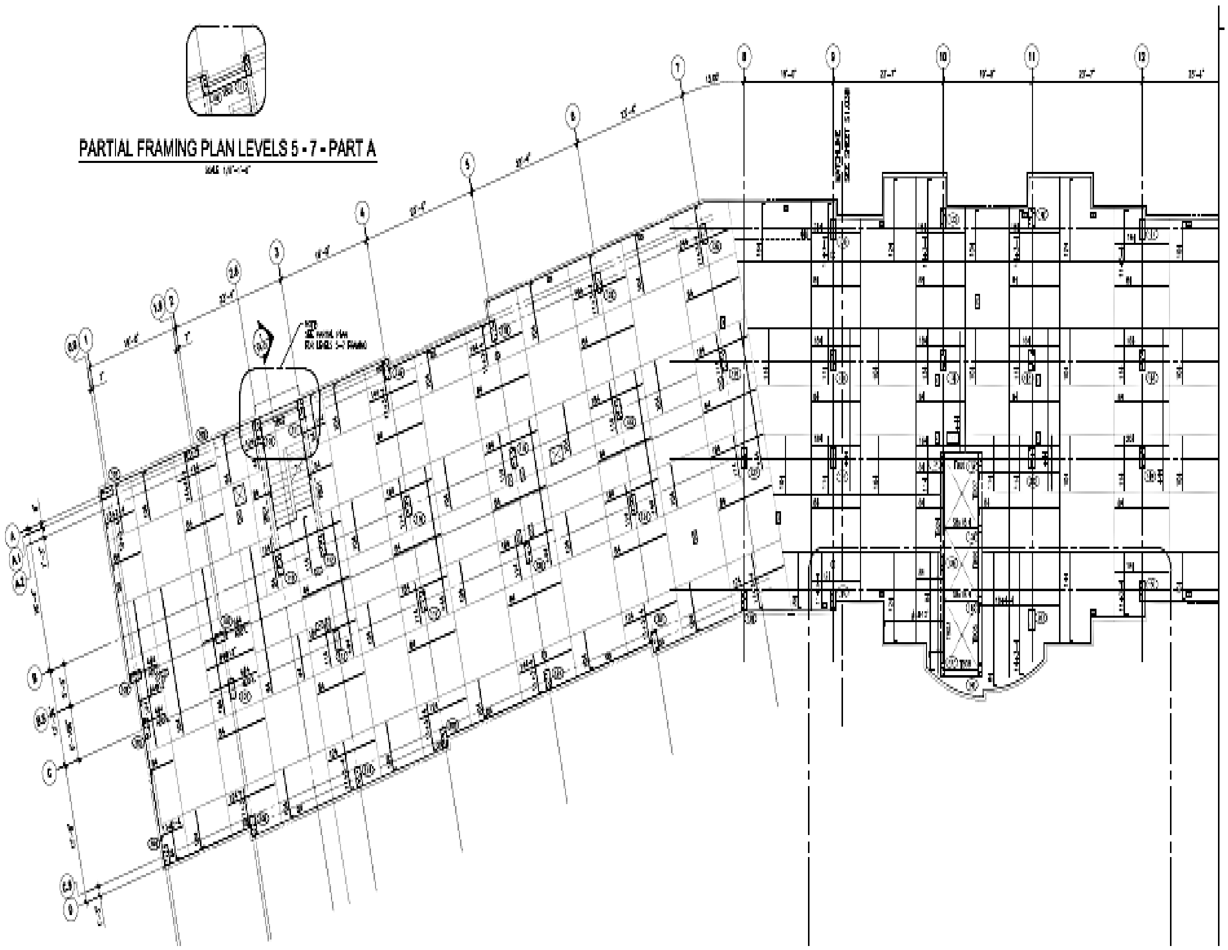
Foundation Plan B



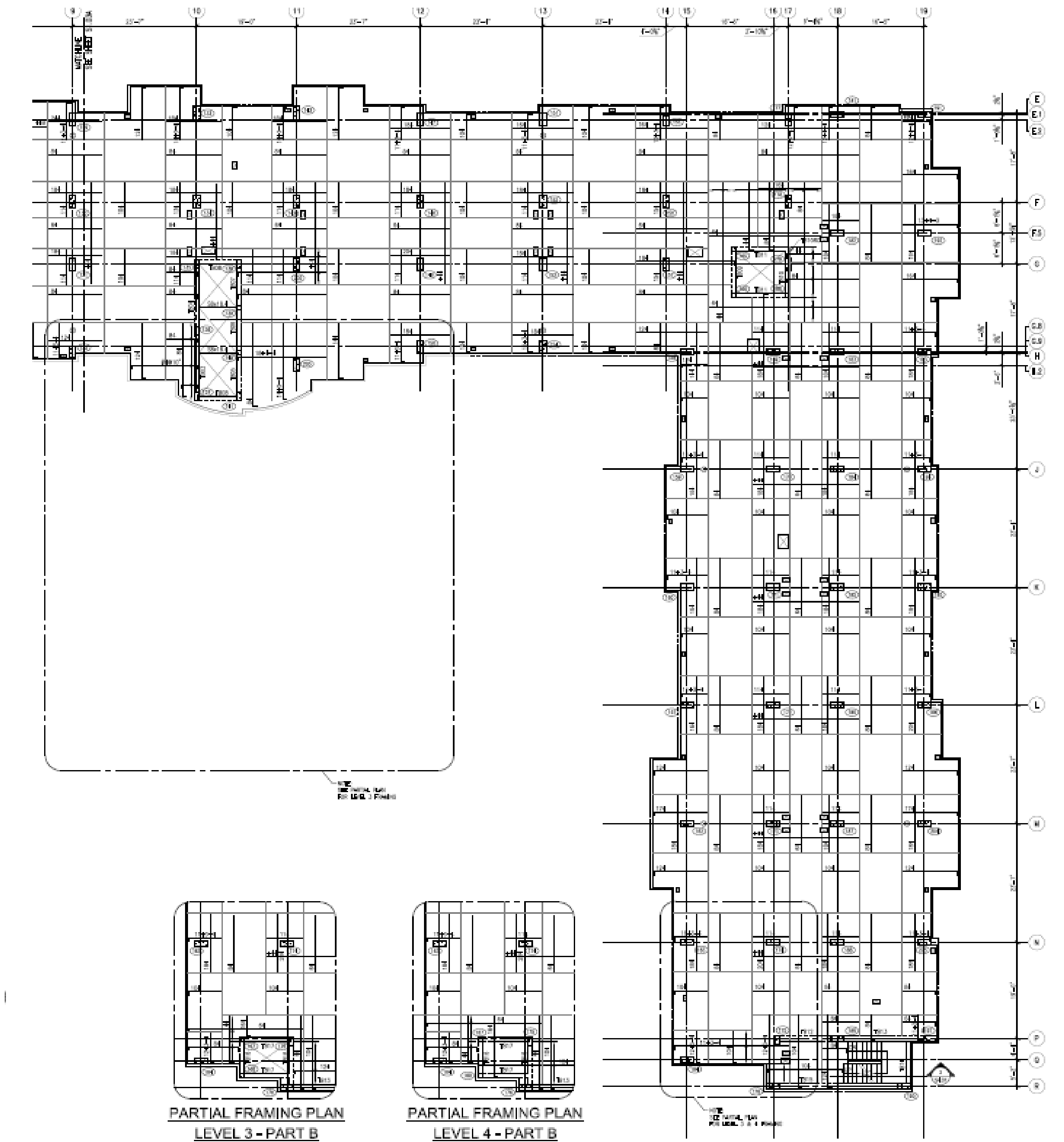
Floor Plan 2 Part A



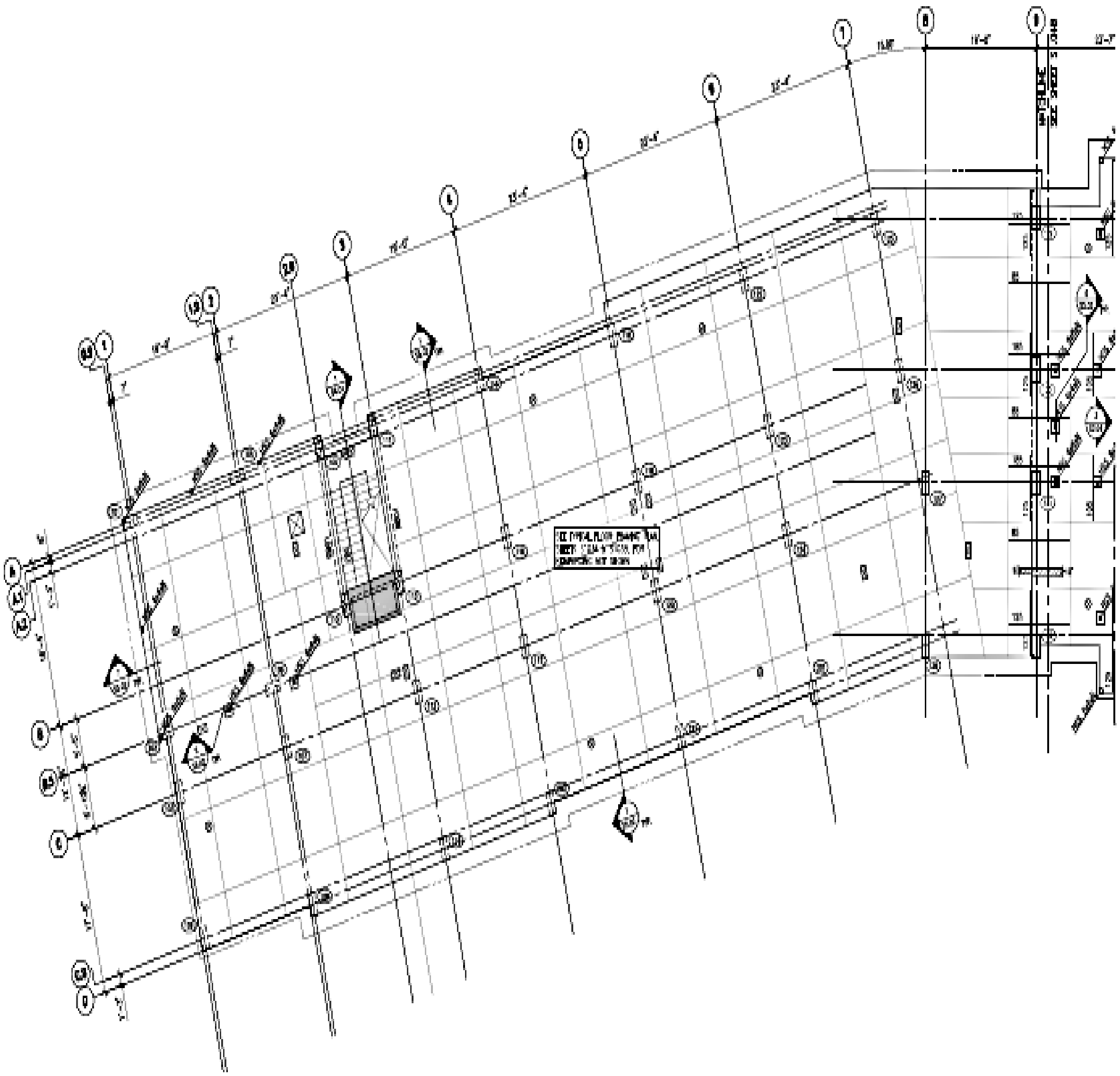
Floors Plan 2 Part B



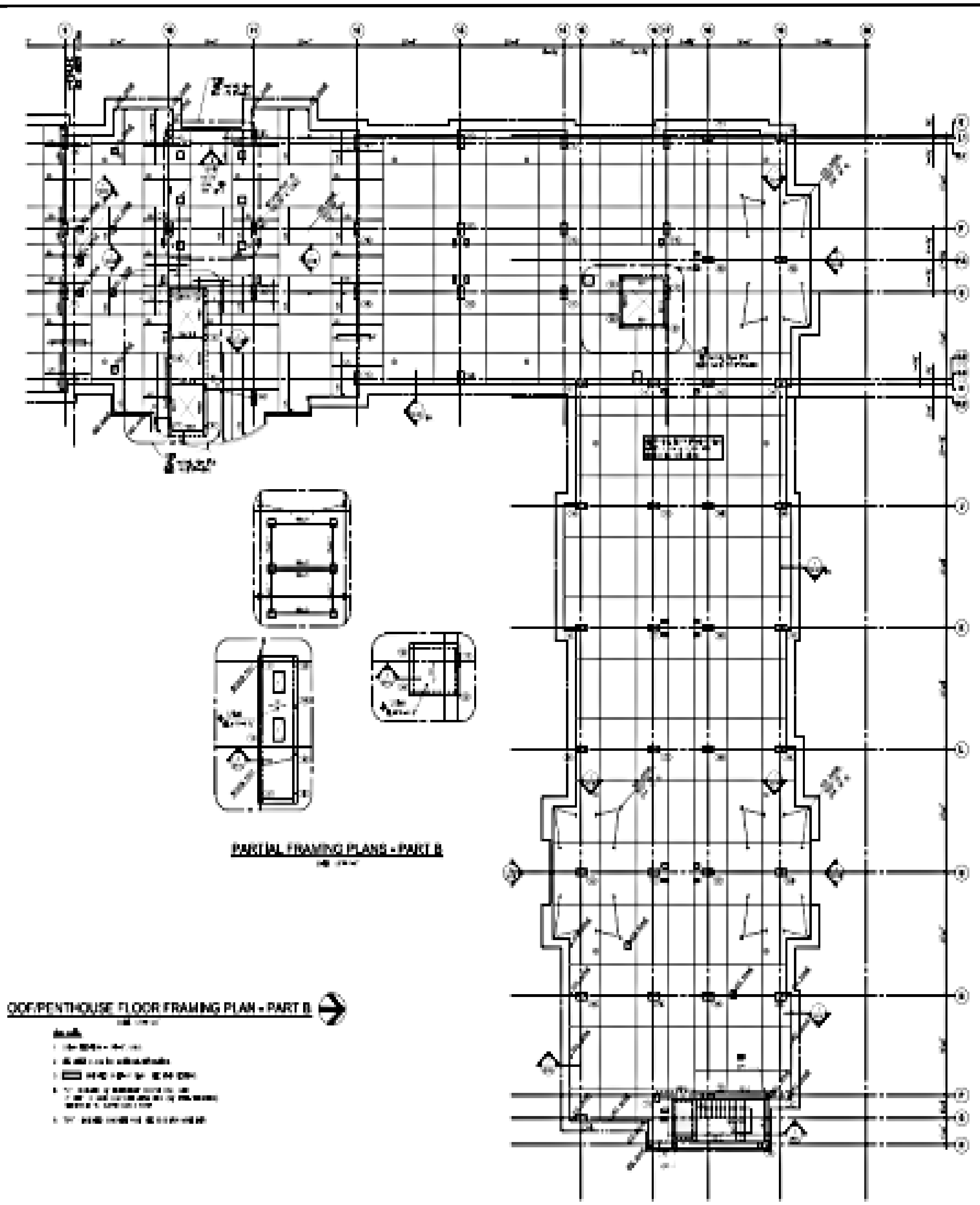
Floors Plan 3 to 7 Part A



Floor Plan 3-7 Part B



Main Roof Level Part A



Main Roof Level Part B

Appendix B: Snow and Sliding Snow Analysis

DL | Snow Analysis | TECH 1

Snow Analysis (Springfield, Va)

- Ground Snow Load → $P_g = 25$ psf
- Exposure factor → $C_e = .9$
- Thermal factor → $C_t = 1.0$
- Importance factor → $I = 1.0$

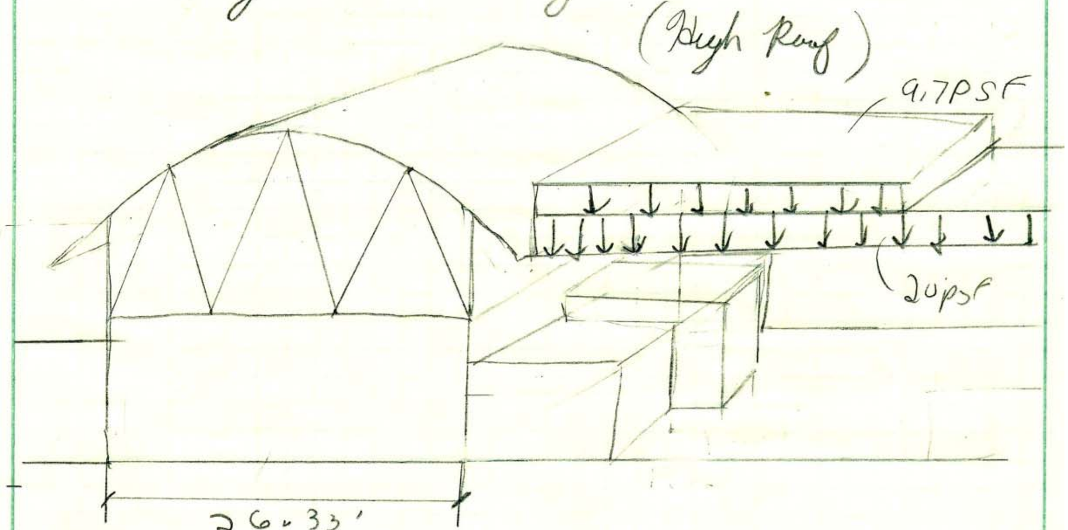
$P_f = .7(C_e)(C_t) I P_g > 20 I$

$P_f = .7(.9)(1.0)(1.0)(25) = 15.75 \text{ psf} < 20(I)$

* Have to use 20 psf as a minimum value

DL | Sliding Snow | TECH | pg 1/1

Sliding Snow Analysis



- slope of roof is large enough (8/18 = .44) for consideration of sliding snow load

$p_s = .7 C_e C_t I p_g$

$p_s = .7(.9)(1.0)(1.0)(25) = 15.75 < 20psf \rightarrow$ use 20psf

- sliding surcharge on lower roof $\rightarrow S = .4 p_f W = .4(20)(18.21') = 145.7 plf$

- distributing over 15' width (ASCE 7-05)
  145.7 psf/15' = 9.71 psf

- An additional load can be 9.71 psf can be applied to lower flat roof with in 15' of sloped high roof

Appendix C: Wind Load Analysis

DL | Wind Analysis | TECH. 1 pg 1/6

Wind Analysis (Using ASCE 7-05)

- location - Springfield, Va
- h > 60' - Method 2 Analytical procedure
- Wind Variables:
  V = 90 MPH, $K_d = .85$, I = 1.0, $K_{zt} = 1.0$, Exposure = B

*K_z values differ at floor heights from values presented in TBL 6-3 - Have to interpolate (CASE II)

Level	Height Above Grade	K_z
1	0'-0"	0
2	18'-0"	.60
3	27'-1½"	.677
4	36'-3"	.738
5	45'-4½"	.787
6	54'-6"	.828
7	63'-7½"	.864
ROOF	74'-0"	.906
PENTHOUSE	91'-10"	.974

- $q_z = .00256 K_z K_{zt} K_d V^2 I$ (velocity pressure)

Example calculation: $.00256(.6)(1.0)(.85)(90)^2(1.0)$
@ Level 2 $= 10.575 = q_z$

* remainder of calculations computed for q_z in TBL.
* Building considered rigid structure, G = .85

DL | Wind Analysis | Tech 1 pg #/6

q_h @ mean roof HT. $\bar{z} = \frac{91.833 + 74}{2} = 82.917'$

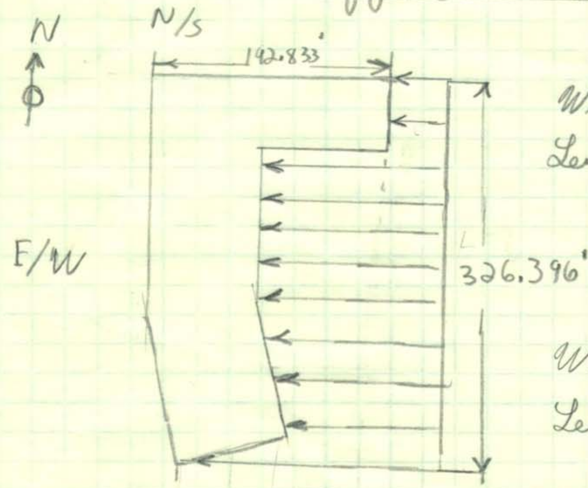
$\bar{z} = .6(82.917') = 49.745'$

$49.745' > z_{min} = 30'$ ok ✓

k_z @ $82.917 = .938$

$q_h = .00256(.938)(1.0)(.85)(90)^2(1.0) = 16.533\ psf$

- Pressure Coefficient, C_p



East / West

Winward $= .8 = C_p$

Leeward - $L/B = \frac{192.833}{326.396} = .59$

$C_p = -.5$

North / South

Winward $= .8 = C_p$

Leeward - $L/B = \frac{326.396}{192.833} = 1.69$

$C_p = -.362$

- Wind Pressure

$P_z = q_z G C_p - q_h G C_{pi}$ → windward

$P_h = q_h G C_p - q_h G C_{pi}$ → leeward

* GC_{pi} is $(+.18, -.18)$ for enclosed buildings

- example - E/W → Level 3

$P_z = (11.993)(.85)(.8) - (16.533\ psf)(-.18) = 11.090\ psf$

$P_h = (16.533)(.85)(-.5) - (16.533\ psf)(.18) = -10.002\ psf$

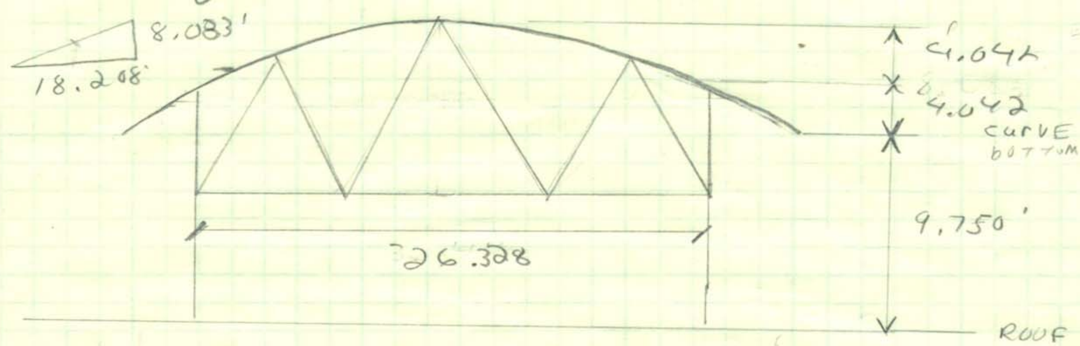
- example - N/S → Level 3

$P_z = (11.993)(.85)(.8) - (16.533)(-.18) = 11.090\ psf$

$P_h = (16.533)(.85)(-.362) - (16.533)(.18) = -8.063\ psf$

DL | Wind Analysis | TECH. 1 pg 3/6

- Penthouse level assumed to be partially enclosed use GC_{pi} = (±).55



- Roof elevated on structure (N/S direction)
  - rise to span ratio → $\frac{8.083'}{18.208'} = .44$
  - $.3 \le .44 \le .6$
  - windward quarter $C_p = 2.75(.44) - .7 = .51$
  - Center half $C_p = -.7 - .44 = -1.14$
  - Leeward quarter $C_p = -.5$

N/S

$P_z = (16.999)(.85)(.51) - (16.533)(\pm.55) = 16.232$ (windward)

$P_h = (16.533)(.85)(-.5) - (16.533)(.55) = -16.120$ (Leeward)

E/W $h/L \le .5$, h to 2h, $C_p = -.5, -.18$

$P_z = (17.009)(.85)(-.5) - (16.533)(\pm.55) = 11.864$ psf

$P_h = (16.533)(.85)(-.18) - (16.533)(.55) = 11.623$ psf

* Center Panel N/S

$P_z = (17.004)(.85)(-1.14) - (16.533)(.55)$

$P_z = 25.575$ psf

DL | Wind Analysis | TECH 1 pg 4/6

Force of Windward wall

F = (BASE)(STORY HT.)(pz)

- example E/W → level 2 (windward wall)

F = (326.346')(9.125')(10.575 psf) = 30283#/1000 = 30.3k

- using TOTAL pressure → level 2

F = (326.346')(9.125)(20.164) = 60.1k

- example N/S → level 2 (windward wall)

F = (192.833)(9.125)(10.575) = 18.6k

- using TOTAL pressure → level 2

F = (192.833)(9.125)(18.23) = 32.1k

- example E/W → Penthouse (top) (windward only)

F = (26.416)(17.833)(1.864) = .878k

- using total load

F = (26.416)(17.833)(12.948) = 6.35k

- example N/S → Penthouse roof (greater, windward only)

F = (53.916)(13.792)(16.232) = 12.1k

- using total load (@ greater)

F = (53.916)(13.792)(32.352) = 24.1k

- * TOTAL LOAD E/W Center panel

F = (53.916)(4.041)(25.575) = 5.572k

Appendix D: Seismic Analysis

Dead Loads(Floors 2)						
Columns						
Element	Material	Shape	Quantity	Weight (pcf)	Floor Ht. (ft.)	Load(K)
Column	Concrete	14x30	182	150	9.125	727.4
Column	Concrete	10x20	6	150	9.125	11.4
Column	Concrete	10x10	6	150	9.125	5.7

Dead Loads(Floors 3)						
Columns						
Element	Material	Shape	Quantity	Weight (pcf)	Floor Ht.(ft.)	Load(K)
Column	Concrete	14x30	184	150	9.125	735.4
Column	Concrete	10x20	6	150	9.125	11.4
Column	Concrete	10x10	6	150	9.125	5.7
Slab						
Thickness(in)	Weight	Load (K)				
8	150	2394.6				
Superimposed						
Type	Weight (psf)	Load (K)				
MEP	**5**	119.7				

Dead Loads (Floors 4-7)						
Columns						
Element	Material	Shape	Quantity	Weight (pcf)	Floor Ht.	Load(K)
Column	Concrete	14x30	184	150	9.125	735.4
Column	Concrete	10x20	6	150	9.125	11.4
Column	Concrete	10x10	6	150	9.125	5.7
Slab						
Thickness(in)	Weight	Load (K)				
8	150	2389.9				
Superimposed						
Type	Weight (psf)	Load (K)				
MEP	**5**	119.5				

Dead Loads (Roof)		
Slab		
Thickness(in)	Weight	Load (K)
3.5	150	971
Superimposed		
Type	Weight (psf)	Load (K)
Metal Deck	**4.36**	104.2
Snow Load*	**6**	143.4

*Due to ASCE 7-05 takes 20% of roof snow load

D.L. | Seismic Analysis | TECH 1 pg 1/3

Seismic Analyses (Using ASCE 7-05)

- $S_1 = .051$, $S_S = .155$, $F_V = 2.4$, $F_a = 1.6$

$S_{MS} = F_a S_S = (1.6)(.155) = .248$

$S_{DS} = (2/3) S_{MS} = (2/3)(.248) = .165$

$S_{M1} = F_V S_1 = (2.4)(.051) = .1224$

$S_{D1} = 2/3(.1224) = .0816$

$S_{DS} = .165$ & OC II $\rightarrow$ SDC = "A" $\rightarrow$ use B
$S_{D1} = .0816$ & OC II $\rightarrow$ SDC = "B"

- **Equivalent Lateral Force Procedure**
(Seismic Base Shear)

- response mod. factor, $R = 3$ (ordinary concrete moment frames)

$T_a = C_t h^x \rightarrow$ for moment frames $h_W =$, $x = .9$
$C_t = .016$

$T_a = (.016)(56')^{(.9)} = .599$

- for Springfield, Virginia, $T_L = 8$ seconds

$C_S = \frac{S_{DS}}{R/I} = \frac{.165}{3/1.0} = .055 \geq .01$ ✓

$T_a = .599 < T_L = 8s$ ✓

DJ | Seismic Analysis | TECH.1 pg 2/3

- Seismic Loads

- Roof → slab = $(\frac{3.25}{12''})(23{,}899\,ft^2)(150) = 971^k$

metal deck = (4.36 psf)(23,899) = 104.2^k

snow load = (20%)(30psf)(23899) = 143.4^k

- Floors 4-7 → slab = $(8''/12)(23{,}899\,ft^2)(150) = 2389.9^k$

MEP = (5psf)(23,899 ft^2) = 119.5^k

columns (* see excell spreadsheet) = 735.4^k

- Floor 3 → slab = (8/12)(23,946 ft^2)(150) 2394.6

MEP = (5psf)(23946 ft) = 119.7^k

columns = (* see excell spreadsheet) = 735.4^k

- Floor 2 → MEP = (5psf)(23,907) = 119.5^k

Columns = 735.4^k

*Do not include slab @ 2 in calculation

TOTAL LOAD → $(971^k + 104.2 + 143.4^k)_{roof}$ +

[2389.9 + 119.5 + 735.4](3 FLOORS)

+ (2394.6 + 119.7 + 735.4) + (119.5 + 735.4)

= 15057.6^k

$V = C_s W$ = (.055)(15057.6) = 828.2^k = base shear

DL | Seismic Analysis | TECH 1 pg 2/3

Vertical Distribution of Seismic Forces

$F_x = C_{vx} V$, $C_{vx} = \frac{w_x h_x^k}{\Sigma w_i h^k}$ $k = 1.0$ $T \leq .5$

$C_{RL} = \frac{1218.2(10.375')^{1.0}}{(3)(FL)(3244.8)(9.125)^{1.0} + (3249.7)(9.125)^{1.0} + 1218.2(10.375)^{1.0}}$

$C_{RL} = .096$

$C_{FL\,4\text{-}7} = \frac{(3244.8)(9.125)^{1.0}}{(3)(3244.8)(9.125)^{1.0} + (3249.7)(9.125)^{1.0} + 1218.2(10.375)^{1.0}}$

$C_{FL\,4\text{-}7} = .2258$

$C_{FL\,3} = \frac{(3249.7)(9.125)}{(3)(3244.8)(9.125)^{1.0} + (3249.7)(9.125)^{1.0} + (1218.2)(10.375)^{1.0}}$

$C_{FL\,3} = .2262$ $\rightarrow$ $.096 + (.2258)(3) + .2262 = 1.0$ ok ✓

$F_{RL} = .096(781^k) = 75^k$

$F_{FL\,4\text{-}7} = .2258(781^k) = 176.3^k$

$F_{FL\,3} = .2262(781^k) = 176.7^k$

Appendix E: K-Value Table

Level	Wind Direction	Bay Size	Load (K)	Delta	K Value (K/in)
7th	E/W	3 Bay	1	0.143	7.0
6th	E/W	3 Bay	1	0.134	7.5
5th	E/W	3 Bay	1	0.125	8.0
4th	E/W	3 Bay	1	0.116	8.6
3rd	E/W	3 Bay	1	0.108	9.3
2nd	E/W	3 Bay	1	0.098	10.2
1st	E/W	3 Bay	1	0.084	11.9
7th	E/W	8 Bay	1	0.096	10.4
6th	E/W	8 Bay	1	0.088	11.4
5th	E/W	8 Bay	1	0.081	12.3
4th	E/W	8 Bay	1	0.075	13.3
3rd	E/W	8 Bay	1	0.067	14.9
2nd	E/W	8 Bay	1	0.059	16.9
1st	E/W	8 Bay	1	0.048	20.8
7th	N/S	15 Bay	1	0.048	20.8
6th	N/S	15 Bay	1	0.044	22.7
5th	N/S	15 Bay	1	0.041	24.4
4th	N/S	15 Bay	1	0.038	26.3
3rd	N/S	15 Bay	1	0.034	29.4
2nd	N/S	15 Bay	1	0.030	33.3
1st	N/S	15 Bay	1	0.025	40.0
7th	N/S	3 Bay	1	0.143	7.0
6th	N/S	3 Bay	1	0.134	7.5
5th	N/S	3 Bay	1	0.125	8.0
4th	N/S	3 Bay	1	0.116	8.6
3rd	N/S	3 Bay	1	0.108	9.3
2nd	N/S	3 Bay	1	0.098	10.2
1st	N/S	3 Bay	1	0.084	11.9

Appendix F: Torsional Force Tables

Wind Tables: East / West Direction

Case 1 E / W Wind									
Level 7									
Floor	Frame	Ki	di	di^2	Kidi^2	Kidi	M(k-ft)	∑ Kidi^2	Fi
7th	Frame 1	7	-175	30625	214375.00	-1225	1525.2	1305555.22	-1.43
7th	Frame 2	7	-156	24336	170352.00	-1092	1525.2	1305555.22	-1.28
7th	Frame 3	7	-132.67	17601.3289	123209.30	-928.69	1525.2	1305555.22	-1.08
7th	Frame 4	7	-113.67	12920.8689	90446.08	-795.69	1525.2	1305555.22	-0.93
7th	Frame 5	7	-90.34	8161.3156	57129.21	-632.38	1525.2	1305555.22	-0.74
7th	Frame 6	7	-67.01	4490.3401	31432.38	-469.07	1525.2	1305555.22	-0.55
7th	Frame 7	7	-43.8	1918.44	13429.08	-306.6	1525.2	1305555.22	-0.36
7th	Frame 8	7	-24.68	609.1024	4263.72	-172.76	1525.2	1305555.22	-0.20
7th	Frame 9	7	-1.1	1.21	8.47	-7.7	1525.2	1305555.22	-0.01
7th	Frame 10	7	17.2	295.84	2070.88	120.4	1525.2	1305555.22	0.14
7th	Frame 11	7	41.48	1720.5904	12044.13	290.36	1525.2	1305555.22	0.34
7th	Frame 12	7	64.81	4200.3361	29402.35	453.67	1525.2	1305555.22	0.53
7th	Frame 13	10.4	88.14	7768.6596	80794.06	916.656	1525.2	1305555.22	1.07
7th	Frame 14	10.4	111.5	12432.25	129295.40	1159.6	1525.2	1305555.22	1.35
7th	Frame 15	10.4	120.8	14592.64	151763.46	1256.32	1525.2	1305555.22	1.47
7th	Frame 16	10.4	137.12	18801.8944	195539.70	1426.048	1525.2	1305555.22	1.67

Case 1 E / W Wind									
Level 6									
Floor	Frame	Ki	di	di^2	Kidi^2	Kidi	M(k-ft)	∑ Kidi^2	Fi
6th	Frame 1	7.5	-175	30625	229687.50	-1312.5	1313.5	1412590.85	-1.22
6th	Frame 2	7.5	-156	24336	182520.00	-1170	1313.5	1412590.85	-1.09
6th	Frame 3	7.5	-132.67	17601.3289	132009.97	-995.025	1313.5	1412590.85	-0.93
6th	Frame 4	7.5	-113.67	12920.8689	96906.52	-852.525	1313.5	1412590.85	-0.79
6th	Frame 5	7.5	-90.34	8161.3156	61209.87	-677.55	1313.5	1412590.85	-0.63
6th	Frame 6	7.5	-67.01	4490.3401	33677.55	-502.575	1313.5	1412590.85	-0.47
6th	Frame 7	7.5	-43.8	1918.44	14388.30	-328.5	1313.5	1412590.85	-0.31
6th	Frame 8	7.5	-24.68	609.1024	4568.27	-185.1	1313.5	1412590.85	-0.17
6th	Frame 9	7.5	-1.1	1.21	9.08	-8.25	1313.5	1412590.85	-0.01
6th	Frame 10	7.5	17.2	295.84	2218.80	129	1313.5	1412590.85	0.12
6th	Frame 11	7.5	41.48	1720.5904	12904.43	311.1	1313.5	1412590.85	0.29
6th	Frame 12	7.5	64.81	4200.3361	31502.52	486.075	1313.5	1412590.85	0.45
6th	Frame 13	11.4	88.14	7768.6596	88562.72	1004.796	1313.5	1412590.85	0.93
6th	Frame 14	11.4	111.5	12432.25	141727.65	1271.1	1313.5	1412590.85	1.18
6th	Frame 15	11.4	120.8	14592.64	166356.10	1377.12	1313.5	1412590.85	1.28
6th	Frame 16	11.4	137.12	18801.8944	214341.60	1563.168	1313.5	1412590.85	1.45

Case 1 E / W Wind									
Level 5									
Floor	Frame	Ki	di	di^2	Kidi^2	Kidi	M(k-ft)	∑ Kidi^2	Fi
5th	Frame 1	8	-175	30625	245000.00	-1400	1288.9	1514266.94	-1.19
5th	Frame 2	8	-156	24336	194688.00	-1248	1288.9	1514266.94	-1.06
5th	Frame 3	8	-132.67	17601.3289	140810.63	-1061.36	1288.9	1514266.94	-0.90
5th	Frame 4	8	-113.67	12920.8689	103366.95	-909.36	1288.9	1514266.94	-0.77
5th	Frame 5	8	-90.34	8161.3156	65290.52	-722.72	1288.9	1514266.94	-0.62
5th	Frame 6	8	-67.01	4490.3401	35922.72	-536.08	1288.9	1514266.94	-0.46
5th	Frame 7	8	-43.8	1918.44	15347.52	-350.4	1288.9	1514266.94	-0.30
5th	Frame 8	8	-24.68	609.1024	4872.82	-197.44	1288.9	1514266.94	-0.17
5th	Frame 9	8	-1.1	1.21	9.68	-8.8	1288.9	1514266.94	-0.01
5th	Frame 10	8	17.2	295.84	2366.72	137.6	1288.9	1514266.94	0.12
5th	Frame 11	8	41.48	1720.5904	13764.72	331.84	1288.9	1514266.94	0.28
5th	Frame 12	8	64.81	4200.3361	33602.69	518.48	1288.9	1514266.94	0.44
5th	Frame 13	12.3	88.14	7768.6596	95554.51	1084.122	1288.9	1514266.94	0.92
5th	Frame 14	12.3	111.5	12432.25	152916.68	1371.45	1288.9	1514266.94	1.17
5th	Frame 15	12.3	120.8	14592.64	179489.47	1485.84	1288.9	1514266.94	1.26
5th	Frame 16	12.3	137.12	18801.8944	231263.30	1686.576	1288.9	1514266.94	1.44

Case 1 E / W Wind									
Level 4									
Floor	Frame	Ki	di	di^2	Kidi^2	Kidi	M(k-ft)	∑ Kidi^2	Fi
4th	Frame 1	8.6	-175	30625	263375.00	-1505	1261.6	1631990.61	-1.16
4th	Frame 2	8.6	-156	24336	209289.60	-1341.6	1261.6	1631990.61	-1.04
4th	Frame 3	8.6	-132.67	17601.3289	151371.43	-1140.962	1261.6	1631990.61	-0.88
4th	Frame 4	8.6	-113.67	12920.8689	111119.47	-977.562	1261.6	1631990.61	-0.76
4th	Frame 5	8.6	-90.34	8161.3156	70187.31	-776.924	1261.6	1631990.61	-0.60
4th	Frame 6	8.6	-67.01	4490.3401	38616.92	-576.286	1261.6	1631990.61	-0.45
4th	Frame 7	8.6	-43.8	1918.44	16498.58	-376.68	1261.6	1631990.61	-0.29
4th	Frame 8	8.6	-24.68	609.1024	5238.28	-212.248	1261.6	1631990.61	-0.16
4th	Frame 9	8.6	-1.1	1.21	10.41	-9.46	1261.6	1631990.61	-0.01
4th	Frame 10	8.6	17.2	295.84	2544.22	147.92	1261.6	1631990.61	0.11
4th	Frame 11	8.6	41.48	1720.5904	14797.08	356.728	1261.6	1631990.61	0.28
4th	Frame 12	8.6	64.81	4200.3361	36122.89	557.366	1261.6	1631990.61	0.43
4th	Frame 13	13.3	88.14	7768.6596	103323.17	1172.262	1261.6	1631990.61	0.91
4th	Frame 14	13.3	111.5	12432.25	165348.93	1482.95	1261.6	1631990.61	1.15
4th	Frame 15	13.3	120.8	14592.64	194082.11	1606.64	1261.6	1631990.61	1.24
4th	Frame 16	13.3	137.12	18801.8944	250065.20	1823.696	1261.6	1631990.61	1.41

Case 1 E / W Wind									
Level 3									
Floor	Frame	Ki	di	di^2	Kidi^2	Kidi	M(k-ft)	∑ Kidi^2	Fi
3rd	Frame 1	9.3	-175	30625	284812.50	-1627.5	1228.5	1793919.46	-1.11
3rd	Frame 2	9.3	-156	24336	226324.80	-1450.8	1228.5	1793919.46	-0.99
3rd	Frame 3	9.3	-132.67	17601.3289	163692.36	-1233.831	1228.5	1793919.46	-0.84
3rd	Frame 4	9.3	-113.67	12920.8689	120164.08	-1057.131	1228.5	1793919.46	-0.72
3rd	Frame 5	9.3	-90.34	8161.3156	75900.24	-840.162	1228.5	1793919.46	-0.58
3rd	Frame 6	9.3	-67.01	4490.3401	41760.16	-623.193	1228.5	1793919.46	-0.43
3rd	Frame 7	9.3	-43.8	1918.44	17841.49	-407.34	1228.5	1793919.46	-0.28
3rd	Frame 8	9.3	-24.68	609.1024	5664.65	-229.524	1228.5	1793919.46	-0.16
3rd	Frame 9	9.3	-1.1	1.21	11.25	-10.23	1228.5	1793919.46	-0.01
3rd	Frame 10	9.3	17.2	295.84	2751.31	159.96	1228.5	1793919.46	0.11
3rd	Frame 11	9.3	41.48	1720.5904	16001.49	385.764	1228.5	1793919.46	0.26
3rd	Frame 12	9.3	64.81	4200.3361	39063.13	602.733	1228.5	1793919.46	0.41
3rd	Frame 13	14.9	88.14	7768.6596	115950.14	1315.522388	1228.5	1793919.46	0.90
3rd	Frame 14	14.9	111.5	12432.25	185555.97	1664.179104	1228.5	1793919.46	1.14
3rd	Frame 15	14.9	120.8	14592.64	217800.60	1802.985075	1228.5	1793919.46	1.23
3rd	Frame 16	14.9	137.12	18801.8944	280625.29	2046.567164	1228.5	1793919.46	1.40

Case 1 E / W Wind									
Level 2									
Floor	Frame	Ki	di	di^2	Kidi^2	Kidi	M(k-ft)	∑ Kidi^2	Fi
2nd	Frame 1	10.2	-175	30625	312375.00	-1785	1186.9	1995942.8	-1.06
2nd	Frame 2	10.2	-156	24336	248227.20	-1591.2	1186.9	1995942.8	-0.95
2nd	Frame 3	10.2	-132.67	17601.3289	179533.55	-1353.234	1186.9	1995942.8	-0.80
2nd	Frame 4	10.2	-113.67	12920.8689	131792.86	-1159.434	1186.9	1995942.8	-0.69
2nd	Frame 5	10.2	-90.34	8161.3156	83245.42	-921.468	1186.9	1995942.8	-0.55
2nd	Frame 6	10.2	-67.01	4490.3401	45801.47	-683.502	1186.9	1995942.8	-0.41
2nd	Frame 7	10.2	-43.8	1918.44	19568.09	-446.76	1186.9	1995942.8	-0.27
2nd	Frame 8	10.2	-24.68	609.1024	6212.84	-251.736	1186.9	1995942.8	-0.15
2nd	Frame 9	10.2	-1.1	1.21	12.34	-11.22	1186.9	1995942.8	-0.01
2nd	Frame 10	10.2	17.2	295.84	3017.57	175.44	1186.9	1995942.8	0.10
2nd	Frame 11	10.2	41.48	1720.5904	17550.02	423.096	1186.9	1995942.8	0.25
2nd	Frame 12	10.2	64.81	4200.3361	42843.43	661.062	1186.9	1995942.8	0.39
2nd	Frame 13	16.9	88.14	7768.6596	131290.35	1489.566	1186.9	1995942.8	0.89
2nd	Frame 14	16.9	111.5	12432.25	210105.03	1884.35	1186.9	1995942.8	1.12
2nd	Frame 15	16.9	120.8	14592.64	246615.62	2041.52	1186.9	1995942.8	1.21
2nd	Frame 16	16.9	137.12	18801.8944	317752.02	2317.328	1186.9	1995942.8	1.38

Wind Tables: North/ South Direction

Case 1 N/S Wind									
Level 7									
Floor	Frame	Ki	di	di^2	Kidi^2	Kidi	M(k-ft)	∑ Kidi^2	Fi
7th	Frame 1	20.8	-58.9	3469.21	72159.57	-1225.12	1649.4	395321.17	-5.11
7th	Frame 2	20.8	-41.23	1699.913	35358.19	-857.584	1649.4	395321.17	-3.58
7th	Frame 3	20.8	-29	841	17492.80	-603.2	1649.4	395321.17	-2.52
7th	Frame 4	20.8	-11.33	128.3689	2670.07	-235.664	1649.4	395321.17	-0.98
7th	Frame 5	7	11.8	139.24	974.68	82.6	1649.4	395321.17	0.34
7th	Frame 6	7	35.2	1239.04	8673.28	246.4	1649.4	395321.17	1.03
7th	Frame 7	7	58.5	3422.25	23955.75	409.5	1649.4	395321.17	1.71
7th	Frame 8	7	82.1	6740.41	47182.87	574.7	1649.4	395321.17	2.40
7th	Frame 9	7	105.68	11168.26	78177.84	739.76	1649.4	395321.17	3.09
7th	Frame 10	7	124.6	15525.16	108676.12	872.2	1649.4	395321.17	3.64

Case 1 N/S Wind									
Level 6									
Floor	Frame	Ki	Di	di^2	Kidi^2	Kidi	M(k-ft)	∑ Kidi^2	Fi
6th	Frame 1	22.7	-58.9	3469.21	78751.07	-1337.03	1415.64	426101.48	-4.44
6th	Frame 2	22.7	-41.23	1699.913	38588.02	-935.921	1415.64	426101.48	-3.11
6th	Frame 3	22.7	-29	841	19090.70	-658.3	1415.64	426101.48	-2.19
6th	Frame 4	22.7	-11.33	128.3689	2913.97	-257.191	1415.64	426101.48	-0.85
6th	Frame 5	7.5	11.8	139.24	1044.30	88.5	1415.64	426101.48	0.29
6th	Frame 6	7.5	35.2	1239.04	9292.80	264	1415.64	426101.48	0.88
6th	Frame 7	7.5	58.5	3422.25	25666.88	438.75	1415.64	426101.48	1.46
6th	Frame 8	7.5	82.1	6740.41	50553.08	615.75	1415.64	426101.48	2.05
6th	Frame 9	7.5	105.68	11168.26	83761.97	792.6	1415.64	426101.48	2.63
6th	Frame 10	7.5	124.6	15525.16	116438.70	934.5	1415.64	426101.48	3.10

Case 1 N/S Wind									
Level 5									
Floor	Frame	Ki	Di	di^2	Kidi^2	Kidi	M(k-ft)	∑ Kidi^2	Fi
5th	Frame 1	24.4	-58.9	3469.21	84648.72	-1437.16	1389.3	455654.1	-4.38
5th	Frame 2	24.4	-41.23	1699.913	41477.87	-1006.01	1389.3	455654.1	-3.07
5th	Frame 3	24.4	-29	841	20520.40	-707.6	1389.3	455654.1	-2.16
5th	Frame 4	24.4	-11.33	128.3689	3132.20	-276.452	1389.3	455654.1	-0.84
5th	Frame 5	8	11.8	139.24	1113.92	94.4	1389.3	455654.1	0.29
5th	Frame 6	8	35.2	1239.04	9912.32	281.6	1389.3	455654.1	0.86
5th	Frame 7	8	58.5	3422.25	27378.00	468	1389.3	455654.1	1.43
5th	Frame 8	8	82.1	6740.41	53923.28	656.8	1389.3	455654.1	2.00
5th	Frame 9	8	105.68	11168.26	89346.10	845.44	1389.3	455654.1	2.58
5th	Frame 10	8	124.6	15525.16	124201.28	996.8	1389.3	455654.1	3.04

Case 1 N/S Wind									
Level 4									
Floor	Frame	Ki	Di	di^2	Kidi^2	Kidi	M(k-ft)	∑ Kidi^2	Fi
4th	Frame 1	26.3	-58.9	3469.21	91240.22	-1549.07	1355.4	490257.85	-4.28
4th	Frame 2	26.3	-41.23	1699.913	44707.71	-1084.35	1355.4	490257.85	-3.00
4th	Frame 3	26.3	-29	841	22118.30	-762.7	1355.4	490257.85	-2.11
4th	Frame 4	26.3	-11.33	128.3689	3376.10	-297.979	1355.4	490257.85	-0.82
4th	Frame 5	8.6	11.8	139.24	1197.46	101.48	1355.4	490257.85	0.28
4th	Frame 6	8.6	35.2	1239.04	10655.74	302.72	1355.4	490257.85	0.84
4th	Frame 7	8.6	58.5	3422.25	29431.35	503.1	1355.4	490257.85	1.39
4th	Frame 8	8.6	82.1	6740.41	57967.53	706.06	1355.4	490257.85	1.95
4th	Frame 9	8.6	105.68	11168.26	96047.06	908.848	1355.4	490257.85	2.51
4th	Frame 10	8.6	124.6	15525.16	133516.38	1071.56	1355.4	490257.85	2.96

Case 1 N/S Wind									
Level 3									
Floor	Frame	Ki	di	di^2	Kidi^2	Kidi	M(k-ft)	∑ Kidi^2	Fi
3rd	Frame 1	29.4	-58.9	3469.21	101994.77	-1731.66	1317.7	536051.23	-4.26
3rd	Frame 2	29.4	-41.23	1699.913	49977.44	-1212.16	1317.7	536051.23	-2.98
3rd	Frame 3	29.4	-29	841	24725.40	-852.6	1317.7	536051.23	-2.10
3rd	Frame 4	29.4	-11.33	128.3689	3774.05	-333.102	1317.7	536051.23	-0.82
3rd	Frame 5	9.3	11.8	139.24	1294.93	109.74	1317.7	536051.23	0.27
3rd	Frame 6	9.3	35.2	1239.04	11523.07	327.36	1317.7	536051.23	0.80
3rd	Frame 7	9.3	58.5	3422.25	31826.93	544.05	1317.7	536051.23	1.34
3rd	Frame 8	9.3	82.1	6740.41	62685.81	763.53	1317.7	536051.23	1.88
3rd	Frame 9	9.3	105.68	11168.26	103864.84	982.824	1317.7	536051.23	2.42
3rd	Frame 10	9.3	124.6	15525.16	144383.99	1158.78	1317.7	536051.23	2.85

Case 1 N/S Wind									
Level 2									
Floor	Frame	Ki	Di	di^2	Kidi^2	Kidi	M(k-ft)	∑ Kidi^2	Fi
2nd	Frame 1	33.3	-58.9	3469.21	115524.69	-1961.37	1268.8	594558.33	-4.19
2nd	Frame 2	33.3	-41.23	1699.913	56607.10	-1372.96	1268.8	594558.33	-2.93
2nd	Frame 3	33.3	-29	841	28005.30	-965.7	1268.8	594558.33	-2.06
2nd	Frame 4	33.3	-11.33	128.3689	4274.68	-377.289	1268.8	594558.33	-0.81
2nd	Frame 5	10.2	11.8	139.24	1420.82	120.4082	1268.8	594558.33	0.26
2nd	Frame 6	10.2	35.2	1239.04	12643.27	359.1837	1268.8	594558.33	0.77
2nd	Frame 7	10.2	58.5	3422.25	34920.92	596.9388	1268.8	594558.33	1.27
2nd	Frame 8	10.2	82.1	6740.41	68779.69	837.7551	1268.8	594558.33	1.79
2nd	Frame 9	10.2	105.68	11168.26	113961.86	1078.367	1268.8	594558.33	2.30
2nd	Frame 10	10.2	124.6	15525.16	158420.00	1271.429	1268.8	594558.33	2.71

Seismic Tables: East / West Direction

Case 1 E / W Seismic									
Level 7									
Floor	Frame	Ki	di	di^2	Kidi^2	Kidi	M(k-ft)	∑ Kidi^2	Fi
7th	Frame 1	7	-198.2	39283.24	274982.68	-1387.4	1740	1374127.59	-1.76
7th	Frame 2	7	-179.2	32112.64	224788.48	-1254.4	1740	1374127.59	-1.59
7th	Frame 3	7	-155.87	24295.46	170068.20	-1091.09	1740	1374127.59	-1.38
7th	Frame 4	7	-136.87	18733.4	131133.78	-958.09	1740	1374127.59	-1.21
7th	Frame 5	7	-113.87	12966.38	90764.64	-797.09	1740	1374127.59	-1.01
7th	Frame 6	7	-90.21	8137.844	56964.91	-631.47	1740	1374127.59	-0.80
7th	Frame 7	7	-67	4489	31423.00	-469	1740	1374127.59	-0.59
7th	Frame 8	7	-47.88	2292.494	16047.46	-335.16	1740	1374127.59	-0.42
7th	Frame 9	7	-24.3	590.49	4133.43	-170.1	1740	1374127.59	-0.22
7th	Frame 10	7	-5.2	27.04	189.28	-36.4	1740	1374127.59	-0.05
7th	Frame 11	7	18.28	334.1584	2339.11	127.96	1740	1374127.59	0.16
7th	Frame 12	7	41.61	1731.392	12119.74	291.27	1740	1374127.59	0.37
7th	Frame 13	10.4	64.94	4217.204	43858.92	675.376	1740	1374127.59	0.86
7th	Frame 14	10.4	88.3	7796.89	81087.66	918.32	1740	1374127.59	1.16
7th	Frame 15	10.4	97.6	9525.76	99067.90	1015.04	1740	1374127.59	1.29
7th	Frame 16	10.4	114	12996	135158.40	1185.6	1740	1374127.59	1.50

Case 1 E / W Seismic									
Level 6									
Floor	Frame	Ki	di	di^2	Kidi^2	Kidi	M(k-ft)	∑ Kidi^2	Fi
6th	Frame 1	7.5	-198.2	39283.24	294624.30	-1486.5	4090.16	1481160.20	-4.10
6th	Frame 2	7.5	-179.2	32112.64	240844.80	-1344	4090.16	1481160.20	-3.71
6th	Frame 3	7.5	-155.87	24295.46	182215.93	-1169.03	4090.16	1481160.20	-3.23
6th	Frame 4	7.5	-136.87	18733.4	140500.48	-1026.53	4090.16	1481160.20	-2.83
6th	Frame 5	7.5	-113.87	12966.38	97247.83	-854.025	4090.16	1481160.20	-2.36
6th	Frame 6	7.5	-90.21	8137.844	61033.83	-676.575	4090.16	1481160.20	-1.87
6th	Frame 7	7.5	-67	4489	33667.50	-502.5	4090.16	1481160.20	-1.39
6th	Frame 8	7.5	-47.88	2292.494	17193.71	-359.1	4090.16	1481160.20	-0.99
6th	Frame 9	7.5	-24.3	590.49	4428.68	-182.25	4090.16	1481160.20	-0.50
6th	Frame 10	7.5	-5.2	27.04	202.80	-39	4090.16	1481160.20	-0.11
6th	Frame 11	7.5	18.28	334.1584	2506.19	137.1	4090.16	1481160.20	0.38
6th	Frame 12	7.5	41.61	1731.392	12985.44	312.075	4090.16	1481160.20	0.86
6th	Frame 13	11.4	64.94	4217.204	48076.12	740.316	4090.16	1481160.20	2.04
6th	Frame 14	11.4	88.3	7796.89	88884.55	1006.62	4090.16	1481160.20	2.78
6th	Frame 15	11.4	97.6	9525.76	108593.66	1112.64	4090.16	1481160.20	3.07
6th	Frame 16	11.4	114	12996	148154.40	1299.6	4090.16	1481160.20	3.59

Case 1 E / W Seismic									
Level 5									
Floor	Frame	Ki	di	di^2	Kidi^2	Kidi	M(k-ft)	∑ Kidi^2	Fi
5th	Frame 1	8	-198.2	39283.24	314265.92	-1585.6	4090.16	1584739.24	-4.09
5th	Frame 2	8	-179.2	32112.64	256901.12	-1433.6	4090.16	1584739.24	-3.70
5th	Frame 3	8	-155.87	24295.46	194363.66	-1246.96	4090.16	1584739.24	-3.22
5th	Frame 4	8	-136.87	18733.4	149867.18	-1094.96	4090.16	1584739.24	-2.83
5th	Frame 5	8	-113.87	12966.38	103731.02	-910.96	4090.16	1584739.24	-2.35
5th	Frame 6	8	-90.21	8137.844	65102.75	-721.68	4090.16	1584739.24	-1.86
5th	Frame 7	8	-67	4489	35912.00	-536	4090.16	1584739.24	-1.38
5th	Frame 8	8	-47.88	2292.494	18339.96	-383.04	4090.16	1584739.24	-0.99
5th	Frame 9	8	-24.3	590.49	4723.92	-194.4	4090.16	1584739.24	-0.50
5th	Frame 10	8	-5.2	27.04	216.32	-41.6	4090.16	1584739.24	-0.11
5th	Frame 11	8	18.28	334.1584	2673.27	146.24	4090.16	1584739.24	0.38
5th	Frame 12	8	41.61	1731.392	13851.14	332.88	4090.16	1584739.24	0.86
5th	Frame 13	12.3	64.94	4217.204	51871.60	798.762	4090.16	1584739.24	2.06
5th	Frame 14	12.3	88.3	7796.89	95901.75	1086.09	4090.16	1584739.24	2.80
5th	Frame 15	12.3	97.6	9525.76	117166.85	1200.48	4090.16	1584739.24	3.10
5th	Frame 16	12.3	114	12996	159850.80	1402.2	4090.16	1584739.24	3.62

Case 1 E / W Wind									
Level 4									
Floor	Frame	Ki	di	di^2	Kidi^2	Kidi	M(k-ft)	∑ Kidi^2	Fi
4th	Frame 1	8.6	-198.2	39283.24	337835.86	-1704.52	1261.6	1631990.61	-1.32
4th	Frame 2	8.6	-179.2	32112.64	276168.70	-1541.12	1261.6	1631990.61	-1.19
4th	Frame 3	8.6	-155.87	24295.46	208940.93	-1340.48	1261.6	1631990.61	-1.04
4th	Frame 4	8.6	-136.87	18733.4	161107.21	-1177.08	1261.6	1631990.61	-0.91
4th	Frame 5	8.6	-113.87	12966.38	111510.84	-979.282	1261.6	1631990.61	-0.76
4th	Frame 6	8.6	-90.21	8137.844	69985.46	-775.806	1261.6	1631990.61	-0.60
4th	Frame 7	8.6	-67	4489	38605.40	-576.2	1261.6	1631990.61	-0.45
4th	Frame 8	8.6	-47.88	2292.494	19715.45	-411.768	1261.6	1631990.61	-0.32
4th	Frame 9	8.6	-24.3	590.49	5078.21	-208.98	1261.6	1631990.61	-0.16
4th	Frame 10	8.6	-5.2	27.04	232.54	-44.72	1261.6	1631990.61	-0.03
4th	Frame 11	8.6	18.28	334.1584	2873.76	157.208	1261.6	1631990.61	0.12
4th	Frame 12	8.6	41.61	1731.392	14889.97	357.846	1261.6	1631990.61	0.28
4th	Frame 13	13.3	64.94	4217.204	56088.81	863.702	1261.6	1631990.61	0.67
4th	Frame 14	13.3	88.3	7796.89	103698.64	1174.39	1261.6	1631990.61	0.91
4th	Frame 15	13.3	97.6	9525.76	126692.61	1298.08	1261.6	1631990.61	1.00
4th	Frame 16	13.3	114	12996	172846.80	1516.2	1261.6	1631990.61	1.17

Case 1 E / W Seismic									
Level 3									
Floor	Frame	Ki	di	di^2	Kidi^2	Kidi	M(k-ft)	∑ Kidi^2	Fi
3rd	Frame 1	9.3	-198.2	39283.24	365334.13	-1843.26	1228.5	1793919.46	-1.26
3rd	Frame 2	9.3	-179.2	32112.64	298647.55	-1666.56	1228.5	1793919.46	-1.14
3rd	Frame 3	9.3	-155.87	24295.46	225947.75	-1449.59	1228.5	1793919.46	-0.99
3rd	Frame 4	9.3	-136.87	18733.4	174220.59	-1272.89	1228.5	1793919.46	-0.87
3rd	Frame 5	9.3	-113.87	12966.38	120587.31	-1058.99	1228.5	1793919.46	-0.73
3rd	Frame 6	9.3	-90.21	8137.844	75681.95	-838.953	1228.5	1793919.46	-0.57
3rd	Frame 7	9.3	-67	4489	41747.70	-623.1	1228.5	1793919.46	-0.43
3rd	Frame 8	9.3	-47.88	2292.494	21320.20	-445.284	1228.5	1793919.46	-0.30
3rd	Frame 9	9.3	-24.3	590.49	5491.56	-225.99	1228.5	1793919.46	-0.15
3rd	Frame 10	9.3	-5.2	27.04	251.47	-48.36	1228.5	1793919.46	-0.03
3rd	Frame 11	9.3	18.28	334.1584	3107.67	170.004	1228.5	1793919.46	0.12
3rd	Frame 12	9.3	41.61	1731.392	16101.95	386.973	1228.5	1793919.46	0.27
3rd	Frame 13	14.92537	64.94	4217.204	62943.34	969.2537	1228.5	1793919.46	0.66
3rd	Frame 14	14.92537	88.3	7796.89	116371.49	1317.91	1228.5	1793919.46	0.90
3rd	Frame 15	14.92537	97.6	9525.76	142175.52	1456.716	1228.5	1793919.46	1.00
3rd	Frame 16	14.92537	114	12996	193970.15	1701.493	1228.5	1793919.46	1.17

Seismic Tables: North/ South Direction

Case 1 N/S Wind Seismic									
Level 7									
Floor	Frame	Ki	di	di^2	Kidi^2	Kidi	M(k-ft)	∑ Kidi^2	Fi
7th	Frame 1	20.8	-50.1	2510.01	52208.21	-1042.08	660	405041.7	-1.70
7th	Frame 2	20.8	-32.43	1051.705	21875.46	-674.544	660	405041.7	-1.10
7th	Frame 3	20.8	-20.2	408.04	8487.23	-420.16	660	405041.7	-0.68
7th	Frame 4	20.8	-2.53	6.4009	133.14	-52.624	660	405041.7	-0.09
7th	Frame 5	7	20.6	424.36	2970.52	144.2	660	405041.7	0.23
7th	Frame 6	7	44	1936	13552.00	308	660	405041.7	0.50
7th	Frame 7	7	67.3	4529.29	31705.03	471.1	660	405041.7	0.77
7th	Frame 8	7	90.87	8257.357	57801.50	636.09	660	405041.7	1.04
7th	Frame 9	7	114.48	13105.67	91739.69	801.36	660	405041.7	1.31
7th	Frame 10	7	133.4	17795.56	124568.92	933.8	660	405041.7	1.52

Case 1 N/S Wind Seismic									
Level 6									
Floor	Frame	Ki	di	di^2	Kidi^2	Kidi	M(k-ft)	∑ Kidi^2	Fi
6th	Frame 1	22.7	-50.1	2510.01	56977.23	-1137.27	1415.64	426101.5	-3.78
6th	Frame 2	22.7	-32.43	1051.705	23873.70	-736.161	1415.64	426101.5	-2.45
6th	Frame 3	22.7	-20.2	408.04	9262.51	-458.54	1415.64	426101.5	-1.52
6th	Frame 4	22.7	-2.53	6.4009	145.30	-57.431	1415.64	426101.5	-0.19
6th	Frame 5	7.5	20.6	424.36	3182.70	154.5	1415.64	426101.5	0.51
6th	Frame 6	7.5	44	1936	14520.00	330	1415.64	426101.5	1.10
6th	Frame 7	7.5	67.3	4529.29	33969.68	504.75	1415.64	426101.5	1.68
6th	Frame 8	7.5	90.87	8257.357	61930.18	681.525	1415.64	426101.5	2.26
6th	Frame 9	7.5	114.48	13105.67	98292.53	858.6	1415.64	426101.5	2.85
6th	Frame 10	7.5	133.4	17795.56	133466.70	1000.5	1415.64	426101.5	3.32

Case 1 N/S Wind									
Level 5									
Floor	Frame	Ki	di	di^2	Kidi^2	Kidi	M(k-ft)	∑ Kidi^2	Fi
5th	Frame 1	24.4	-50.1	2510.01	61244.24	-1222.44	1389.3	455654.1	-3.73
5th	Frame 2	24.4	-32.43	1051.705	25661.60	-791.292	1389.3	455654.1	-2.41
5th	Frame 3	24.4	-20.2	408.04	9956.18	-492.88	1389.3	455654.1	-1.50
5th	Frame 4	24.4	-2.53	6.4009	156.18	-61.732	1389.3	455654.1	-0.19
5th	Frame 5	8	20.6	424.36	3394.88	164.8	1389.3	455654.1	0.50
5th	Frame 6	8	44	1936	15488.00	352	1389.3	455654.1	1.07
5th	Frame 7	8	67.3	4529.29	36234.32	538.4	1389.3	455654.1	1.64
5th	Frame 8	8	90.87	8257.357	66058.86	726.96	1389.3	455654.1	2.22
5th	Frame 9	8	114.48	13105.67	104845.36	915.84	1389.3	455654.1	2.79
5th	Frame 10	8	133.4	17795.56	142364.48	1067.2	1389.3	455654.1	3.25

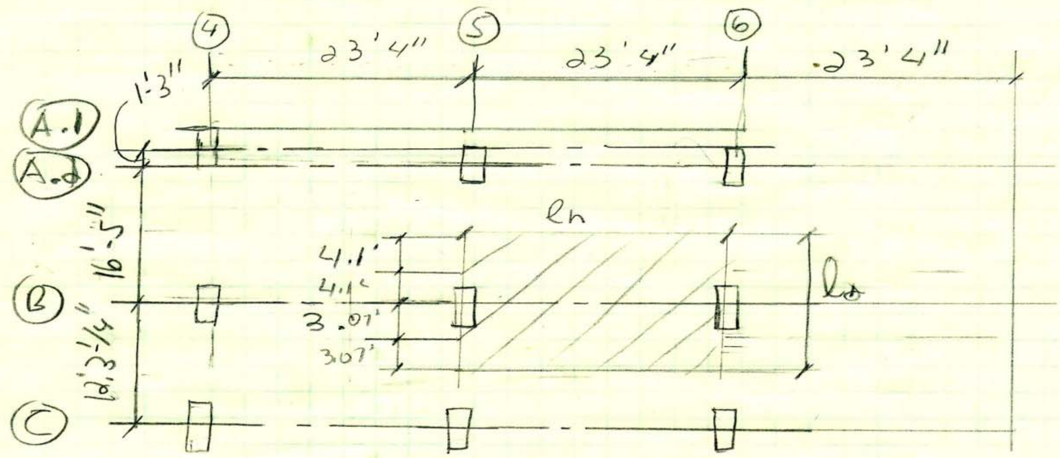
Case 1 N/S Wind Seismic									
Level 4									
Floor	Frame	Ki	di	di^2	Kidi^2	Kidi	M(k-ft)	∑ Kidi^2	Fi
4th	Frame 1	26.3	-50.1	2510.01	66013.26	-1317.63	1355.4	490257.9	-3.64
4th	Frame 2	26.3	-32.43	1051.705	27659.84	-852.909	1355.4	490257.9	-2.36
4th	Frame 3	26.3	-20.2	408.04	10731.45	-531.26	1355.4	490257.9	-1.47
4th	Frame 4	26.3	-2.53	6.4009	168.34	-66.539	1355.4	490257.9	-0.18
4th	Frame 5	8.6	20.6	424.36	3649.50	177.16	1355.4	490257.9	0.49
4th	Frame 6	8.6	44	1936	16649.60	378.4	1355.4	490257.9	1.05
4th	Frame 7	8.6	67.3	4529.29	38951.89	578.78	1355.4	490257.9	1.60
4th	Frame 8	8.6	90.87	8257.357	71013.27	781.482	1355.4	490257.9	2.16
4th	Frame 9	8.6	114.48	13105.67	112708.77	984.528	1355.4	490257.9	2.72
4th	Frame 10	8.6	133.4	17795.56	153041.82	1147.24	1355.4	490257.9	3.17

Case 1 N/S Wind Seismic									
Level 3									
Floor	Frame	Ki	di	di^2	Kidi^2	Kidi	M(k-ft)	∑ Kidi^2	Fi
3rd	Frame 1	29.4	-50.1	2510.01	73794.29	-1472.94	1317.7	536051.2	-3.62
3rd	Frame 2	29.4	-32.43	1051.705	30920.12	-953.442	1317.7	536051.2	-2.34
3rd	Frame 3	29.4	-20.2	408.04	11996.38	-593.88	1317.7	536051.2	-1.46
3rd	Frame 4	29.4	-2.53	6.4009	188.19	-74.382	1317.7	536051.2	-0.18
3rd	Frame 5	9.3	20.6	424.36	3946.55	191.58	1317.7	536051.2	0.47
3rd	Frame 6	9.3	44	1936	18004.80	409.2	1317.7	536051.2	1.01
3rd	Frame 7	9.3	67.3	4529.29	42122.40	625.89	1317.7	536051.2	1.54
3rd	Frame 8	9.3	90.87	8257.357	76793.42	845.091	1317.7	536051.2	2.08
3rd	Frame 9	9.3	114.48	13105.67	121882.73	1064.664	1317.7	536051.2	2.62
3rd	Frame 10	9.3	133.4	17795.56	165498.71	1240.62	1317.7	536051.2	3.05

Appendix G: Slab Spot Check

DL | Slab check | TECH 1 pg 1/5

2 Way Slab Spot Check



8" Concrete Slab

#4 reinforcing spaced 10" O.C each way

fy = 5000psi , fy = 60,000psi

l_n = 23'.33 , l_2 = 14.34'

- Dead Load
  - concrete = 150pcf (8/12) = 100psf
  - MEP = 10psf
- Live Loads
  - Guestroom floors → 40psf
  - partitions → 15psf

DL | slab check | TECH 1 pg 2/5

$q_u = 1.2(110) + 1.6(55) = 220$ psf

$M_u = \frac{q_u l_2 l_n^2}{8} = \frac{.220(14.34)(23.33)^2}{8} = 214.6$ k-ft

- Positive & Negative Moments (interior span)

$M^- = .65 M_u = .65(214.6$ k-ft$) = 139.5$ k-ft

$M^+ = .35 M_u = .35(214.6$ k-ft$) = 74.4$ k-ft

- Column Strip Moments

$M^-_{col} = .75(M^-) = .75(139.5$ k-ft$) = 104.6$ k-ft $l_1/l_2 = \frac{23.33}{14.34} = 1.63$

$M^+_{col} = .60(M^+) = .6(74.9$ k-ft$) = 44.9$ k-ft

- Middle Strip Moments

$M^-_{mid} = .25(M^-) = (.25)(139.5) = 42.25$ k-ft

$M^+_{mid} = .4(M^+) = (.4)(74.4) = 36.4$ k-ft

- for column strip

$b = 86.04$ $h = 8"$, $d = 8" - .5" - .25" = 7.25$

(18) #4 @ 10" o.c. (bottom)

$A_s = (18)(.2) = 3.6$

$a = \frac{A_s f_y}{.85 f'_c b} = \frac{(3.6)(60)}{.85(5)(86.04)} = .591$

$c = a/\beta_1 = \frac{.591}{.8} = .739$

$\varepsilon_y = \frac{\varepsilon_c}{c}(d-c)$, $\varepsilon_y = \frac{.003}{.738}(7.25 - .739)$

$\varepsilon_y > .005$ use $\phi = .9$

DL | Slab check | TECH 1 pg 3/5

$\phi M_N = .9(3.6)(60)(7.25 - \frac{.738}{2}) = 111.5^{k\text{-}ft}$

$\phi M_N = 115^{k\text{-}ft} \geq M^-_{col} = 104.6^{k\text{-}ft}$ ok ✓

- using same reinforcement (positive reinforcement)
  (18) #4 (bottom & top)
  $\phi M_N = 111.5^{k\text{-}ft} > M^+_{col} = 44.9^{k\text{-}ft}$ ok ✓

- for middle strip
  * parameters same as above
  $A_s = (9)(.2) = 1.8$
  $a = \frac{(1.8)(60)}{(.85)(5)(86.04)} = .295$, $c = \frac{.295}{.8} = .369$
  $\varepsilon_y = \frac{.003}{.369}(7.25 - .369)$, $\varepsilon_y > .005$, so $\phi = .9$
  $\phi M_N = .9(1.8)(60)(7.25 - \frac{.295}{2}) = 57.5^{k\text{-}ft}$
  $\phi M_N = 57.5^{k\text{-}ft} > M^-_{MID} = 42.25^{k\text{-}ft}$ ok ✓

- using same reinforcement (positive reinforcement)
  $\phi M_N = 57.5^{k\text{-}ft} > M^+_{MID} = 36.4^{k\text{-}ft}$ ok ✓

- * slab is ok for flexure

DJ | Slab check | TECH 1 pg 4/5

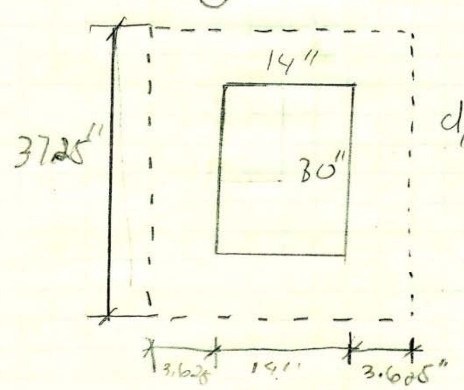
- per ACI 318-08 Tbl. 9.5c

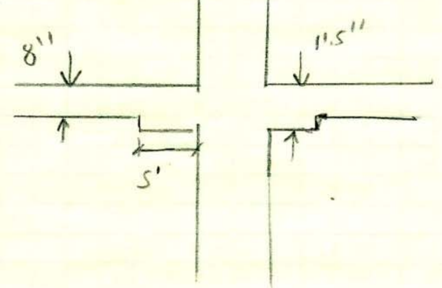
thickness $> \frac{l_n}{36}$, $t > \frac{279.96}{36} = 7.78''$

- actual slab thickness 8" ok ✓
- no need to check deflection

- Punching Shear

$h = 11.5''$
$d = 7.25''$





self wt — $1.2\left[\left(\frac{11.5}{12}\right)(150) + 10\,psf\right] + 1.6(55\,psf) = .261\,ksf$

$V_u = .261\,ksf\left[(23.33')(14.34') - \left(\frac{21.25}{12}\right)\left(\frac{37.25}{12}\right)\right] = 85.9^k$

$b_o = 2(21.25 + 37.25) = 117''$

$V_c = 4\sqrt{f'c}\, b_o d = 4\sqrt{5000}\,(117)(7.25) = 239.9^k$

DL | Slab check | TECH 1 pg 5/5

$V_c = \left(2 + \frac{4}{(30/_{14})}\right)\sqrt{5000}\,(117)(7.25) = 291.4^{k}$

$V_c = \left(\frac{(40)(7.25)}{117} + 2\right)\sqrt{5000}\,(117)(7.25) = 268.6^{k}$

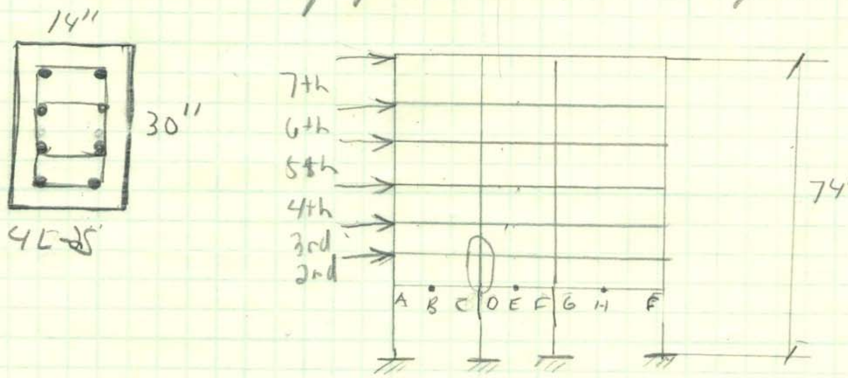
$\phi V_c = .75(239.9) = 179.9 > 85.4^{k}$ ok ✓

* slab ok for punching shear

Appendix H: Frame Spot Check

Dominick Lovallo | Frame Check | Tech 3 pg 1/3

Column Spot Check - 3BAY FRAME



Load combo → 1.2D + 1.0W + L

Trib area → = (23.33')(15.79) = 357 ft²

DL

- floor slab → (8"/12)(357)(150pcf)(5 floors) = 178.5^k
- MEP → (5psf)(357)(5 floors) = 8.9^k
- Roof SLAB → (3.25"/12")(357ft²)(110pcf) = 10.6^k (LWC)
- Metal Deck → (4.36psf)(357ft²) = 1.6^k
- COL. SW → ((14)(30)/144)(46.9')(150pcf) = 20.5^k

LL

- Roof live → (30psf)(357ft²) = 10.7^k
- Guest Room floor → (40psf)(357ft²)(5 floors) = 71.4^k
- Partitions → (15psf)(357ft²)(5 floors) = 26.8^k

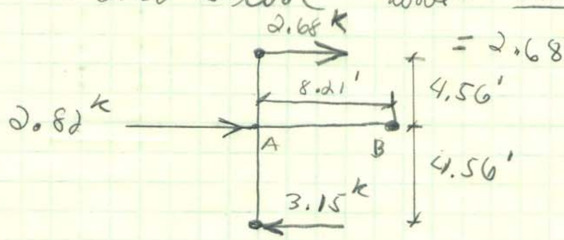
1.2(20.5^k + 178.5^k + 8.9^k + 10.6^k + 1.6^k) + (10.7 + 71.4 + 26.8)

264.12 + 108.9 = 373^k = Pu

Dominick Lovallo | Tech 3 | Frame Check pg 2/13

- Portal Method

@ 2nd Floor $P_{above} = \frac{3.76^k + 3.21^k + 3.14^k + 3.07^k + 2.95^k}{6} = 2.68^k$

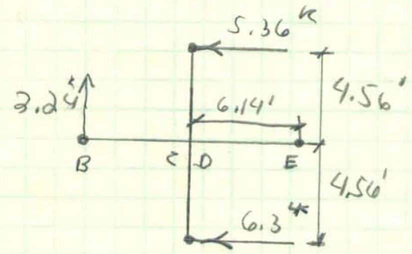


$\frac{2.82^k + 2.68^k + 2.68^k + 5.36^k + 5.36^k}{6} = 3.15^k$

$\Sigma M_A = (4.56')(2.68^k) + (4.56)(3.15^k) + (8.21')(F)$

$F = 3.24^k$

$M = (3.24^k)(8.21') = 26.6^{k\text{-}ft}$



$\Sigma M_{CD} = (4.56')(5.36^k) + (4.56')(6.3^k) - (3.24^k)(8.21') + F(6.14) = 4.33^k$

$M = (4.33^k)(6.14') = 26.6^{k\text{-}ft}$

$M_4 = 214.6^{k\text{-}ft} + 26.6^{k\text{-}ft}$

((Direct design method spread check)

CRSI Design Guide

BARS	RHO	AXIS	Max Cap		0% f_y		25% f_y		50% f_y		100% f_y		$\varepsilon_t = 0.005$		Zero Axial Load
			ϕM_n	ϕP_n	ϕM_n	ϕP_n	ϕM_n	ϕP_n	ϕM_n	ϕP_n	ϕM_n	ϕP_n	ϕM_n	ϕP_n	ϕM_n
4-#10	1.22	MA	2394	885	3110	799	3941	671	4427	569	4983	412	6189	359	3031
2E		MI	1395	885	2007	752	2397	631	2616	534	2850	384	3262	297	1744
4-#11	1.50	MA	2474	919	3352	815	4215	682	4743	575	5393	407	6747	354	3648
2E		MI	1424	919	2133	764	2530	638	2764	537	3010	372	3416	271	2066
4-#14	2.16	MA	2678	1000	3880	861	4861	715	5513	595	6418	402	8096	341	5128
2E		MI	1508	1000	2401	808	2850	670	3141	556	3469	356	3919	226	2826
4-#18	3.85	MA	3131	1206	5160	982	6436	803	7396	649	8934	389	11290	298	8732
2E		MI	1690	1206	3024	923	3602	753	3996	598	4504	309	5001	90	4588
6-#8	1.14	MA	2375	875	3028	797	3859	670	4339	569	4874	415	6047	361	2857
2L-3S		MI	1289	875	1797	757	2151	635	2328	537	2475	391	2839	252	1661
6-#8	1.14	MA	2175	875	2719	805	3468	677	3867	575	4238	423	5166	306	2852
3L-2S		MI	1391	875	1961	753	2358	632	2578	536	2811	389	3252	310	1653
6-#9	1.44	MA	2481	912	3281	819	4168	685	4708	578	5366	412	6724	359	3567
2L-3S		MI	1315	912	1891	778	2260	649	2455	546	2642	388	3028	222	2038
6-#9	1.44	MA	2238	912	2892	828	3676	694	4114	586	4565	422	5616	288	3548
3L-2S		MI	1439	912	2095	773	2519	646	2768	544	3063	385	3538	295	2033
6-#10	1.83	MA	2611	960	3600	846	4561	705	5177	591	5992	409	7587	355	4467
2L-3S		MI	1349	960	2007	805	2397	669	2616	557	2850	383	3262	182	2504
6-#10	1.83	MA	2317	960	3110	858	3941	716	4427	600	4983	422	6189	264	4422
3L-2S		MI	1496	960	2263	799	2721	665	3008	556	3377	381	3892	275	2508
6-#11	2.25	MA	2726	1011	3943	872	4963	724	5647	602	6611	404	8432	349	5375
2L-3S		MI	1370	1011	2133	827	2530	683	2764	564	3010	369	3416	123	2949
6-#11	2.25	MA	2387	1011	3352	886	4215	736	4743	612	5393	418	6747	235	5296
3L-2S		MI	1538	1011	2437	822	2915	680	3229	564	3621	365	4133	238	2967
6-#14	3.25	MA	3015	1133	4720	944	5924	776	6799	634	8150	397	10462	331	7575
2L-3S		MI	1442	1133	2401	898	2850	733	3141	592	3469	349	3919	7	3905
6-#14	3.25	MA	2573	1133	3880	963	4861	792	5513	648	6418	415	8096	166	7366
3L-2S		MI	1659	1133	2828	891	3390	730	3794	594	4311	344	4893	172	4074
6-#18	5.77	MA	3042	1442	5160	1159	6436	936	7396	738	8934	407	11290	-25	11221
3L-2S		MI	1931	1442	3741	1070	4508	861	5074	664	5871	277	6530	-28	6507
8-#7	1.15	MA	2385	877	3032	800	3874	672	4363	571	4911	416	6102	362	2901
2L-4S		MI	1271	877	1746	764	2092	640	2254	544	2375	392	2750	248	1687
8-#7	1.15	MA	2234	877	2796	806	3575	677	4002	576	4425	422	5429	321	2898
3E		MI	1320	877	1836	760	2209	638	2403	540	2579	393	2982	269	1683
8-#7	1.15	MA	2144	877	2633	812	3362	683	3729	583	4053	426	4966	295	2878
4L-2S		MI	1398	877	1961	757	2368	635	2595	539	2838	390	3302	313	1677
8-#8	1.52	MA	2515	921	3337	826	4249	691	4812	583	5511	413	6928	359	3763
2L-4S		MI	1298	921	1843	790	2205	659	2384	556	2546	388	2953	212	2136
8-#8	1.52	MA	2325	921	3028	834	3859	698	4339	589	4874	421	6047	304	3750
3E		MI	1360	921	1961	786	2358	656	2578	551	2811	389	3252	240	2144
8-#8	1.52	MA	2213	921	2814	842	3579	705	3982	598	4386	426	5439	270	3695
4L-2S		MI	1458	921	2124	782	2565	653	2829	549	3148	387	3664	298	2140
8-#9	1.92	MA	2652	971	3669	855	4659	712	5303	596	6166	410	7832	355	4703
2L-4S		MI	1327	971	1948	820	2319	684	2524	569	2730	384	3167	171	2561
8-#9	1.92	MA	2423	971	3281	865	4168	721	4708	603	5366	420	6724	285	4673

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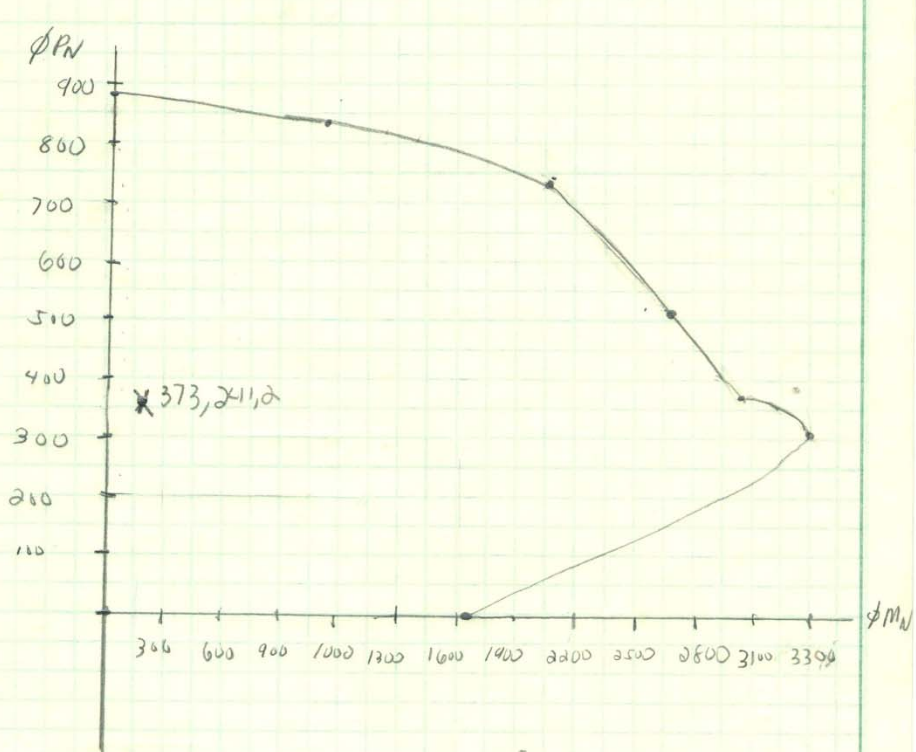
Interaction Diagram - Using CRSI Design Guide



* column ok for loading ✓

Appendix I: Center Of Rigidity and Center of Mass

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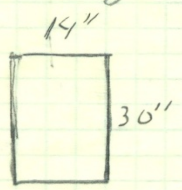
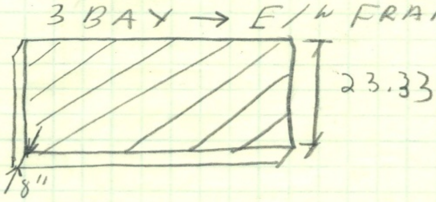
Analysis – Wind Load + Seismic Load

3 BAY → E/W FRAME COL. LINE (5)



Column



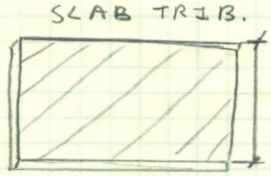
according to ACI section 10.10.4.1
columns → .7 I_g
flat plate → .25 I_g

(.7)(30") = 21"
(.25)(23.33) = 5.8325' → FOR MODELING VALUES

* see excell spreadsheet for list of all k-values

$k = \frac{P}{\Delta_p}$ * use P of 1k

* 6 BAY FRAME
SLAB TRIB.



columns → .7(30") = 21"
flat plate → .25(14.34') = 3.585"

* 15 BAY FRAME
SAME TRIB AS 6 BAY.

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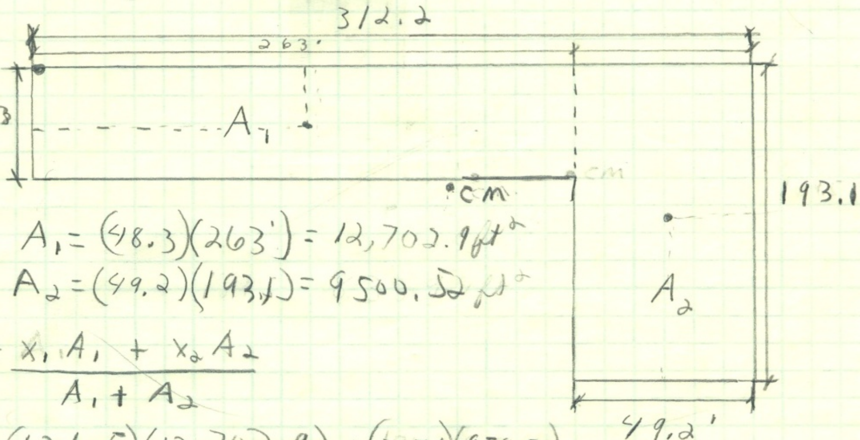
center of mass



$A_1 = (48.3)(263') = 12,702.9 ft^2$

$A_2 = (49.2)(193.1) = 9500.52 ft^2$

$\bar{X}_m = \frac{x_1 A_1 + x_2 A_2}{A_1 + A_2}$

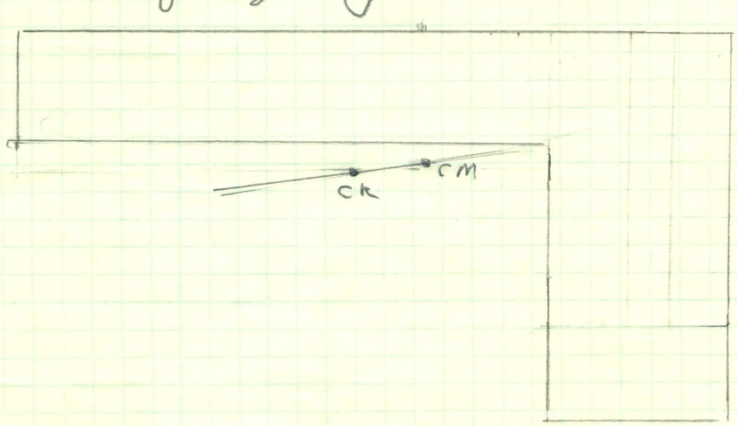
$\bar{X}_m = \frac{(131.5)(12,702.9) + (287.6)(9500.52)}{12,702.9 + 9500.52}$

$\bar{X}_m = 198.2'$

$\bar{Y}_m = \frac{y_1 A_1 + y_2 A_2}{A_1 + A_2} = \frac{(24.15)(12,702.9) + (84.75)(9500.52)}{12,702.9 + 9500.52}$

$\bar{Y}_m = 50.1'$

center of rigidity



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$\bar{X}_R = \frac{\Sigma kx}{\Sigma k}$

$\Sigma kx = (7)(0) + (7)(19) + (7)(42.33) + (7)(61.33) + (7)(84.66) + (7)(107.99) + (7)(131.2) + (7)(150.32) + (7)(173.9) + (7)(192.9) + (7)(216.48) + (7)(239.81) + (10.4)(263.14) + (10.4)(286.5) + (10.4)(295.8) + (10.4)(312.2)$

$= (7)(1419.92) + (10.4)(1157.64)$

$= 21{,}976.4$

$\Sigma k = (7)(12) + (10.4)(4) = 125.6$

$\bar{X}_R = \frac{21976.4}{125.6} = 175'$

$\bar{Y}_R = \frac{\Sigma ky}{Y}$

$\Sigma ky = (20.8)(0) + (20.8)(17.67) + (20.8)(29.9) + (20.8)(47.57) + (7)(70.7) + (7)(94.1) + (7)(117.4) + (7)(140.97) + (7)(164.58) + (7)(183.5)$

$= (20.8)(95.14) + (7)(771.25) = 7377.7$

$\Sigma k = (4)(20.8) + (7)(6) = 125.2'$

$\bar{Y}_R = \frac{7377.7}{125.2} = 58.9'$

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Example load calculation of % of P distributed to frame 7th floor (E/W) direction

$P = 80.7^k$

$\Sigma k = (12)(7) + (4)(10.4) = 125.6$

$\frac{7}{125.6}(80.7^k) = 4.5^k$, $\frac{10.4}{125.6}(80.7^k) = 6.68^k$

M = P·e

FLOOR		k-ft
7	$80.7^k(175-156.1)$ =	1525.23
6	$69.5^k(18.9)$ =	1313.5
5	68.2 (18.9) =	1288.9
4	66.75 (18.9) =	1261.6
3	65.00 (18.9) =	1228.5
2	62.8 (18.9) =	1186.4
1		

N/S WIND

M = P.e

FLOOR		k-ft
7	43.81 (96.55-58.9) =	1649.4
6	37.6 (37.65) =	1415.64
5	36.9 (37.65) =	1389.3
4	36 (37.65) =	1355.4
3	35 (37.65) =	1317.7
2	33.71 (37.65) =	1268.8
1	32.1 (37.65) =	1208.56