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R. Bryan Peiffer– Structural Option

AE Senior Thesis 2011

Three PNC Plaza, Pittsburgh Pa.

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Presentation Outline

Introduction
Existing Structure
Thesis Goals
Structural Depth
Architectural Breadth
Construction Management Breadth
Conclusion
Questions & Comments

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Project Information

Location:	Pittsburgh, PA
Occupancy Type:	Mixed-Use Office
Size:	780,000 SF
Height:	342 Feet
Cost:	$179 Million
Condominiums:	28 Units
Hotel:	185 Rooms
Parking Garage:	330 Spaces Underground
LEED:	Core and Shell Gold
	Fairmont Hotel Gold

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Project Information

- Owner: The PNC Financial Services Group
- Design Architect: Gensler
- Local Architect of Record: Astorino
- Main Tenants: PNC
  Reed Smith Law Firm
- Hotel Operator: Fairmont Hotels & Resorts
- Condominiums: Howard Hanna Real Estate

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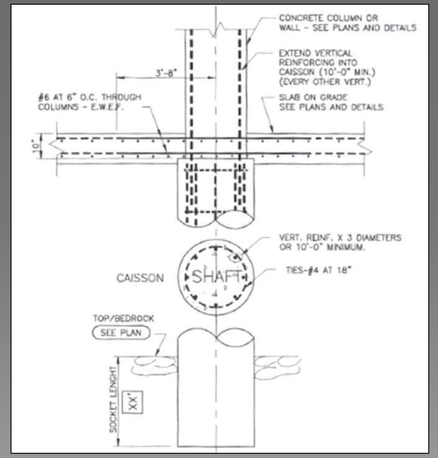
Cassion Detail



Provided by Astorino

Existing Structure

Foundation System

- Soil Overburden 60' to Bedrock
- Typical Column Reaction of 3500 kips
- Caisson drilled till auger refusal or socket into bedrock

CAISSONS $F_{BR.}$ =30K/SQ. FT.

MARK	SIZE Ø	VERT.REINF. length=3 X DIA.	TIES	DOWELS
A.	48"	7-#10	#4@18" O.C.	4-#8 X 8'-0" DEVELOP INTO PEDESTAL
B.	54"	9-#10	#4@18" O.C.	
C.	42"	7-#9	#3@18" O.C.	
D.	60"	9-#11	#3@18" O.C.	

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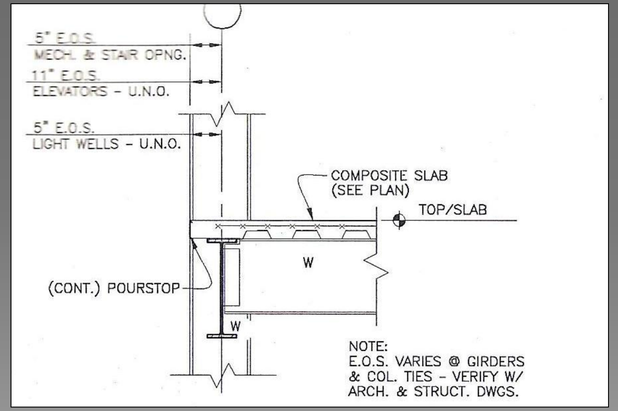
Floor Detail



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Existing Structure

Gravity System

- Typical Bay Size 30' by 42.5'
- 5 ½" Composite Floor Construction
- W21x44 Fill Beams
- W24x62 Girders
- W14 Columns Ranging from 68 to 740 lb/ft

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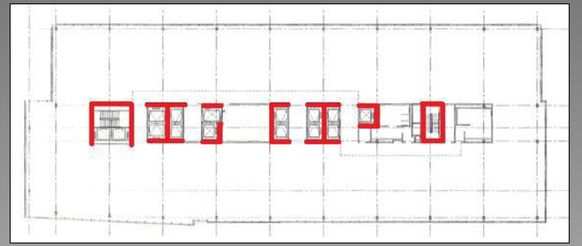
Existing Structure

Lateral System

- Concrete Core Shear Walls
  - Stop at 14th Floor
  - Size change at 8th floor
- Steel Moment Frame



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Thesis Goals

Structural Depth

- Redesign building with concrete to try and reduce costs with minimal impact to current floor plans
  - New Gravity System
  - New Lateral System

Construction Management Breadth

- Compare sequencing and cost

Architectural Breadth

- Determine effects on floor plans

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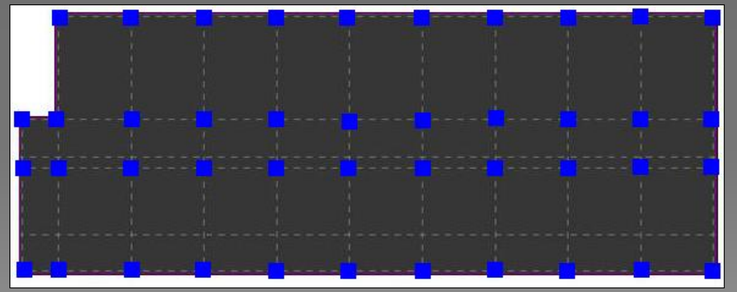
Initial Column Layout



Structural Depth

Design Process

1. Initial Plan Layout
2. Gravity System Design
3. Lateral System Design

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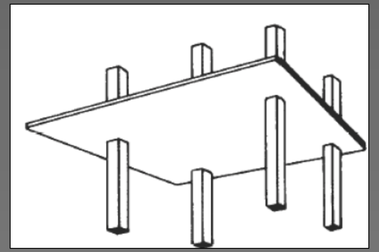
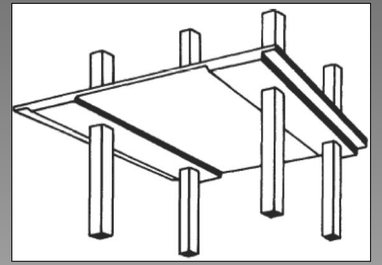


Tensacciai - Guide to PT Systems



Tensacciai - Guide to PT Systems

Structural Depth

Slab Design Alternatives

1. Flat Slab System
2. Two-Way Post-Tensioned Slab
3. One-Way Post-Tensioned Slab with Wide Shallow Beams

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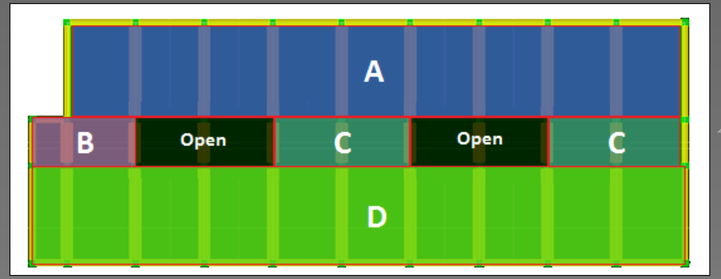
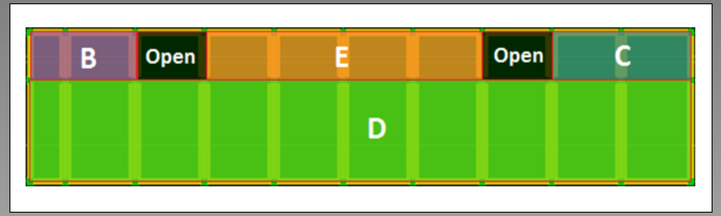
Ground – 14th Floor



15th Floor– 23rd Floor



Structural Depth

One-Way Slab Design

- 8" Uniform Thickness
  L/h = 45
- Typical span length of 30'
- 100 psf Live Load
- 20 psf Superimposed Dead Load
- Broke up into Sections and Design Individually
- ADAPT-PT modeled 1' wide sections
- Pre-stressed Class U properties
- #4 Rebar for Ordinary Reinforcing

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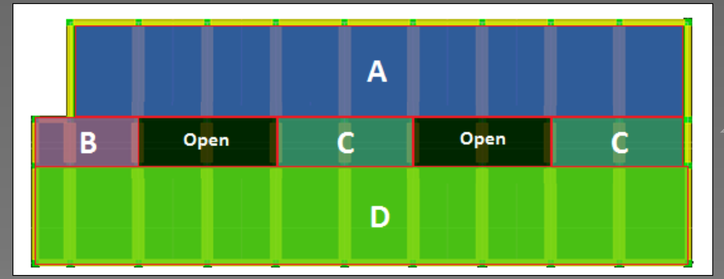
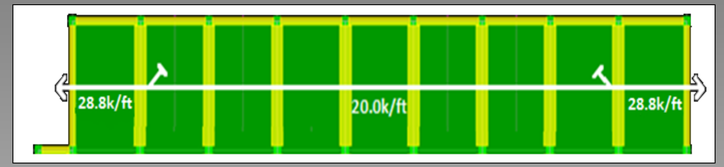


Slab A Design

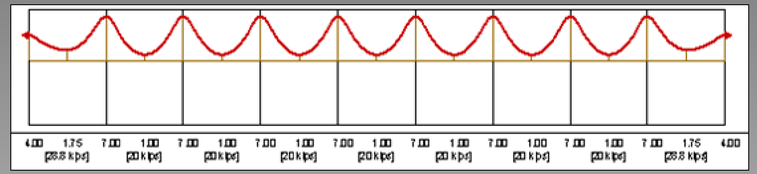


Structural Depth

Slab A Design

- 9 Spans at 30'
- ½", 7-wire tendons
- Exterior bays PT Force of 28.8 kips/ft
- Interior bays PT Force of 20.0 kips/ft
- Pre-stressed Class U properties

Slab A Tendon Profile



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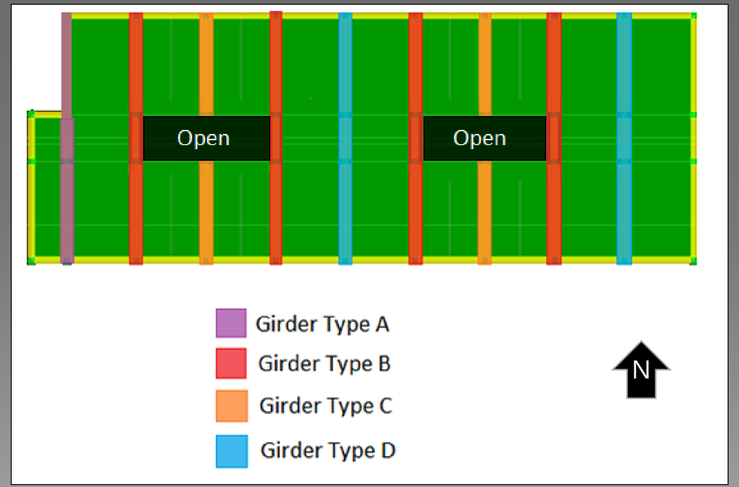
Ground – 14th Floor



Structural Depth

Girder Design

- Broken up into types and designed individually
- ADAPT-PT used for analysis
- Typically 60" wide by 18" deep

  L/h = 30
- # 8 Rebar for Ordinary Reinforcing

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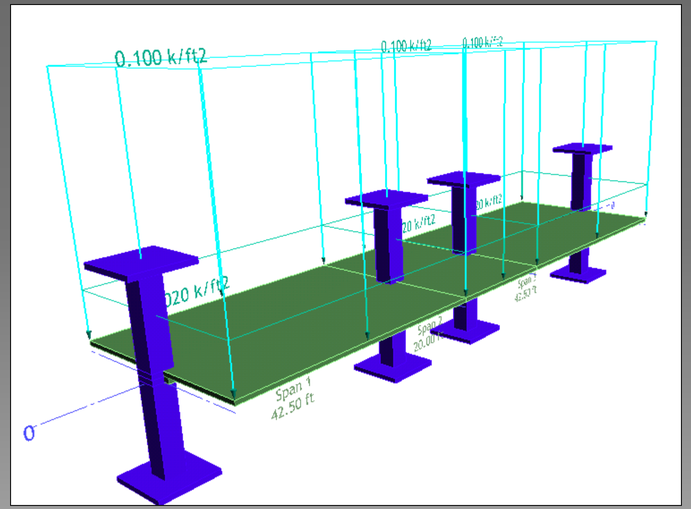
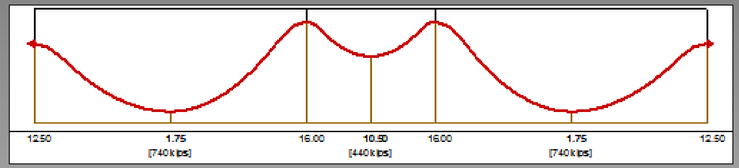
ADAPT-PT Model



Structural Depth

Girder Design Type D

- Modeled as "T-Beams", effective width according to ACI 318
- 100 psf Live Load
- 20 psf Superimposed Dead Load
- PT Force Required
  - Exterior: 740 Kips from 29 strands
  - Interior 440 kips from 19 Strands



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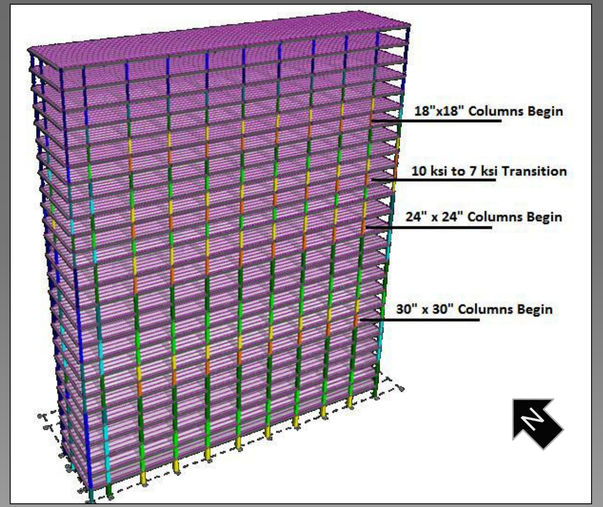
RAM Model



Structural Depth

Column Design

- Preliminary Size of 36" by 36"
- Modeled in RAM Structural System
- Size Changes Every 6 Floors
- Strength Change from 10ksi to 7ksi at 14th Floor

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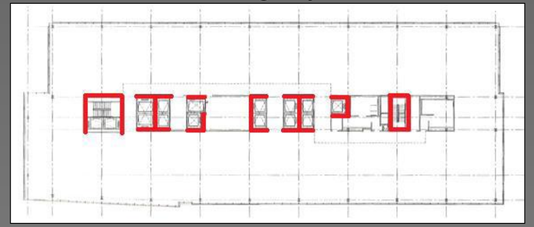
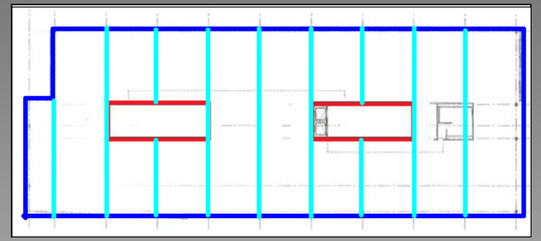
Existing Layout



New Layout



Structural Depth

Lateral System Design

- Concrete Core Shear Walls till 14th Floor
- Perimeter Moment Frame
- Moment Frame in Short Direction of Building
- Dual System Classification: R = 5.5

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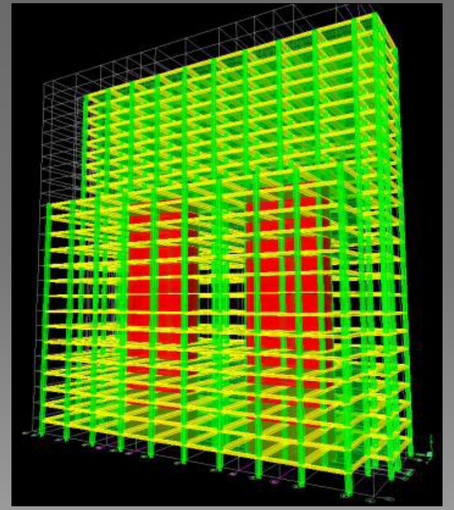
ETABS Model



Structural Depth

ETABS Model Results

- Period of Vibration:
  - Mode 1= 3.37
  - Mode 2= 2.65
  - Mode 3= 2.34
- Cu*Ta = 2.1
- Building Weight = 103700 kips
- Seismic Base Shear = 2390 kips
- Wind Base Shear N/S = 2814 kips
- Wind Base Shear E/W = 795 kips

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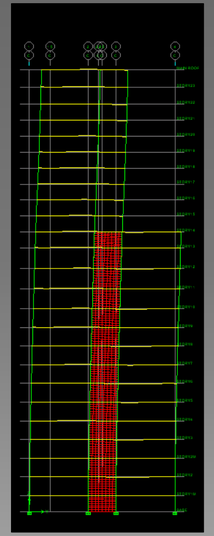

Maximum Lateral Displacement in Y Direction (North South) due to wind load

Floor Level	Floor Height (ft)	Total Height (ft)	Displacement (in)	Story Drift (in)	Allowable Displacement (in) L/400	Allowable Story Drift (in)
Main Roof	23	319.0	5.93	0.2	9.57	0.375
23	12.5	306.5	5.73	0.24	9.195	0.345
22	11.5	295.0	5.49	0.24	8.85	0.345
21	11.5	283.5	5.25	0.27	8.505	0.345
20	11.5	272.0	4.98	0.3	8.16	0.345
19	11.5	260.5	4.68	0.33	7.815	0.345
18	11.5	249.0	4.35	0.35	7.47	0.345
17	11.5	237.5	4.00	0.37	7.125	0.345
16	11.5	226.0	3.63	0.38	6.78	0.345
15	11.5	214.5	3.25	0.33	6.435	0.345
14	11.5	203.0	2.92	0.22	6.09	0.45
13	15	188.0	2.70	0.3	5.64	0.435
12	14.5	173.5	2.40	0.28	5.205	0.435
11	14.5	159.0	2.12	0.27	4.77	0.405
10	13.5	145.5	1.85	0.25	4.365	0.405
9	13.5	132.0	1.60	0.24	3.96	0.405
8	13.5	118.5	1.36	0.23	3.555	0.405
7	13.5	105.0	1.13	0.22	3.15	0.405
6	13.5	91.5	0.91	0.2	2.745	0.405
5	13.5	78.0	0.71	0.19	2.34	0.405
4	13.5	64.5	0.52	0.16	1.935	0.405
3	13.5	51.0	0.36	0.14	1.53	0.405
2mezz	13.5	37.5	0.22	0.11	1.125	0.405
2	13.5	24.0	0.11	0.076	0.72	0.345
1mezz	11.5	12.5	0.034	0.034	0.375	0.375
Ground	12.5	0.0	0.00	0	0	0

Structural Depth

Lateral System Deflections

- Wind Controlled in North/South
- Seismic Controlled in East/West
- Max Allowable Deflection of 9.57" from wind loads
  h/400
- Max Allowable Seismic Story Drift from equation
  $0.015h_{sx}$
  - North/South Deflection Due to Wind = 5.93"
  - East/West Deflection Due to Seismic = 2.56"

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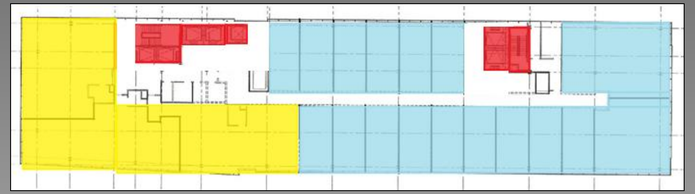
Existing Layout

New Layout



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Architectural Breadth

Movement of Vertical Circulation Wells Impact to key areas:

- 2nd Floor: Restaurant and Ballroom
- 8th Floor: Typical Office Level
- 15th Floor: Typical Condo/Hotel Level

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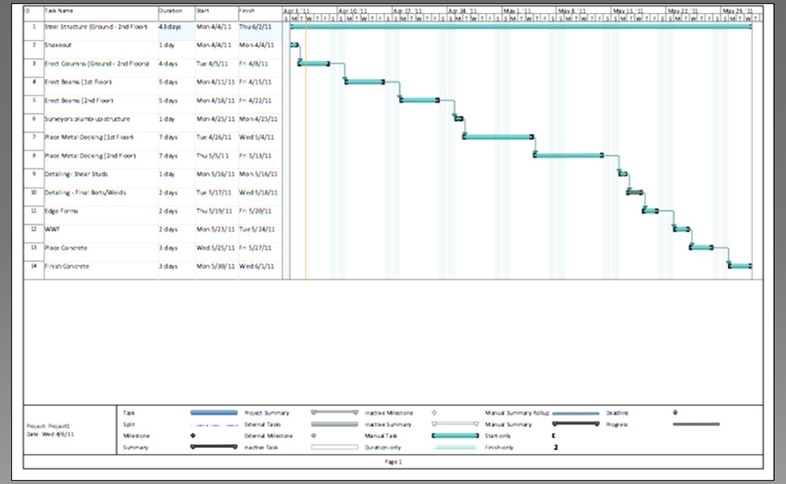
Construction Management Breadth

Steel Schedule

- 2 Floors Scheduled
- 43 days per 2 Floor
- Approx: 537 Days



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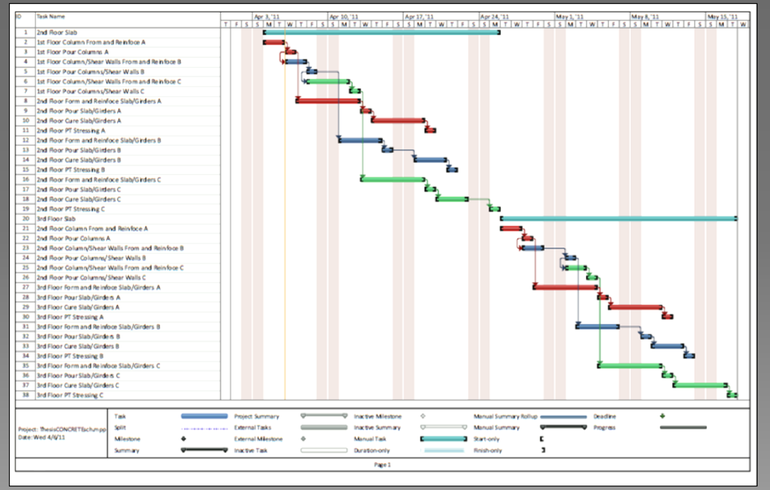
Steel Schedule

- 2 Floors Scheduled
- 43 days per 2 Floor
- Approx: 537 Days

Concrete Schedule

- 2 Floors Scheduled
- Broken up into 3 Sections
- 16 Days per Floor
- Approx.: 400 Days Total



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Concrete Schedule

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- Approx.: 400 Days Total

Cost Comparison			
	Bare Costs	O&P Costs	Total
Steel	$16,008,174	$3,610,772	$19,618,946
Concrete	$16,599,099	$5,062,030	$21,661,129

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Conclusions

The goal of creating a more cost effective concrete structure was not met with this redesign.

Increased building weight would require a redesign of the foundation system. Which was not in the scope of this project.

New system also resulted in a lost of useable space for the tenants, in particular the hotel portion of the building.

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Acknowledgments

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- Professor Robert Holland
- The entire AE faculty and staff
- The AE Class of 2011

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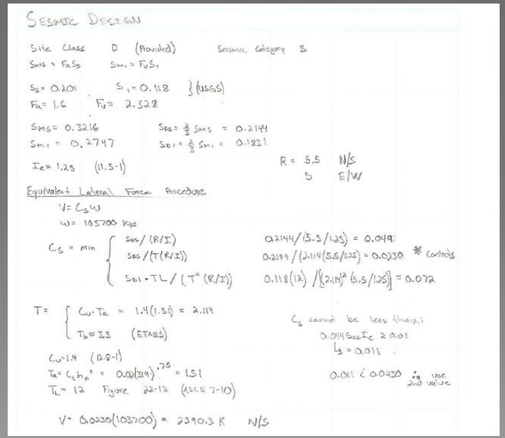
Floor Level	Floor Height (ft)	Total Height (ft)	Weight (kips)	w^*h^k	C_{vx}	f_i (kips)	V_i (kips)	M_z (k-ft)
Main Roof	23	319.0	3200	18765276	0.080	191	191	60831
23	12.5	306.5	3200	17669646	0.075	180	370	55035
22	11.5	295.0	3200	16681385	0.071	170	540	50007
21	11.5	283.5	3200	15712393	0.067	160	699	45266
20	11.5	272.0	3200	14763053	0.063	150	849	40806
19	11.5	260.5	3200	13833772	0.059	141	990	36621
18	11.5	249.0	3200	12924983	0.055	131	1121	32704
17	11.5	237.5	3200	12037151	0.051	122	1244	29051
16	11.5	226.0	3200	11170772	0.047	114	1357	25655
15	11.5	214.5	3200	10326379	0.044	105	1462	22509
14	11.5	203.0	4900	14553841	0.062	148	1610	30023
13	15	188.0	4900	12965929	0.055	132	1742	24771
12	14.5	173.5	4900	11490576	0.049	117	1859	20259
11	14.5	159.0	4900	10076246	0.043	102	1961	16281
10	13.5	145.5	4900	8816676	0.037	90	2051	13036
9	13.5	132.0	4900	7614824	0.032	77	2128	10214
8	13.5	118.5	4900	6473545	0.028	66	2194	7795
7	13.5	105.0	4900	5396174	0.023	55	2249	5758
6	13.5	91.5	4900	4386669	0.019	45	2293	4079
5	13.5	78.0	4900	3449836	0.015	35	2328	2734
4	13.5	64.5	4900	2591692	0.011	26	2355	1699
3	13.5	51.0	4900	1820075	0.008	18	2373	943
2mezz	13.5	37.5	4000	935356	0.004	10	2383	356
2	13.5	24.0	4900	585348	0.002	6	2388	143
1mezz	11.5	12.5	4000	179023	0.001	2	2390	23
Ground	12.5	0.0	4900	0	0.000	0	2390	0
			103700	235220621	1	2390		536598

T=	1.510	s
k=	1.505	
V_b=	2390.3	kips

Seismic Design Criteria			
Seismic Use Group		III	
Site Class		D	Provided
Seismic Design Category		B	Table 11.6-1
Importance Factor	I_e	1.25	Table 11.5-1
Spectral Response Acceleration (Short)	S_s	0.201	USGS
Spectral Response Acceleration (1s)	S_1	0.118	USGS
Site Coefficient	F_a	1.6	Table 11.4-1
	F_v	2.328	table 11.4-2
Soil Modified Acceleration	S_{MS}	0.3216	Calculated
	S_{M1}	0.2747	Calculated
Design Spectral Response (Short)	S_{DS}	0.2144	Calculated
Design Spectral Response (1s)	S_{D1}	0.1831	Calculated
Response Modification Coefficient	R_x	5.5	Table 12.2-1
	R_y	5.5	Table 12.2-1
Approximate Period Parameter	C_t	0.02	Table 12.8-2
Building Height	h_n	319	
Approximate Period Parameter	x	0.75	Table 12.8-2
Approximate Fundamental Period	T_a	1.51	Table 12.8-8
Period Upper Limit Coefficient	C_u	1.4	Table 12.8-1
Long Period Transition Period	T_L	12	Figure 22-12



North/South

Story	Height (ft)	kz or kh	qz	Windward (psf)	Windward (plf)	Windward (kips)	Leeward (psf)	Leeward (plf)	Leeward (kips)	Story Force (kips)	Moment (k-ft)
Building Portion A											
1mezz	12.50	0.57	17.86	19.52	5796.52	36.34	-25.96	-7711.17	-46.27	82.61	1032.57
2.00	24.00	0.65	20.43	21.34	6338.93	38.06	-25.96	-7711.17	-48.19	86.25	2070.09
2mezz	37.50	0.75	23.34	23.33	6929.32	44.78	-25.96	-7711.17	-52.05	96.83	3631.15
3.00	51.00	0.81	25.51	24.79	7362.97	48.24	-25.96	-7711.17	-52.05	100.29	5114.63
4.00	64.50	0.87	27.20	25.93	7699.99	50.84	-25.96	-7711.17	-52.05	102.89	6636.27
5.00	78.00	0.92	28.89	27.05	8034.75	53.10	-25.96	-7711.17	-52.05	105.16	8202.10
6.00	91.50	0.96	30.22	27.94	8297.13	55.12	-25.96	-7711.17	-52.05	107.17	9806.10
7.00	105.00	1.00	31.41	28.72	8530.75	56.79	-25.96	-7711.17	-52.05	108.84	11428.67
8.00	118.50	1.04	32.47	29.42	8737.44	58.28	-25.96	-7711.17	-52.05	110.33	13074.17
9.00	132.00	1.07	33.53	30.11	8943.56	59.67	-25.96	-7711.17	-52.05	111.72	14747.54
10.00	145.50	1.10	34.50	30.75	9132.28	61.01	-25.96	-7711.17	-52.05	113.06	16449.70
11.00	159.00	1.13	35.35	31.30	9295.99	64.52	-25.96	-7711.17	-53.98	118.50	18841.12
12.00	173.50	1.16	36.25	31.89	9471.48	68.03	-25.96	-7711.17	-55.91	123.94	21503.25
13.00	188.00	1.18	37.04	32.40	9622.04	70.42	-25.96	-7711.17	-56.87	127.29	23929.89
Building Portion B											
14.00	203.00	1.20	37.75	32.89	9767.96	64.17	-25.96	-7711.17	-51.09	115.25	23396.16
15.00	214.50	1.22	38.33	33.26	9878.22	56.48	-25.96	-7711.17	-44.34	100.82	21626.32
16.00	226.00	1.24	38.90	33.63	9988.37	57.12	-25.96	-7711.17	-44.34	101.46	22928.98
17.00	237.50	1.26	39.48	34.00	10098.42	57.75	-25.96	-7711.17	-44.34	102.09	24246.07
18.00	249.00	1.28	40.06	34.37	10208.37	58.38	-25.96	-7711.17	-44.34	102.72	25577.59
19.00	260.50	1.29	40.57	34.70	10305.32	58.98	-25.96	-7711.17	-44.34	103.32	26913.84
20.00	272.00	1.31	41.07	35.02	10400.97	59.53	-25.96	-7711.17	-44.34	103.87	28252.59
21.00	283.50	1.33	41.58	35.34	10496.55	60.08	-25.96	-7711.17	-44.34	104.42	29602.95
22.00	295.00	1.34	42.08	35.66	10592.07	60.63	-25.96	-7711.17	-44.34	104.97	30965.85
23.00	306.50	1.36	42.55	35.96	10679.54	63.83	-25.96	-7711.17	-46.27	110.09	33743.44
Roof Main	319.00	1.37	43.02	36.26	10767.90	95.29	-25.96	-7711.17	-68.44	163.73	52228.48
Roof High	342.00	1.40	43.88	36.80	10930.35	61.92	-25.96	-7711.17	-44.34	106.25	36339.10
									Sum=	2813.86	512388.61

Wind Load Design Criteria		
Category		
Basic Wind Speed	V	120
Importance Factor	I	
Exposure Category	-	B
Directionality Factor	K_d	0.85
Topographic Factor	K_{zt}	1
Intensity of Turbulence	I_z	0.2238
Integral Length of Scale of Turbulence	L_z	574.945
Background Response Factor	Q	0.7766
Gust Effect Factor	G_f	0.8231
	GC_{pi}	+/- 0.18
Windward Pressure	C_p	0.8
Leeward Pressure	C_p	-0.5

East/West

Story	Height (ft)	kz or kh	qz	Windward (psf)	Windward (plf)	Windward (kips)	Leeward (psf)	Leeward (plf)	Leeward (kips)	Story Force (kips)	Moment (k-ft)
Building Portion A											
1mezz	12.50	0.57	17.86	20.43	2507.65	15.68	-19.16	-2351.79	-14.11	29.79	372.42
2.00	24.00	0.65	20.43	22.23	2729.22	16.42	-19.16	-2351.79	-14.70	31.12	746.86
2mezz	37.50	0.75	23.34	24.21	2971.40	19.24	-19.16	-2351.79	-15.87	35.11	1316.78
3.00	51.00	0.81	25.51	25.64	3146.94	20.65	-19.16	-2351.79	-15.87	36.52	1862.72
4.00	64.50	0.87	27.20	26.74	3282.15	21.70	-19.16	-2351.79	-15.87	37.57	2423.44
5.00	78.00	0.92	28.89	27.84	3417.56	22.61	-19.16	-2351.79	-15.87	38.49	3001.92
6.00	91.50	0.96	30.22	28.70	3522.74	23.42	-19.16	-2351.79	-15.87	39.30	3595.78
7.00	105.00	1.00	31.41	29.46	3616.33	24.09	-19.16	-2351.79	-15.87	39.97	4196.74
8.00	118.50	1.04	32.47	30.13	3699.01	24.69	-19.16	-2351.79	-15.87	40.56	4806.82
9.00	132.00	1.07	33.53	30.81	3781.94	25.25	-19.16	-2351.79	-15.87	41.12	5428.21
10.00	145.50	1.10	34.50	31.43	3857.84	25.78	-19.16	-2351.79	-15.87	41.66	6061.37
11.00	159.00	1.13	35.35	31.96	3923.44	27.24	-19.16	-2351.79	-16.46	43.71	6949.13
12.00	173.50	1.16	36.25	32.54	3994.06	28.70	-19.16	-2351.79	-17.05	45.75	7937.87
13.00	188.00	1.18	37.04	33.03	4054.39	29.68	-19.16	-2351.79	-17.34	47.03	8841.06
Building Portion B											
14.00	203.00	1.20	37.75	34.23	2139.39	21.35	-15.41	-962.85	-11.59	32.94	6687.25
15.00	214.50	1.22	38.33	34.58	2161.05	12.36	-15.41	-962.85	-5.54	17.90	3839.59
16.00	226.00	1.24	38.90	34.93	2182.83	12.49	-15.41	-962.85	-5.54	18.03	4073.67
17.00	237.50	1.26	39.48	35.28	2204.71	12.61	-15.41	-962.85	-5.54	18.15	4310.76
18.00	249.00	1.28	40.06	35.63	2226.67	12.74	-15.41	-962.85	-5.54	18.28	4550.88
19.00	260.50	1.29	40.57	35.93	2245.86	12.86	-15.41	-962.85	-5.54	18.39	4791.88
20.00	272.00	1.31	41.07	36.24	2264.86	12.97	-15.41	-962.85	-5.54	18.50	5033.28
21.00	283.50	1.33	41.58	36.54	2283.92	13.08	-15.41	-962.85	-5.54	18.61	5277.11
22.00	295.00	1.34	42.08	36.85	2303.04	13.19	-15.41	-962.85	-5.54	18.72	5523.56
23.00	306.50	1.36	42.55	37.13	2320.47	13.87	-15.41	-962.85	-5.78	19.65	6022.68
Roof Main	319.00	1.37	43.02	37.41	2338.01	20.70	-15.41	-962.85	-8.55	29.24	9327.67
Roof High	342.00	1.40	43.88	37.93	2370.44	13.44	-15.41	-962.85	-5.54	18.98	6491.15
									Sum=	795.11	123470.60