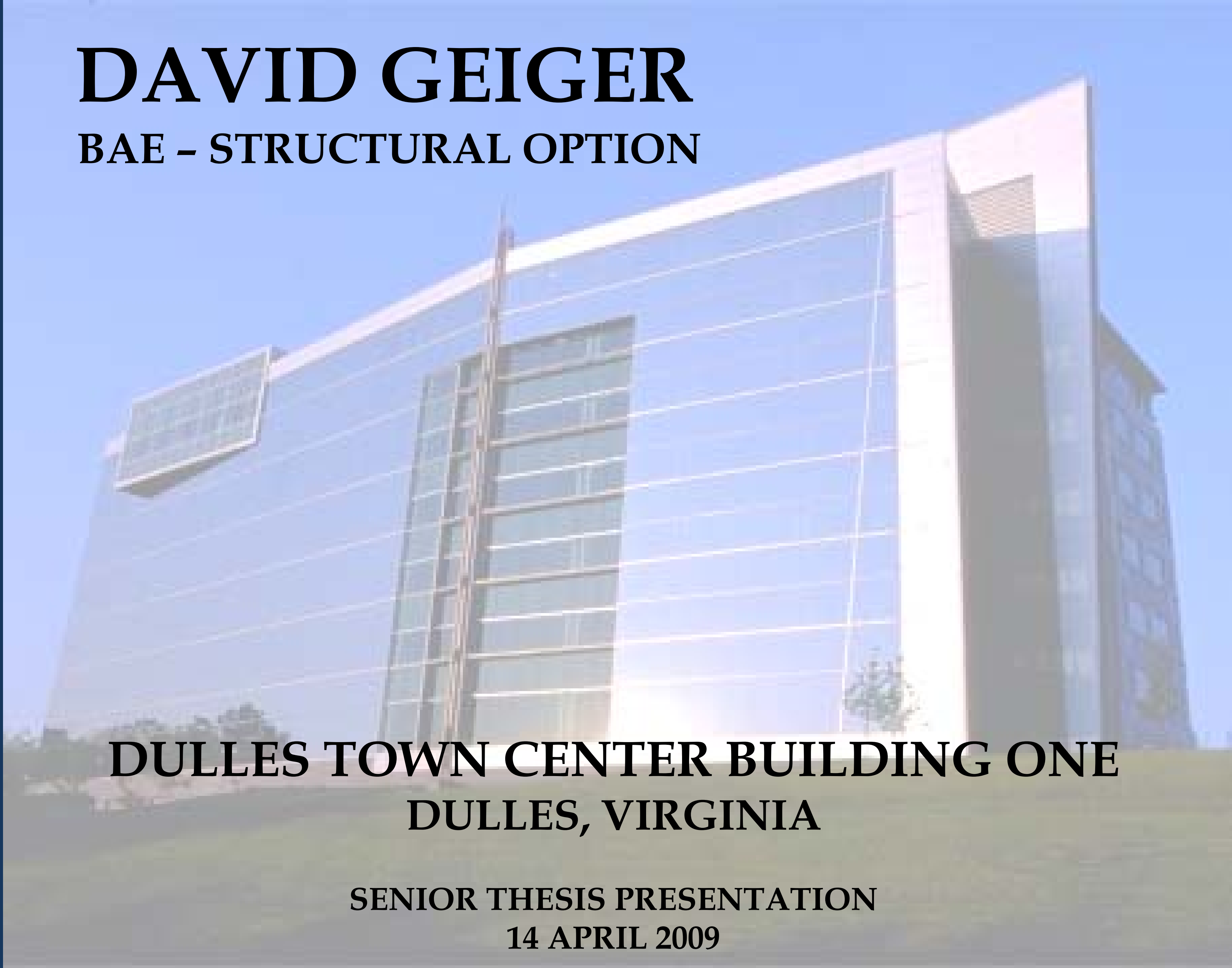


DAVID GEIGER

BAE – STRUCTURAL OPTION

DULLES TOWN CENTER BUILDING ONE

DULLES, VIRGINIA

SENIOR THESIS PRESENTATION
14 APRIL 2009

INTRODUCTION

- Building Overview
- Proposal Summary
- Goals
- Depth Study
  - Structural System Redesign
- Breadth Study
  - Cost Comparison
  - Schedule Comparison
  - 7th Floor Acoustics
- Conclusions
- Questions

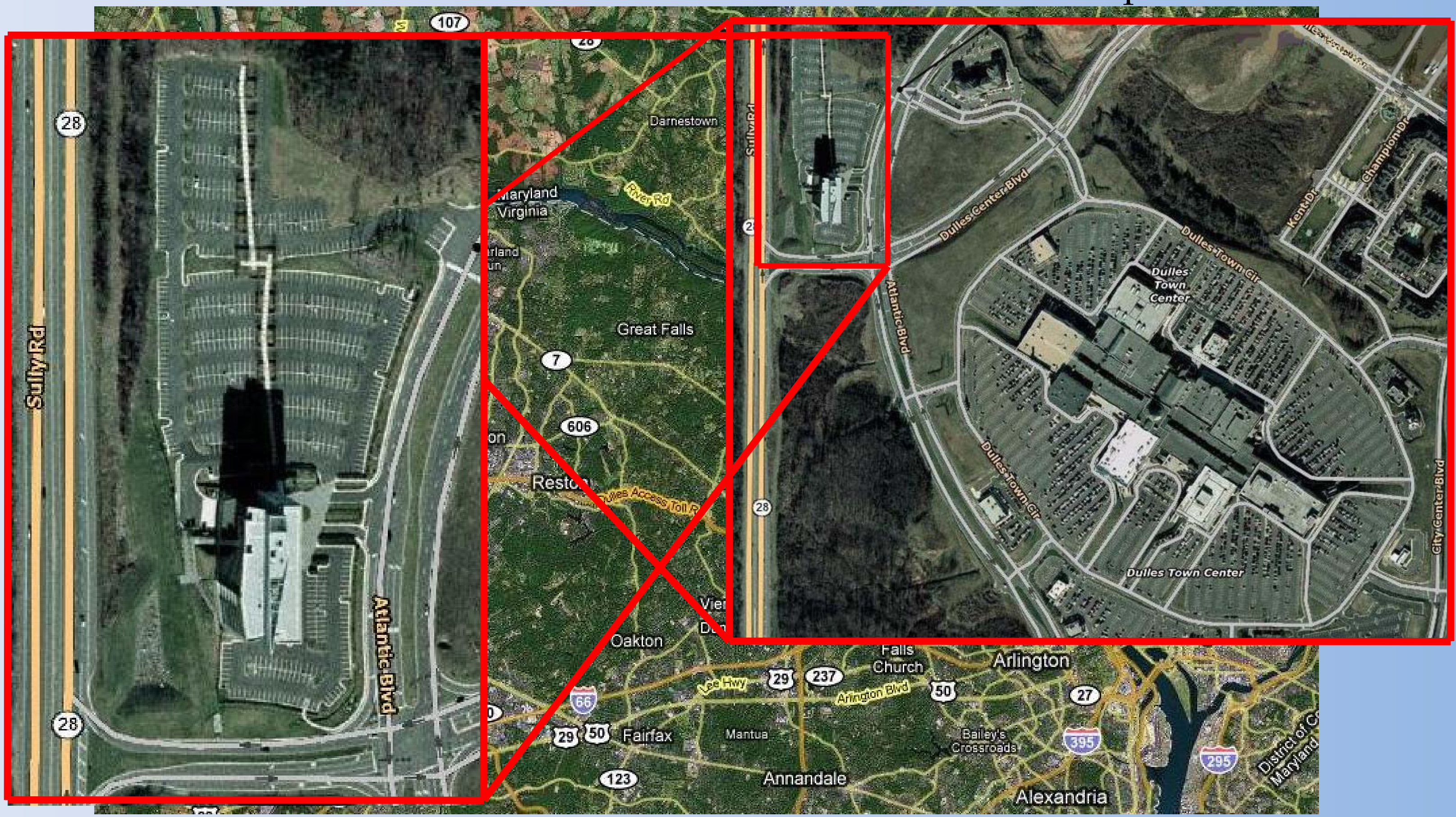
OVERVIEW

- 7 Story Commercial/Office Building
  - (7) Stories of office space above grade
  - (1) Sub-grade floor

    Houses building services and amenities
- Square Footage: 202,110 gross floor area
- Site Area: 12.37 acres
- Project Duration
  - Fall 2000 – Spring 2002
- Project Delivery Method
  - Design-Bid-Build

Location: 21000 Atlantic Boulevard
Dulles, Virginia 20101

- 25 miles northwest of Washington, D.C.
- 5 minutes from Dulles International Airport

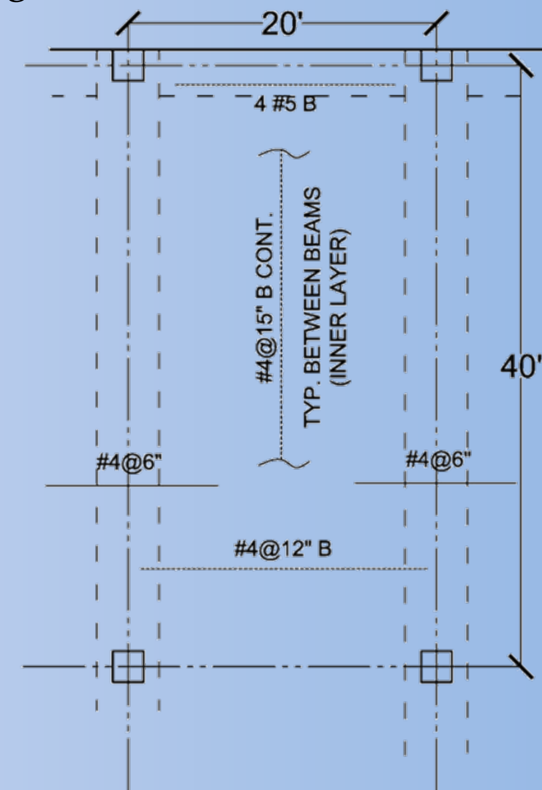


Project Team

- Owner: LERNER ENTERPRISES
- Architect: SMITHGROUP architecture engineering interiors planning
- Structural Engineer: SK&A Consulting Structural Engineers
- MEP Engineer: ***KCF-SHG Inc.***
- Civil Engineer: Dewberry
- General Contractor: TOMPKINS BUILDERS, INC.

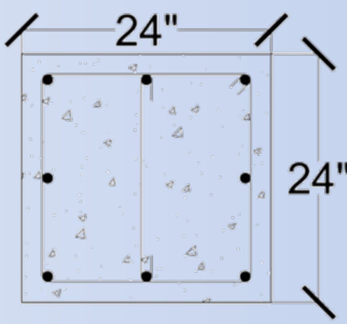
Existing Floor System

- 7″ one-way slab on post-tensioned beam system
- F'_c = 5000 psi
- ½″ DIA. 7 wire, low-relaxation strand
- 48″x 17″ post-tensioned beams
- 3-day curing time before post-tensioning
- 40′ spans



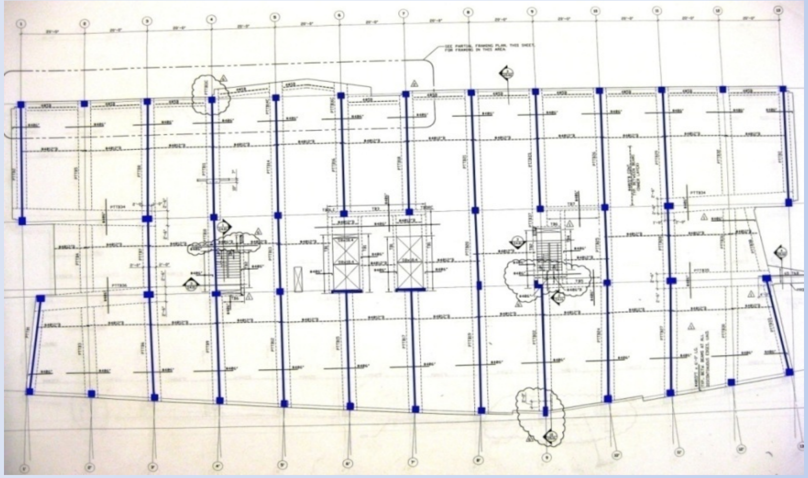
Existing Columns

- Cast-in-place
- 24″x 24″
- f'_c = 5000 psi (Floors C-2)
- f'_c = 4000 psi (Floors 4-PH)



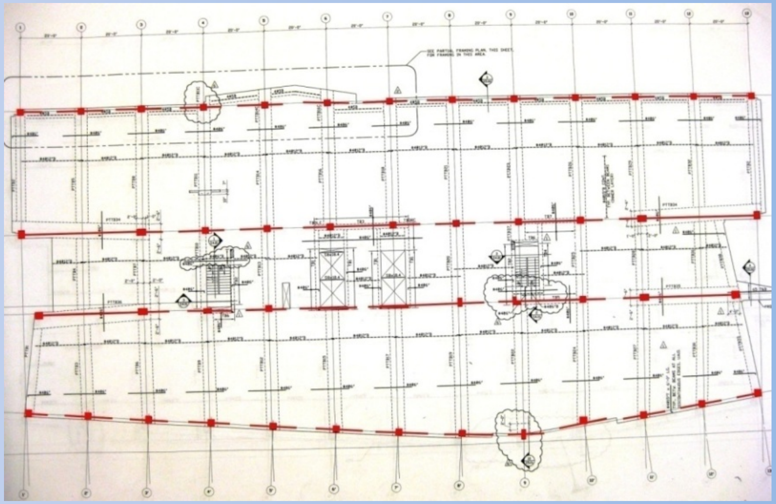
Existing Lateral System

- Ordinary reinforced concrete moment frames in both directions
  - Post-tensioned beams
  - Reinforced columns
  - Slab drops



- Frames in east-west direction
- PT beams and C-I-P columns

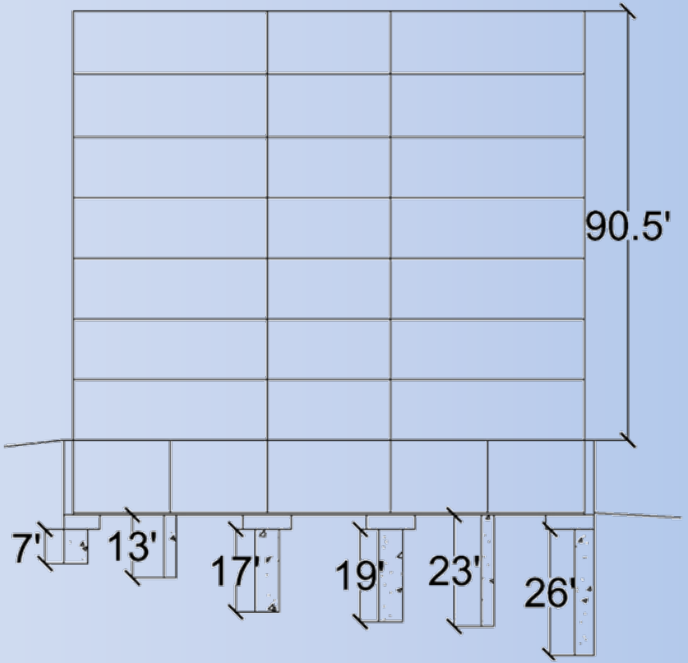
- Frames in north-south direction
- Slab drops
- C-I-P columns
- and slab itself



introduction
overview
proposal
goals
depth
breadth
conclusion

Existing Foundation

- 5″ slab on grade reinforced with 6x6 – W2.0xW2.0 WWF
- Strap beams ranging from 24″x 36″ to 48″x 48″
- 24″ foundation wall
- Pile caps
- Cast-in-place caissons with diameters ranging from 30″ to 75″



South Elevation

Proposal Summary

- To perform a comparison between the existing concrete system and a steel redesign to determine which building material resulted in more benefits, both in regards to time and money

  - Gravity System
    - Composite metal deck system
  - Lateral System
    - Ordinary steel moment frames
  - Foundation System
    - Resist overturning
    - Reduce number of caissons, if possible

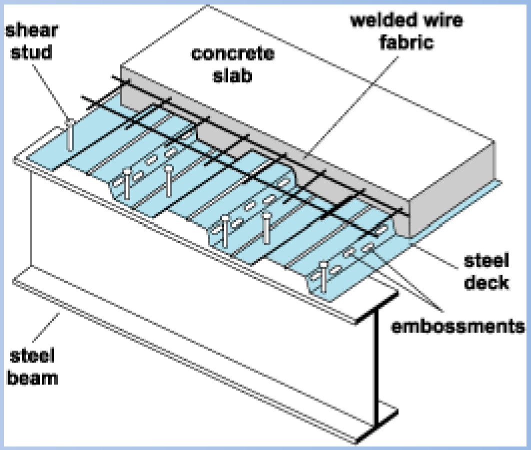
introduction overview proposal goals depth breadth conclusion

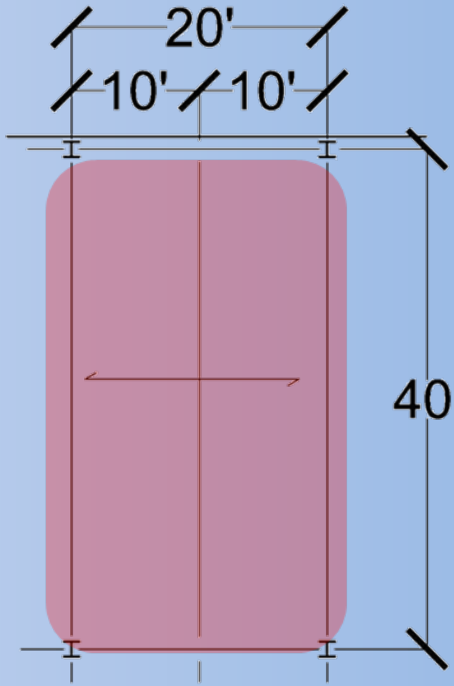
Design Goals

- Respect the current column layout to maintain large spans and open floor plans
- Limit total floor depth to preserve floor-to-ceiling heights of 9′ and prevent additional façade costs
- Establish a design that quickens construction and decreases total project costs
- Preserve a suitable working environment within the 7^{th} floor office space
- Become more familiar with steel design and construction

Floor System

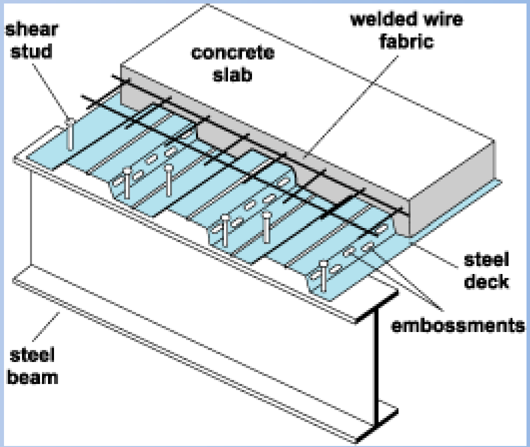
- **Composite metal deck**
- Chapter 4, ASCE 7-05
- Vulcraft Product Catalog
- Design governed by fire rating
- Benefits
  - Speed of steel construction
  - No shoring
- Drawbacks
  - Maximum clear span of 17′
  - Infill beam needed
  - Larger slab depth
- Using 3 VLI, 19″ gage, 7 ½″ slab

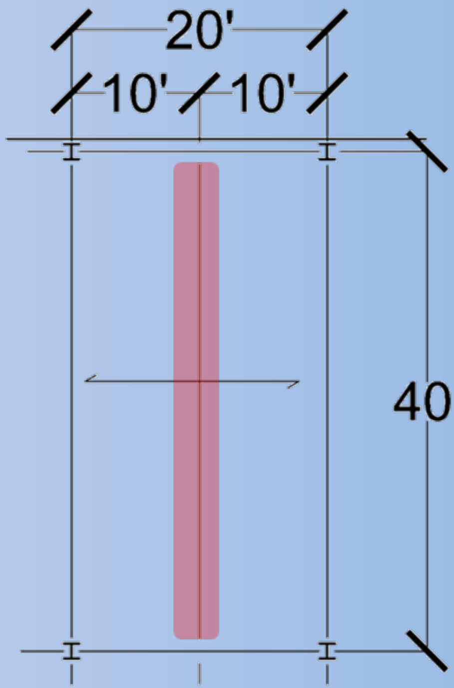




Floor System

- **Infill beams**
- Chapter 4, ASCE 7-05
- LRFD method
- 13th Ed. AISC Steel Manual
- Design governed by Δ_{LL}
- Benefits
  - Can span 40’
  - Lighter than concrete
- Drawbacks
  - Larger beam depth
  - Needs fireproofing
- In order to keep floor-to-ceiling heights at 9’, need to camber





Camber

Method	Camber	Beam Size	Depth (in.)
By Hand, AISC	No	W21x62	21
RAM	No	W24x55	23.6
RAM	Yes	W16x50	16.3

- Reduces overall cost of infill beams compared to no camber

IMAGE COURTESY OF PEDDINGHAUS CORPORATION

Typical floor layout of cambered beams

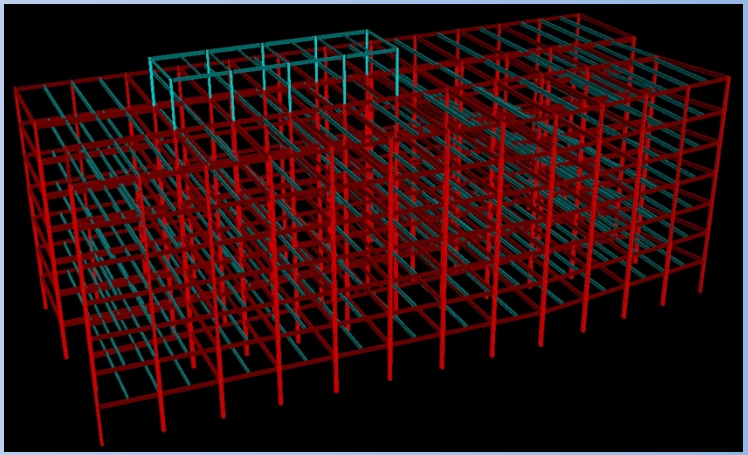
Lateral System

- Ordinary steel moment frames in both the east-west and north-south directions

- Beam to column connections are fixed by providing flange welds

- Benefits
  - Lighter framing
  - Better in tension
  - Can span the necessary 40'

- Drawbacks
  - Beam depth
  - Expensive connections



Lateral System Design Loads

- Wind
  - ASCE 7-05, Chapter 6
    - Method 2
    - Serviceability controlled strength in east-west direction

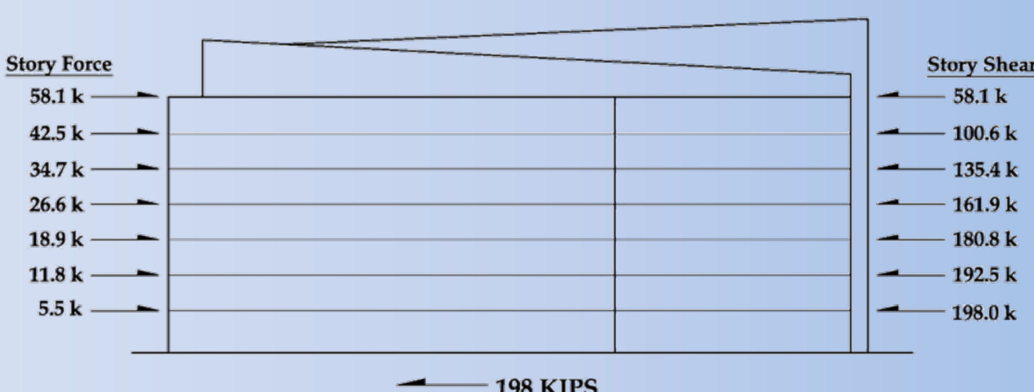
Wind (East - West Direction)									
Floor	Height (ft)	Tributary Height (ft)	K_z	q_z	Windward (psf)	Leeward (psf)	Total (psf)	Story Force (kips)	Story Shear (kips)
Mean Fin Ht.	112.50	11.00	1.022	18.014	12.54	-7.82	20.36	53.74	53.74
Roof	90.50	13.75	0.960	16.928	11.78	-7.82	19.60	82.32	136.06
Seventh	77.50	12.50	0.919	16.195	11.27	-7.82	19.09	58.41	194.47
Sixth	65.00	12.50	0.874	15.401	10.72	-7.82	18.54	55.61	250.08
Fifth	52.50	12.50	0.822	14.489	10.08	-7.82	17.90	53.71	303.79
Fourth	40.00	12.50	0.761	13.406	9.33	-7.82	17.15	51.45	355.24
Third	27.50	12.75	0.683	12.045	8.38	-7.82	16.20	49.60	403.84
Second	15.00	17.50	0.575	10.130	7.05	-7.82	14.87	49.07	452.91
Ground	0.00	6.50	0.000	0.000	0.00	0.00	0.00	0.00	452.91

Wind (North-South Direction)									
Floor	Height (ft)	Tributary Height (ft)	K_z	q_z	Windward (psf)	Leeward (psf)	Total (psf)	Story Force (kips)	Story Shear (kips)
Max. Fin Height	118.00	13.75	1.036	18.262	13.70	-5.20	18.90	6.63	6.63
Roof	90.50	20.75	0.960	16.928	12.70	-5.20	17.90	24.33	30.96
Seventh	77.50	12.75	0.919	16.195	12.20	-5.20	17.40	23.41	54.37
Sixth	65.00	12.50	0.874	15.401	11.60	-5.20	16.80	22.16	75.53
Fifth	52.50	12.50	0.822	14.489	10.90	-5.20	16.10	21.23	97.76
Fourth	40.00	12.50	0.761	13.406	10.10	-5.20	15.30	20.18	117.94
Third	27.50	12.75	0.683	12.045	9.10	-5.20	14.30	19.24	137.18
Second	15.00	17.50	0.575	10.130	7.62	-5.20	12.82	23.67	168.51
Ground	0.00	6.50	0.000	0.000	0.00	0.00	0.00	0.00	168.51

Lateral System Design Loads

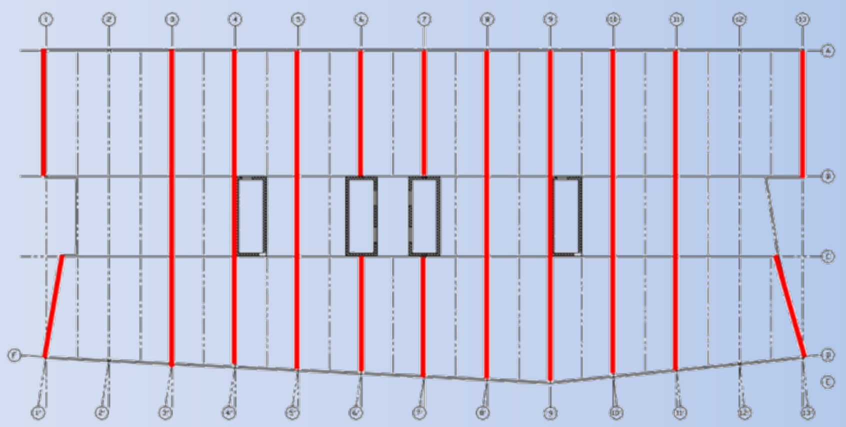
- Seismic
  - ASCE 7-05, Chapter 12
    - Equivalent Lateral Force Procedure
    - Controls strength in north-south direction

Seismic Base Shear							
Floor	Height (ft)	Tributary Height (ft)	Dead Load (kips)	$w_x h_x^k$	C_{vx}	Lateral Force (kips)	Story Shear (kips)
Roof	90.5	6.5	3027.1	924635.3	0.2936	58.14	58.14
Seventh	77.5	12.75	2694.6	675938.9	0.2147	42.50	100.64
Sixth	65	12.5	2751.4	552018.6	0.1753	34.71	135.35
Fifth	52.5	12.5	2760	422193.4	0.1341	26.55	161.90
Fourth	40	12.5	2768.4	299809.3	0.0952	18.85	180.75
Third	27.5	12.5	2778.7	186979.6	0.0594	11.76	192.51
Second	15	13.75	2800	87255.72	0.0277	5.49	198.00
Ground	0	7.5	162.8	0	0.0000	0.00	198.00
Total	90.5	-	19743	3148831	1.0000	198.00	198.00

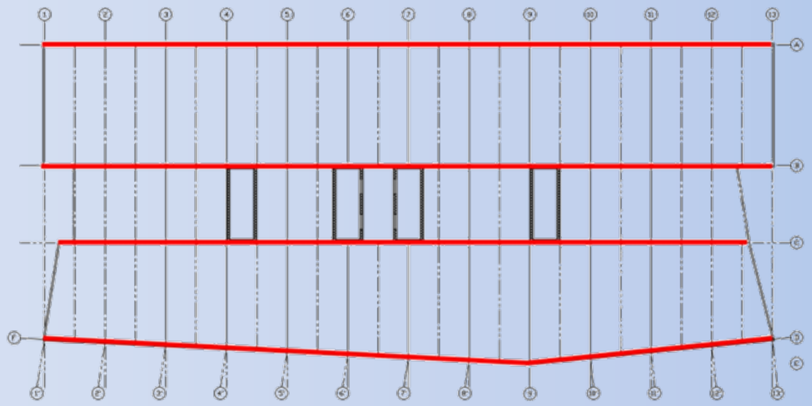


Lateral System Layout

- East-West



- North-South



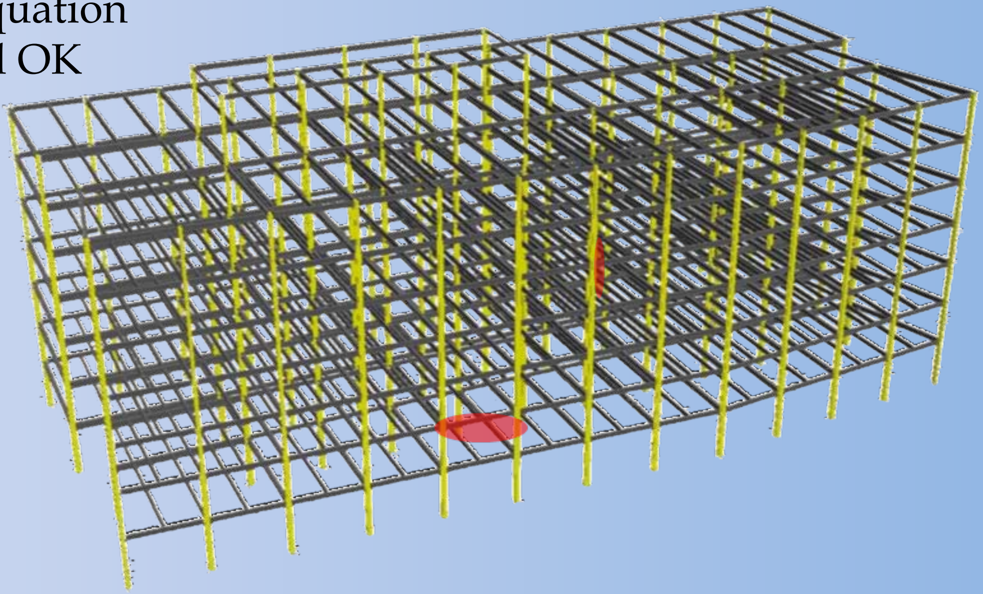
Lateral System Design Loads

- Inherent Torsion
  - $M_t = V(e)$
- Accidental
  - $M_{t,a} = V\ (e + .05L)$
- Minimal effects due to symmetry
  - Maximum shear caused by torsion less than 1 kip per frame

Torsion Constants											
Floor	Center of Mass		Center of Rigity		e_x	e_y	$e_{acc,x}$	$e_{acc,y}$	I_x (in^4)	I_y (in^4)	I_p (in^4)
	x_r (ft)	y_r (ft)	x_r (ft)	y_r (ft)							
Roof	122.26	52.75	120.70	52.75	1.56	0.00	13.50	5.28	384931	1103200	1488131
Seventh	122.26	52.75	120.70	52.75	1.56	0.00	13.50	5.28	384931	1103200	1488131
Sixth	122.26	52.75	120.70	52.75	1.56	0.00	13.50	5.28	384931	1103200	1488131
Fifth	122.26	52.75	120.70	52.75	1.56	0.00	13.50	5.28	384931	1103200	1488131
Fourth	122.26	52.75	120.70	52.75	1.56	0.00	13.50	5.28	384931	1103200	1488131
Third	122.26	52.75	120.70	52.75	1.56	0.00	13.50	5.28	384931	1103200	1488131
Second	122.26	52.75	120.70	52.75	1.56	0.00	13.50	5.28	384931	1103200	1488131

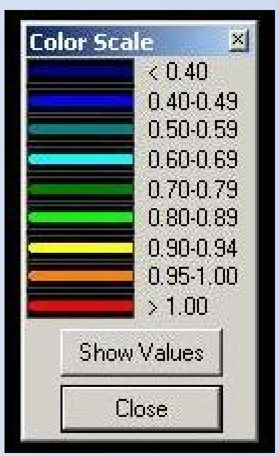
Lateral System Member Design

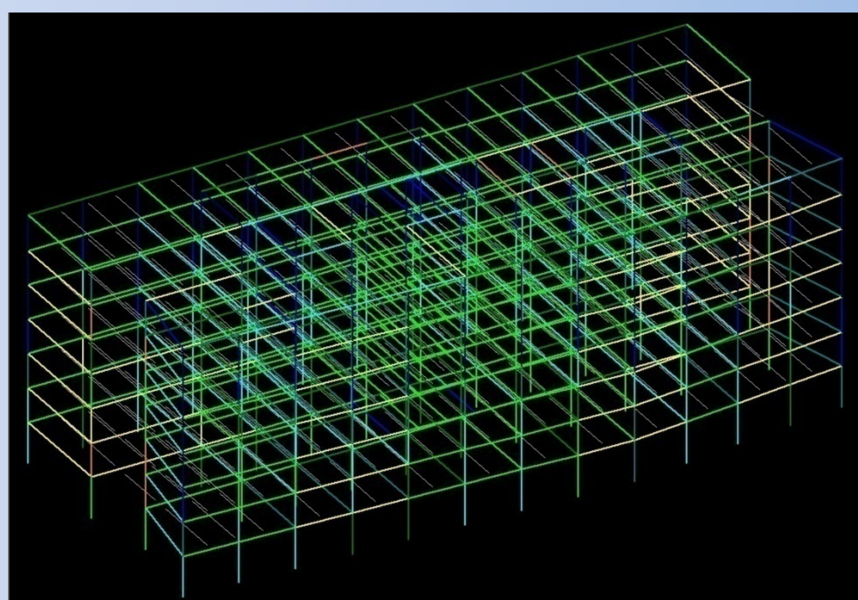
- Preliminary hand calculations
  - Design loads from ASCE 7-05 procedures
  - Portal Frame Analysis for Moments
    - Exterior, façade-supporting beam
      - deflection of L/500 controlled
      - used conjugate beam method
    - Column, interior
      - Axial from load take-downs, live load reduction used
      - Table 6-1, AISC Steel Manual
      - Interaction equation
      - Iteration until OK



Lateral System Member Design

- RAM Analysis
  - Design loads from ASCE 7-05
    - Beams
      - drift controlled design
      - repetition of members
    - Column
      - used Eq. H1-1a, interaction equation
      - drift controlled design
      - repetition of members





Serviceability

- Wind
  - h/400

- Seismic
  - $.020h_{sx}$

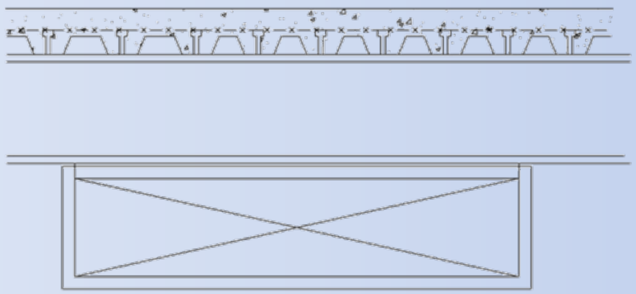
- Drifts taken from RAM, which used ASCE 7-05 for lateral loads, were then compared to the allowable drifts
  - Seismic drifts used an amplification factor
    - o $\delta_x = (C_d \times \delta_{xe})/I$

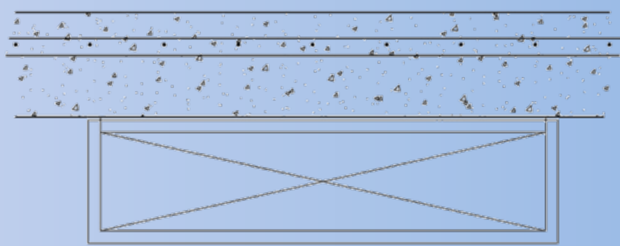
- Serviceability controls design in the east-west direction only

Controlling Wind Drift E-W										
Floor	Story Height (ft)	Total Height (ft)	Story Drift (in)	Allowable Story Drift (in) $\Delta_{WIND} = h/400$			Total Drift (in)	Allowable Total Drift (in) $\Delta_{WIND} = h/400$		
Roof	13.0	90.5	0.384	<	0.390	Acceptable	2.575	<	2.715	Acceptable
Seventh	12.5	77.5	0.372	<	0.375	Acceptable	2.191	<	2.325	Acceptable
Sixth	12.5	65.0	0.374	<	0.375	Acceptable	1.819	<	1.950	Acceptable
Fifth	12.5	52.5	0.372	<	0.375	Acceptable	1.445	<	1.575	Acceptable
Fourth	12.5	40.0	0.373	<	0.375	Acceptable	1.073	<	1.200	Acceptable
Third	12.5	27.5	0.372	<	0.375	Acceptable	0.700	<	0.825	Acceptable
Second	15.0	15.0	0.328	<	0.450	Acceptable	0.328	<	0.450	Acceptable

Floor Depth

- Due to serviceability standards, beams as large as W18x130's were incorporated into the moment frames





Steel Redesign Floor Depth	
Building Component	Depth (in)
Floor slab w/ deck	7.5
Steel Beam	19.3
Insulation	2
Airduct	16
Total	44.8
Excess	-2.8

Existing Concrete System Floor Depth	
Building Component	Depth (in)
Floor Slab	7
PT Beam	10
Insulation	2
Air Duct	16
Total	35
Excess	7

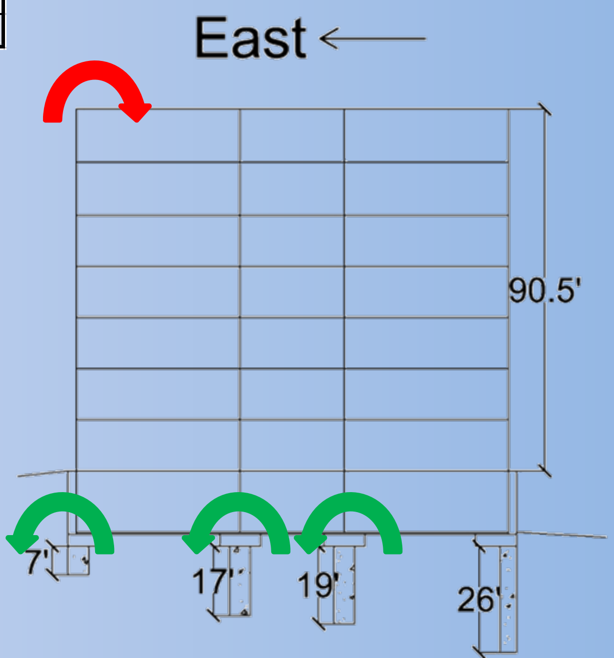
- Preserving floor-to-ceiling height of 9′ not achieved, must use 8′-8″

Foundation

- Overturning moment calculated in both directions

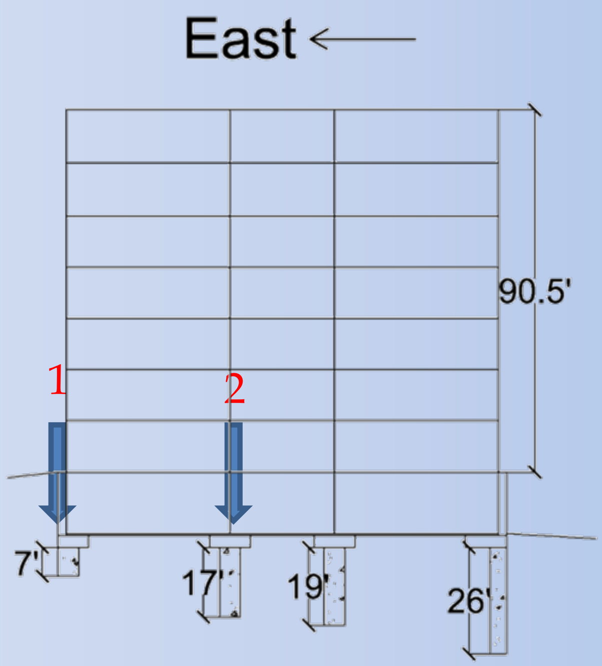
Wind Loads					
Floor	Height	North-South (kips)	East-West (kips)	OT Moment N-S (kip-ft)	OT Moment E-W (kip-ft)
Roof	90.5	25.27	136.24	2286.94	12329.72
Seventh	77.5	23.75	58.31	4127.57	16848.75
Sixth	65	22.55	55.50	5590.07	20456.25
Fifth	52.5	21.69	53.70	6728.80	23275.50
Fourth	40	20.70	51.60	7556.80	25339.50
Third	27.5	19.52	49.05	8093.60	26688.37
Second	15	19.56	50.13	8387.00	27440.32
Ground	0	153.04	454.53	8387.00	27440.32

- North-south direction good by inspection
- East-west direction checked for overturning
  - .9D + 1.6W
- $M_{resisting} > M_{overturning}$



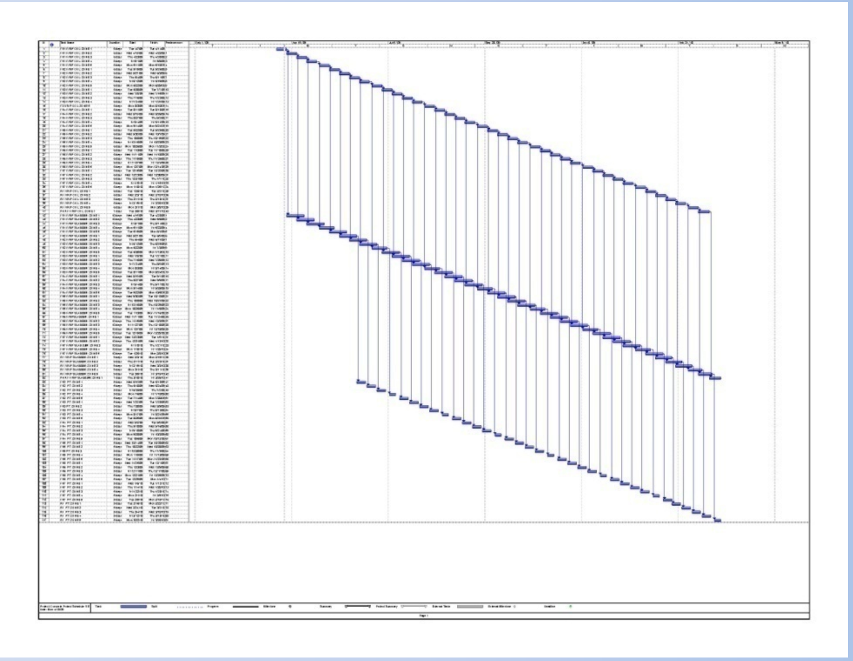
Foundation

- Intermediate caissons removed
- 84 C.Y. of concrete saved
- Loads on caissons checked using cantilever method and compared to existing loads on plans
  - Live load reduction
  - $1.2D + 1.6W + L + .5L_r$



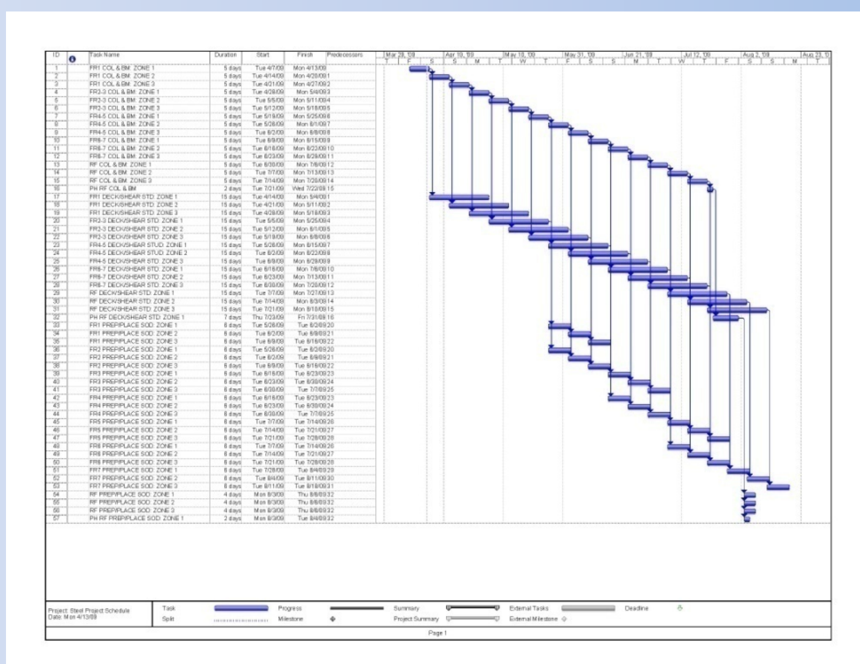
Schedule Analysis

- Existing Concrete System
  - R.S. Means
  - Multiple crews used for forming and post-tensioning
  - Construction zones: 5
  - Column construction per floor: 30 days
  - Slab and beam construction per floor: 10 days
  - Post-tensioning per floor: 25 days
  - Total construction time: 258 days



Schedule Analysis

- Steel Redesign
  - R.S. Means
  - Single crews used
  - Construction zones: 3
  - Framing construction per floor: 15 days
  - Deck and detailing: 45 days
  - SOD preparation and placement: 18 days
  - Total construction time: 96 days



Cost Analysis

- Existing System
  - R.S. Means

Concrete							
Building Component	Cost				Cost Index		
	Material	Labor	Equipment	Total	Material	Installation	Total
Concrete	780571			780571	1.002		782132.1
Formwork	881071	4820804		5701875	0.941	0.761	4497720
Reinforcement	527250	225490		752740	0.902	0.822	660932.3
Concrete Placement		158875	70544	229418		0.808	198914.6
Slab Finish		31882		31882		0.808	25760.33
Post-Tensioning	55552	175696	3584	234832			234832
Crane		60960	182880	243840			243840
Total	2244444	5473706	257008	7975158	TTL w/ Index		6644131

- Steel Redesign
  - R.S. Means

Steel							
Building Component	Cost				Cost Index		
	Material	Labor	Equipment	Total	Material	Labor	Total
Steel Framing	3609375	10412	166320	3786107	0.972	0.967	3684701
Fireproofing	43719	47520	7440	98679			98679
Metal Deck	677058	8180	81876	767114	0.972	0.967	747886.4
Welded Wire Fabric	54188	52233		106421	0.902	0.822	91813.1
Concrete	382456			382456	0.1002		38322.09
Concrete Placement		51310	18707	70017		0.808	60165.48
Slab Finish		31811		31811		0.808	25703.29
Crane		22800	68400	91200			91200
Total	4766796	224266	342743	5333805	TTL w/ Cost Index		4838470

- Overall estimated savings of approximately $1.8 million
- Moment connection costs not included

Breadth Comparison

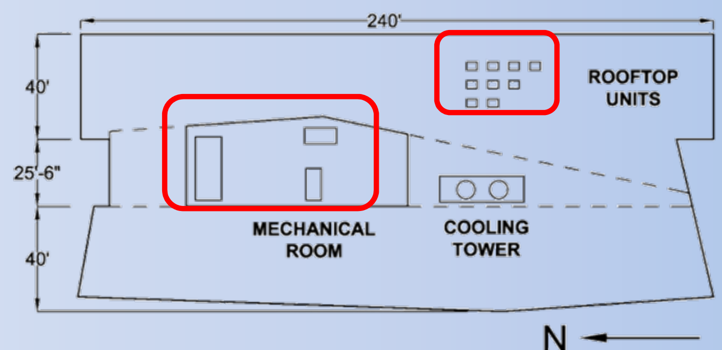
- Cost and Schedule comparison

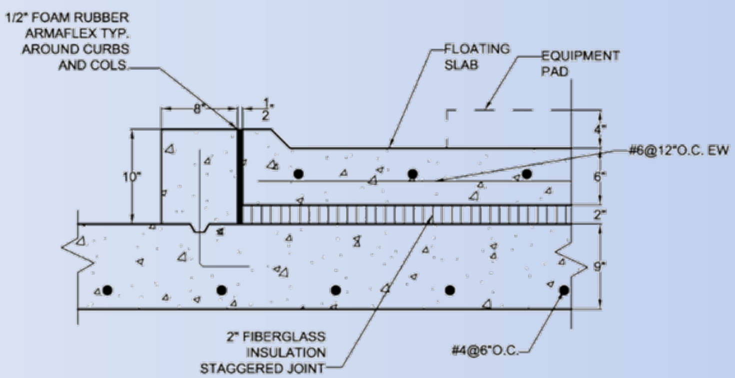
Building System Comparison			
Post-Tensioned Beam One Way Slab System w/ Concrete Moment Frames		Composite Metal Deck System w/ Steel Moment Frames	
Costs		Costs	
Material	$2,142,351	Material	$4,297,332
Labor	$4,244,772	Labor	$198,396
Equipment	$257,008	Equpment	$342,743
TOTAL	$6,644,131	TOTAL	$4,838,471*
Saves an estimated $1.8 million			
Time		Time	
Days	258	Days	96
Saves an estimated 162 days			

* Moment connection costs not included

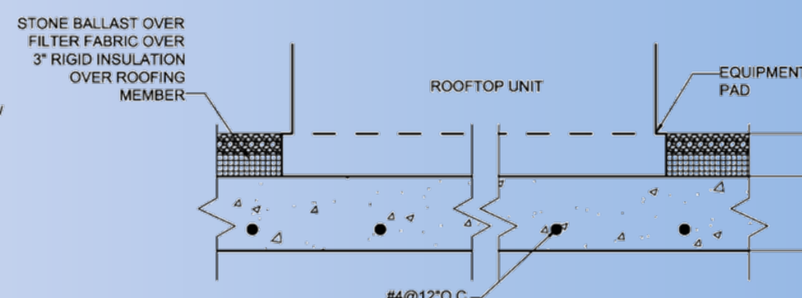
Acoustic Study

- Checked for sound infiltration in the 7th floor office space due to the reduction in depth of the floor slab



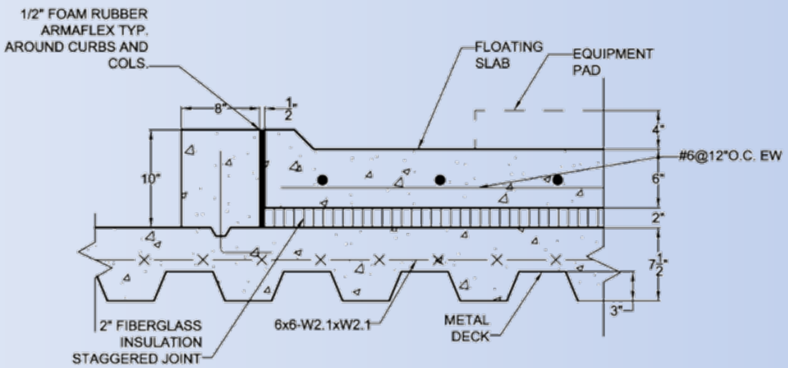


Existing PH Floor

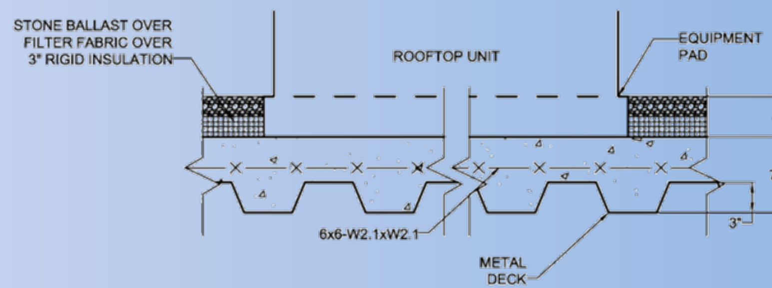


Existing Roof

Acoustics Study



Redesigned PH Floor



Redesigned Roof

Acoustic Analysis for Office Space below Mechanical Room						
Floor Design Criteria	Sound Pressure Level (dB)					
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Likely Noise in Mechanical Room	92	90	90	89	85	76
Minus background level in office (RC-30)	45	40	35	30	25	20
=Required Noise Reduction (NR)	47	50	55	59	60	56
Minus $10\log(a_2/S)$	-20	-20	-17	-17	-17	-17
Required Transmission Loss (TL)	67	70	72	76	77	73
Floor System Check	Sound Pressure Level (dB)					
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
6" Reinforced Concrete Slab	38	43	52	59	67	72
2" Fiberglass Insulation	6	9	11	16	20	25
4.5" Reinforced Concrete Slab	48	42	45	56	57	66
19 Gage Metal Deck	17	22	26	30	35	41
Total Transmission Loss (TL)	109	116	134	161	179	204

Acoustics Analysis for Office Space Below Rooftop Units						
Floor Design Criteria	Sound Pressure Level (dB)					
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Likely Noise from Rooftop Units	93	89	85	80	75	69
Minus Background Noise Level in Office (RC-30)	45	40	35	30	25	20
= Required Noise Reduction (NR)	48	49	50	50	50	49
Minus $10\log(a_2/S)$	-6	-2	-2	-2	-1	-1
Required Transmission Loss (TL)	54	51	52	52	51	50
Floor System Check	Sound Pressure Level (dB)					
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Rigid Insulation	6	9	11	16	20	25
4.5" Reinforced Concrete Slab	48	42	45	56	57	66
19 Gage Metal Deck	17	22	26	30	35	41
Total Transmission Loss (TL)	71	73	82	102	112	132

- Result: No sound penetration found in either case

Were goals met?

- Respect the current column layout to maintain large spans and open floor plans

  YES

- Limit total floor depth to prevent additional façade costs and preserve floor-to-ceiling heights of 9′

  YES/NO

- Establish a design that quickens construction and decreases total project costs

  YES

- Preserve a suitable working environment within the 7th floor office space

  YES

- To become more familiar with steel design

  YES

Recommendation

- Gravity/Lateral system redesign
  - Applicable to DTC One
  - Minimal change to architecture
- Schedule Analysis
  - reduced schedule by an estimated 162 days
  - benefits owner with sooner building opening
- Cost Analysis
  - Material costs went up, but overall costs went down
  - Estimated an approximate savings of $1.8 million
- Acoustic Analysis
  - No new sound penetration caused by the thinner slab

- Redesign of DTC One in steel is feasible

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Questions?