Biobehavioral Health Building

The Pennsylvania State University

Daniel Bodde
Structural Option
Advisor – Heather Sustersic

Presentation Outline

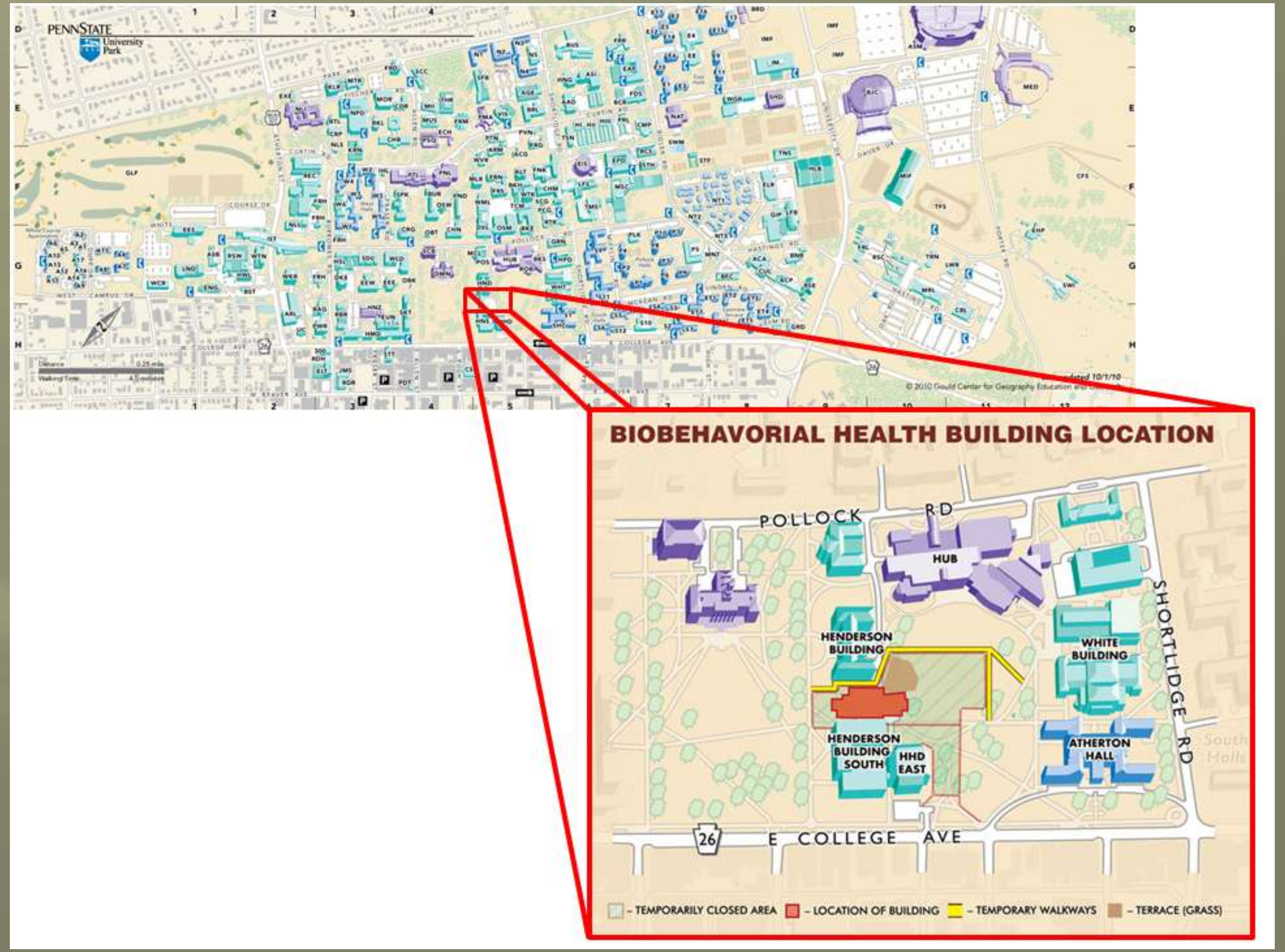
<u>Building Introduction</u>
Existing Structure
Problem Statement
Structural Depth
Façade Study Breadth
Schedule Impact Breadth
Conclusion
Questions & Comments

Building Introduction

Location:
- The Pennsylvania State University
  University Park, PA

Project Size:
- 5 Stories above grade
- Full basement (100% below ground)
- Approximately 93,500 sqft

Cost:
- $40 Million



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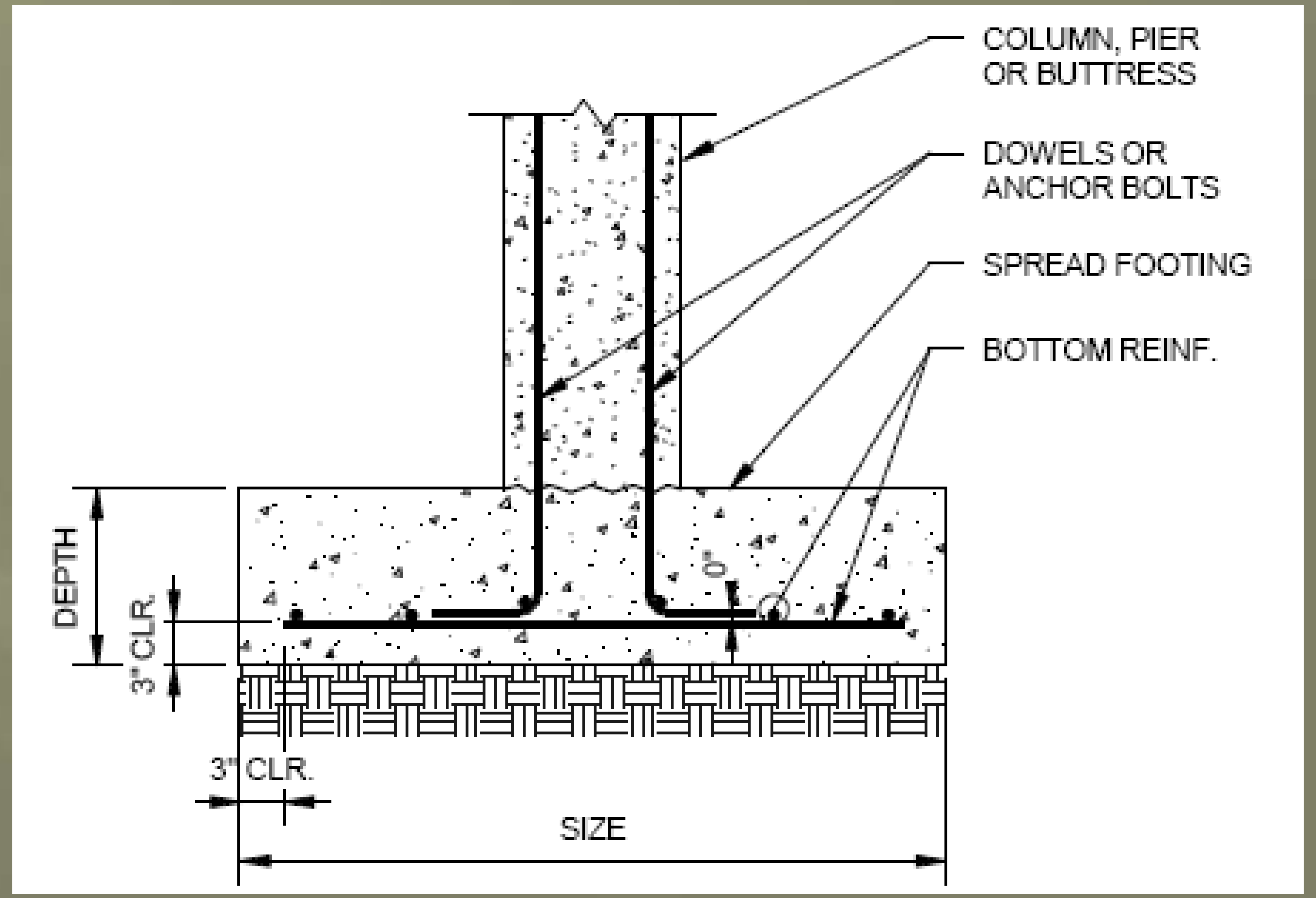
Existing Structure

Foundation System:

- Spread footing
- Sits on bedrock (15 ksi)

Typical Section



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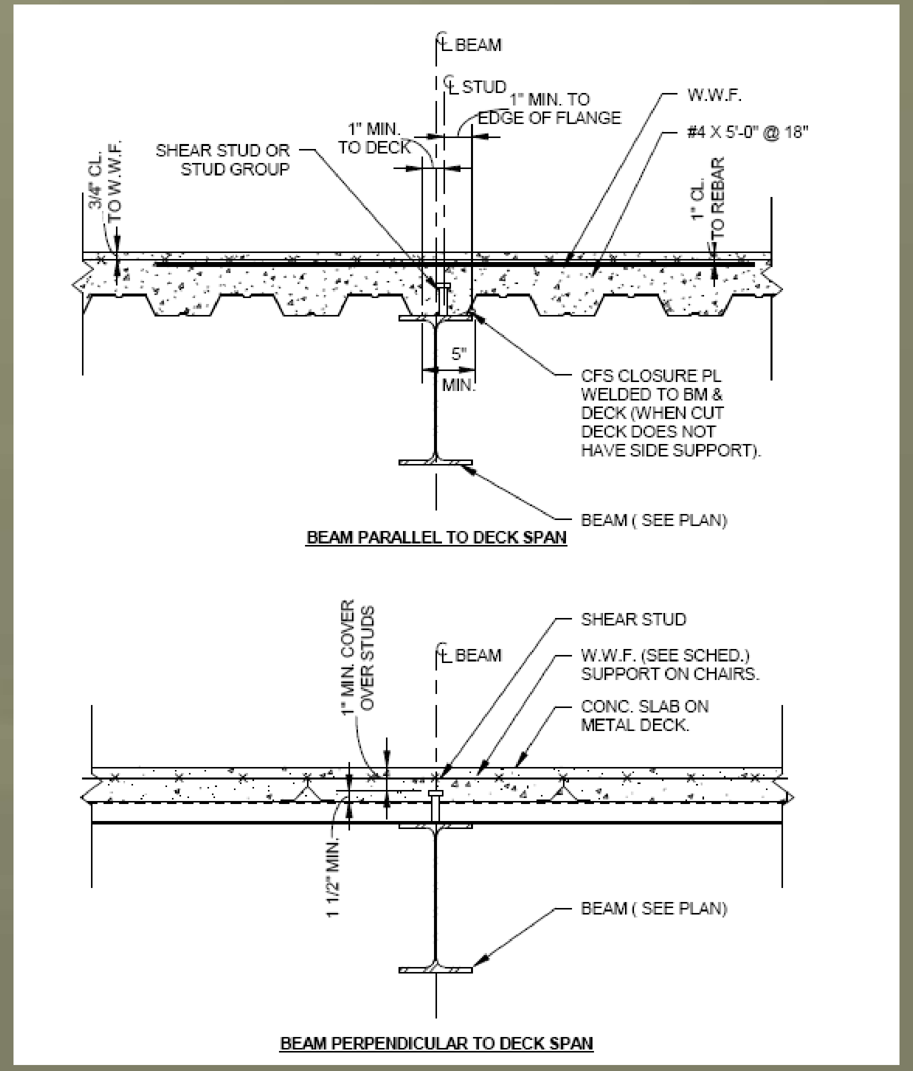
<u>Superstructure:</u>

- Concrete and composite metal deck

Typical Section



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Superstructure:
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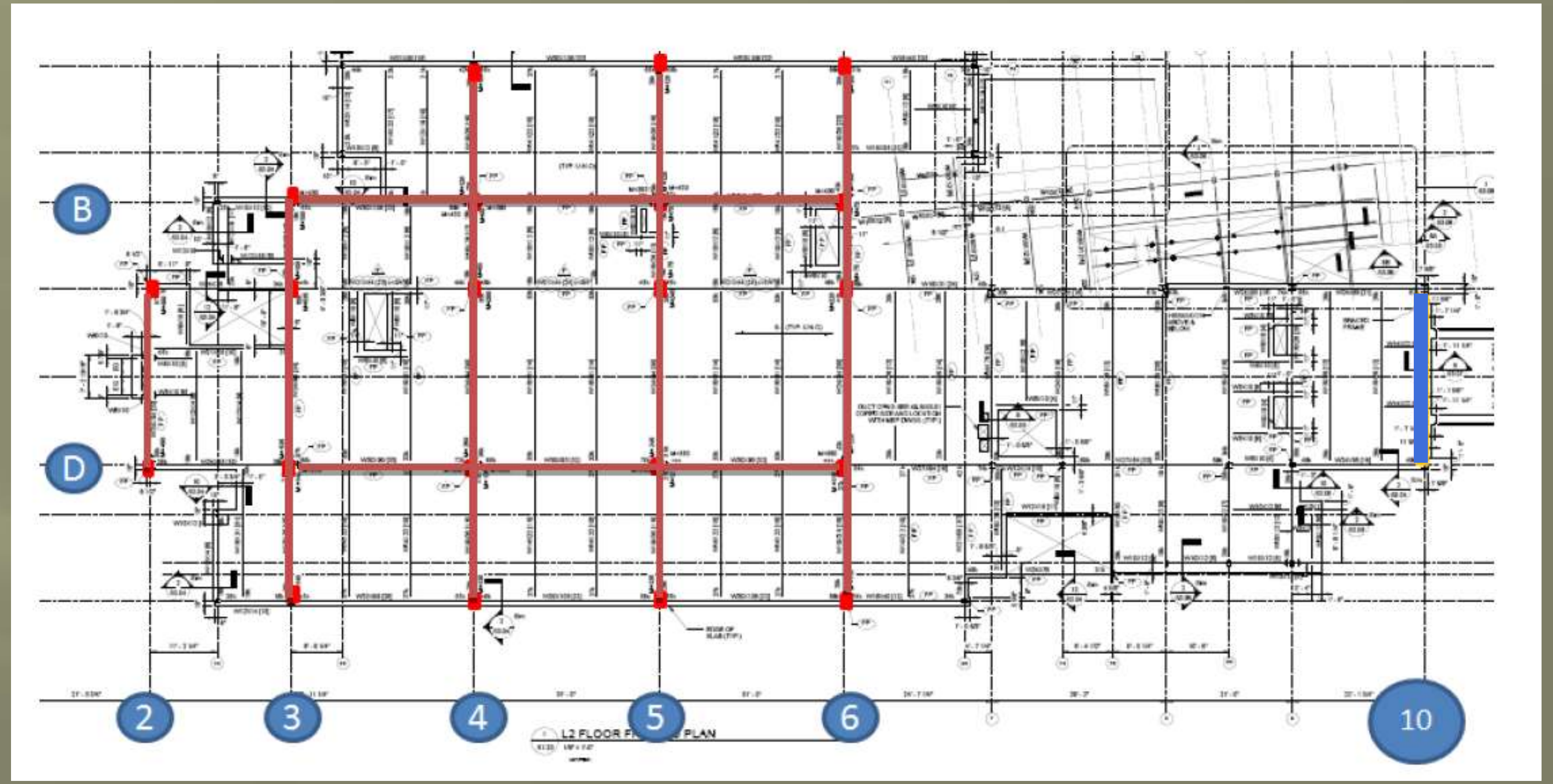
Lateral System:
- Steel Moment Frames
- Eccentric Braced Frame (Column Line 10)

Lateral Layout



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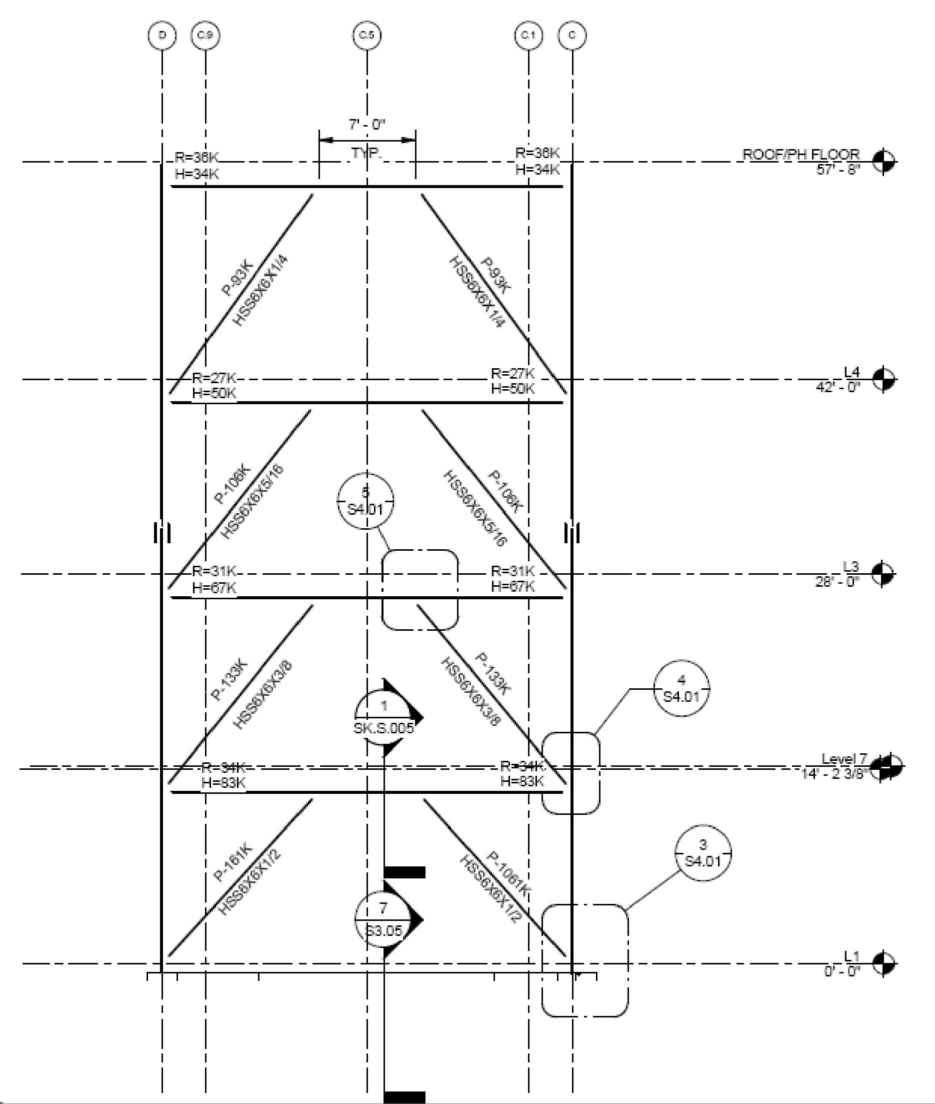
Eccentric Braced Frame



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Problem Statement

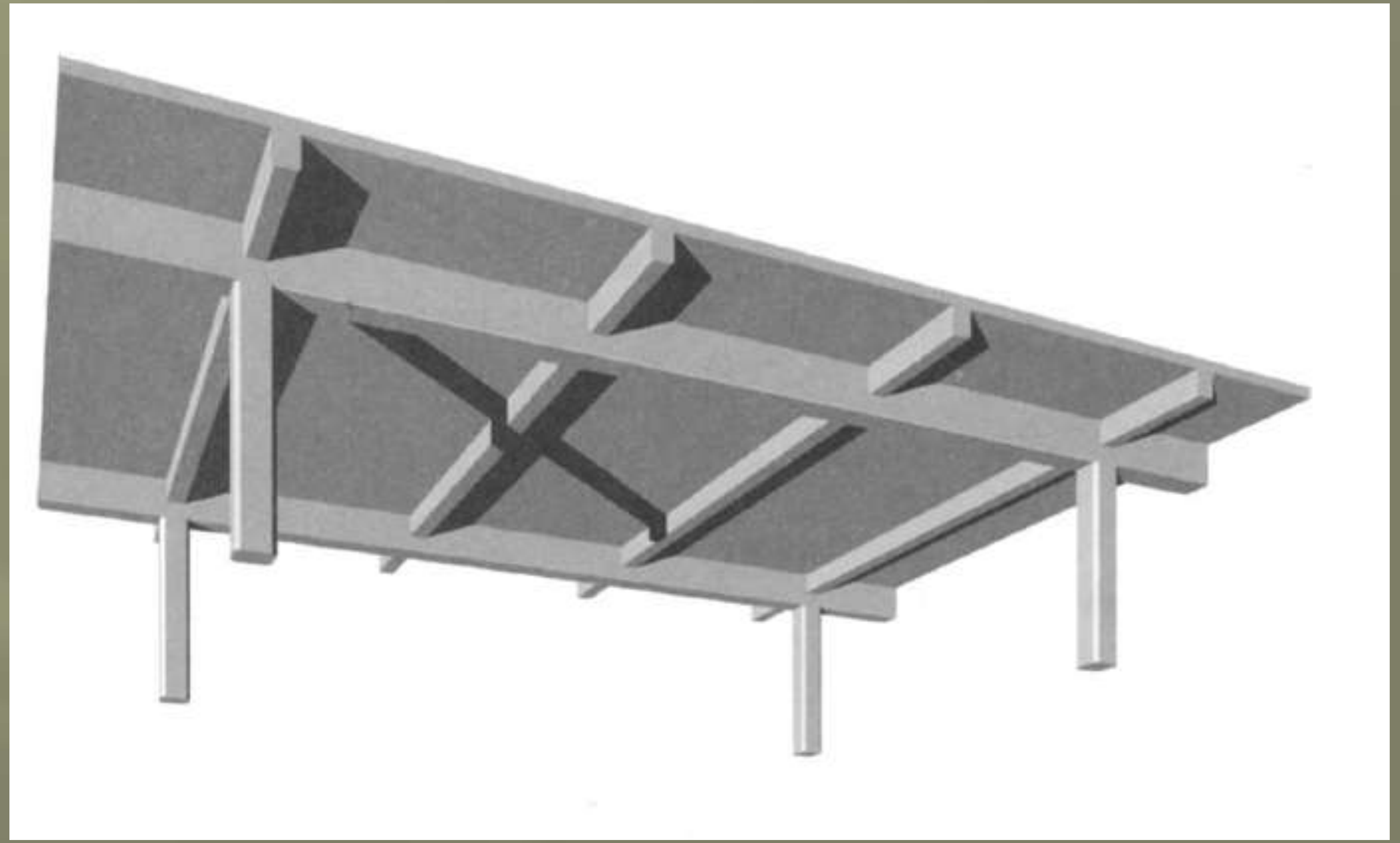
Statement:

- Steel has become an unviable option as main structural material

Solution:

Structural Depth - Redesign the structure using reinforced concrete with minimal impact on existing interior architecture and spaces

- One-way slab with interior beam
- Concrete moment frame



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Façade Study Breadth – Change façade to precast

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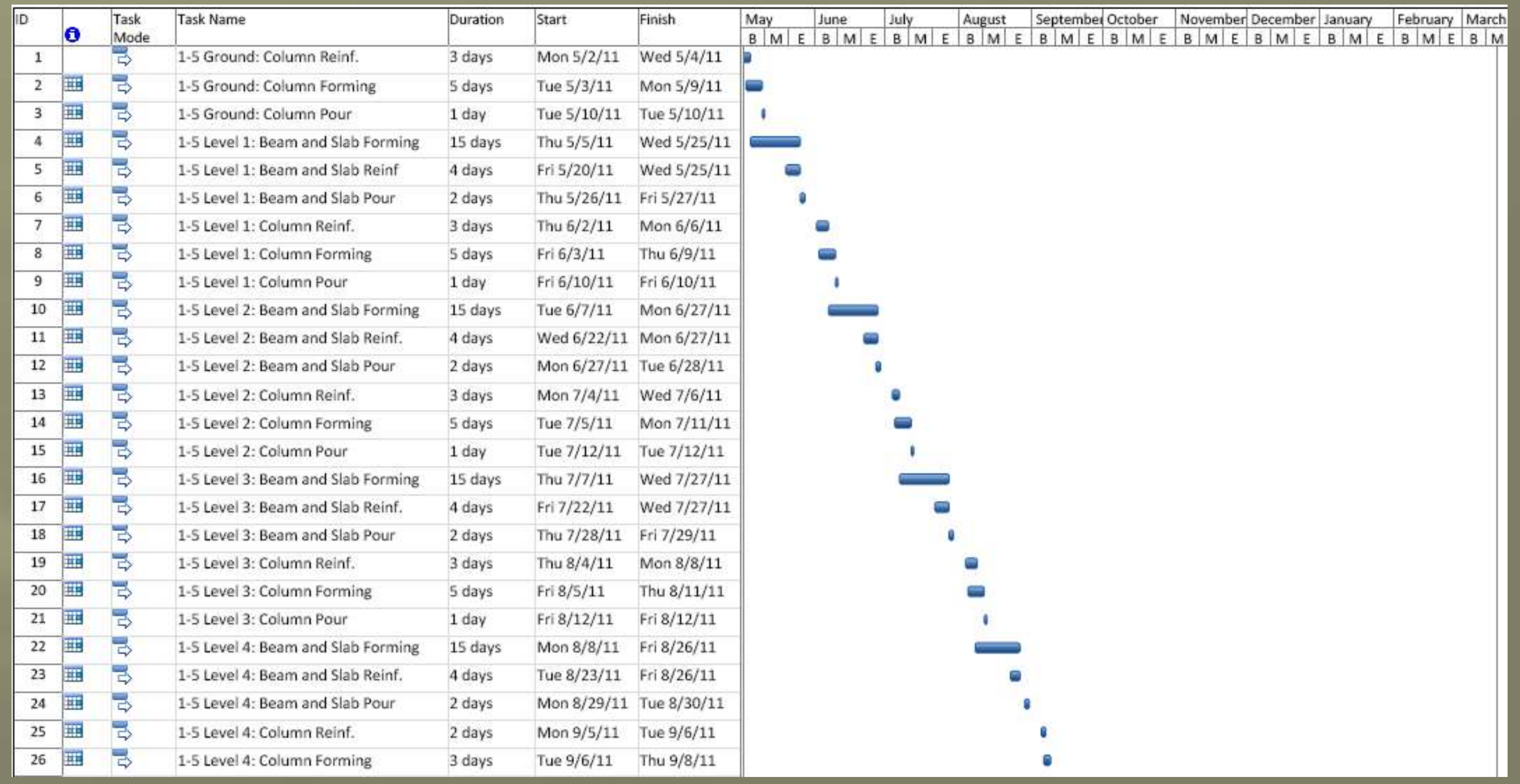
<u>Façade Study Breadth</u> – Change façade to precast

<u>Schedule Impact Breadth</u>– Determine what impact the concrete redesign and precast façade have on the construction schedule



ID		Task Mode	Task Name	Duration	Start	Finish
1			1-5 Ground: Column Reinf.	3 days	Mon 5/2/11	Wed 5/4/11
2			1-5 Ground: Column Forming	5 days	Tue 5/3/11	Mon 5/9/11
3			1-5 Ground: Column Pour	1 day	Tue 5/10/11	Tue 5/10/11
4			1-5 Level 1: Beam and Slab Forming	15 days	Thu 5/5/11	Wed 5/25/11
5			1-5 Level 1: Beam and Slab Reinf	4 days	Fri 5/20/11	Wed 5/25/11
6			1-5 Level 1: Beam and Slab Pour	2 days	Thu 5/26/11	Fri 5/27/11
7			1-5 Level 1: Column Reinf.	3 days	Thu 6/2/11	Mon 6/6/11
8			1-5 Level 1: Column Forming	5 days	Fri 6/3/11	Thu 6/9/11
9			1-5 Level 1: Column Pour	1 day	Fri 6/10/11	Fri 6/10/11
10			1-5 Level 2: Beam and Slab Forming	15 days	Tue 6/7/11	Mon 6/27/11
11			1-5 Level 2: Beam and Slab Reinf.	4 days	Wed 6/22/11	Mon 6/27/11
12			1-5 Level 2: Beam and Slab Pour	2 days	Mon 6/27/11	Tue 6/28/11
13			1-5 Level 2: Column Reinf.	3 days	Mon 7/4/11	Wed 7/6/11
14			1-5 Level 2: Column Forming	5 days	Tue 7/5/11	Mon 7/11/11
15			1-5 Level 2: Column Pour	1 day	Tue 7/12/11	Tue 7/12/11
16			1-5 Level 3: Beam and Slab Forming	15 days	Thu 7/7/11	Wed 7/27/11
17			1-5 Level 3: Beam and Slab Reinf.	4 days	Fri 7/22/11	Wed 7/27/11
18			1-5 Level 3: Beam and Slab Pour	2 days	Thu 7/28/11	Fri 7/29/11
19			1-5 Level 3: Column Reinf.	3 days	Thu 8/4/11	Mon 8/8/11
20			1-5 Level 3: Column Forming	5 days	Fri 8/5/11	Thu 8/11/11
21			1-5 Level 3: Column Pour	1 day	Fri 8/12/11	Fri 8/12/11
22			1-5 Level 4: Beam and Slab Forming	15 days	Mon 8/8/11	Fri 8/26/11
23			1-5 Level 4: Beam and Slab Reinf.	4 days	Tue 8/23/11	Fri 8/26/11
24			1-5 Level 4: Beam and Slab Pour	2 days	Mon 8/29/11	Tue 8/30/11
25			1-5 Level 4: Column Reinf.	2 days	Mon 9/5/11	Tue 9/6/11
26			1-5 Level 4: Column Forming	3 days	Tue 9/6/11	Thu 9/8/11

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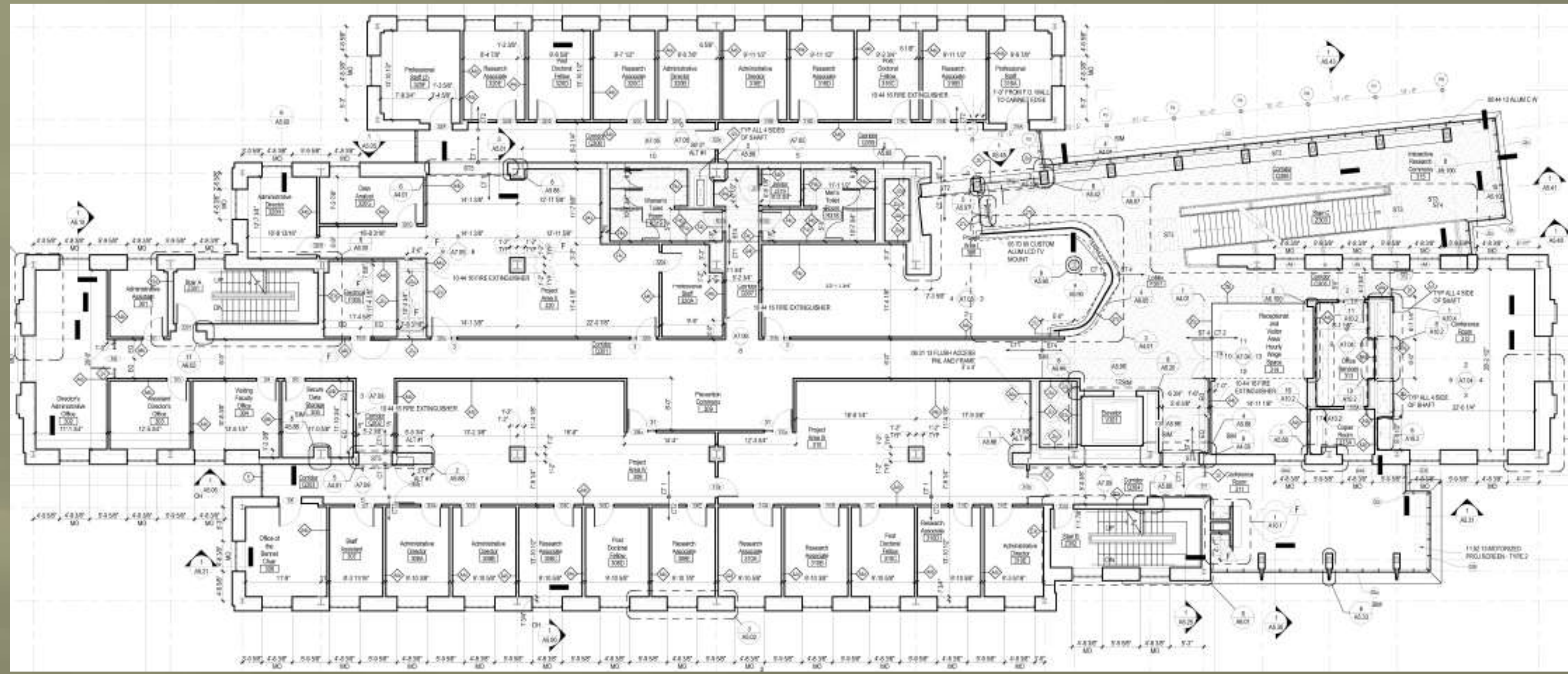
Structural Depth - Loads

<u>**Gravity Loads:**</u>

Dead
- Structure Self weight
- Superimposed (5 psf)
- Slate Floor (20 psf)

Live
- Lobbies/Assembly (100 psf)



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Live

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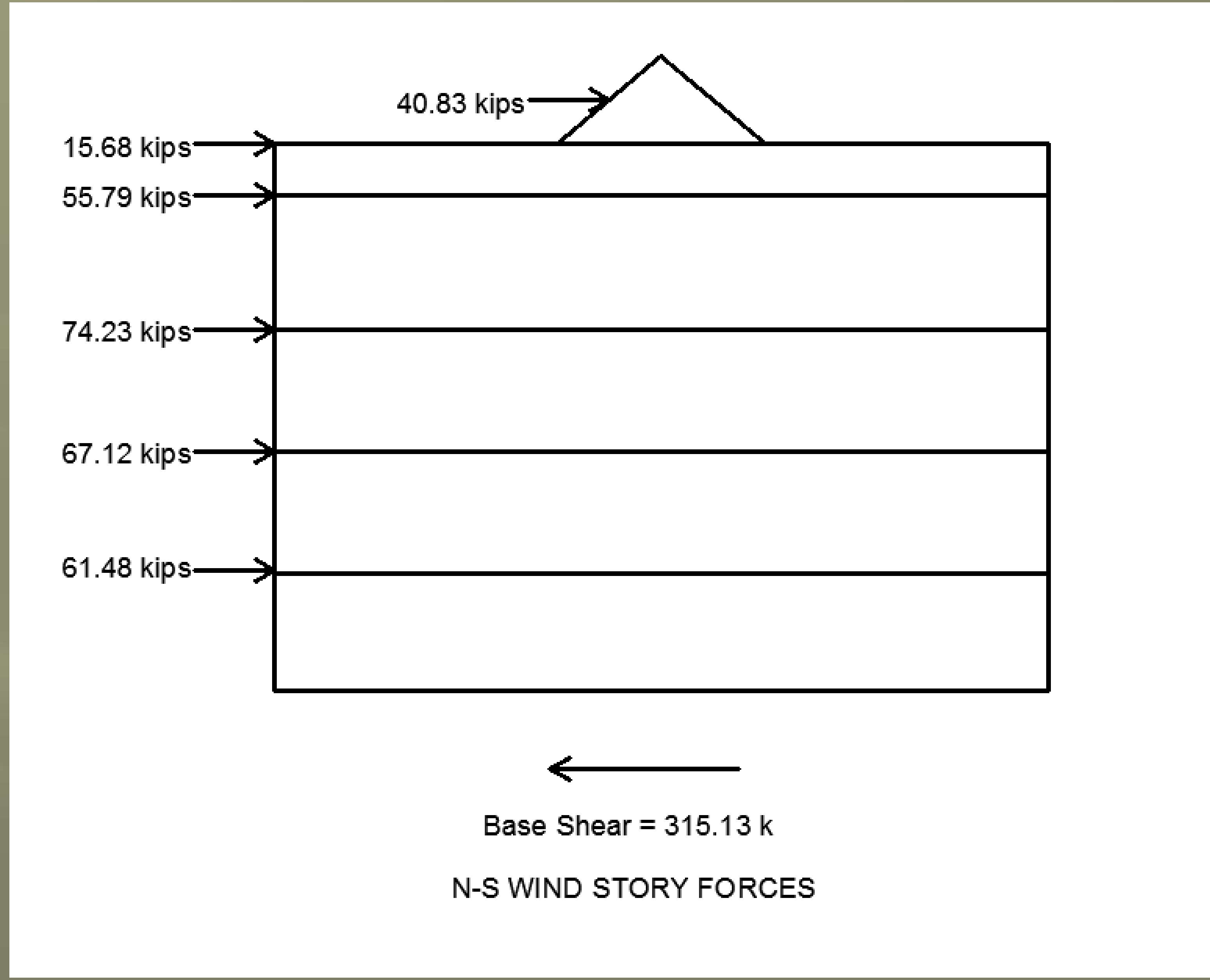
Lateral Loads:

- Wind (Controls)
- Seismic



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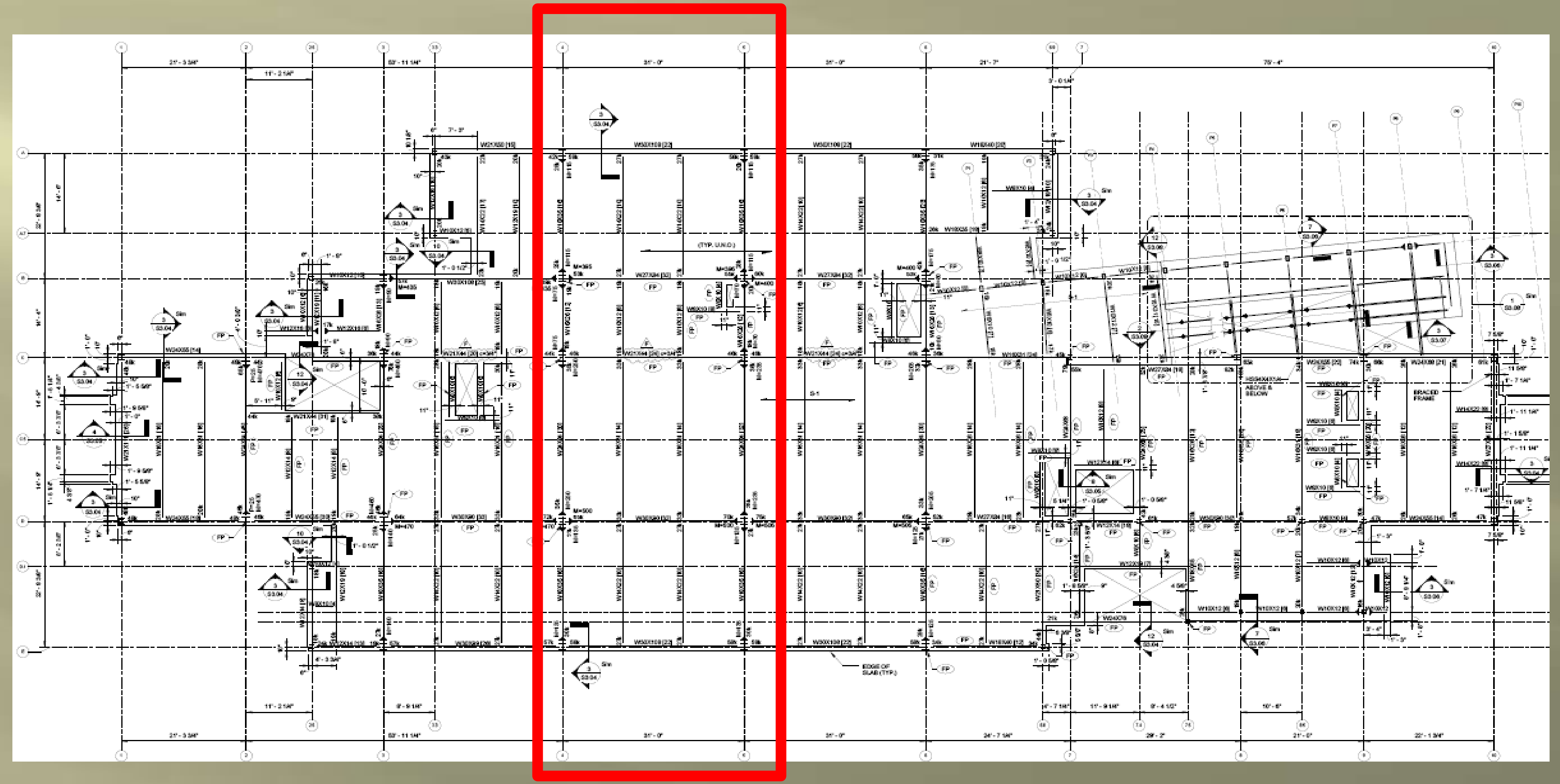

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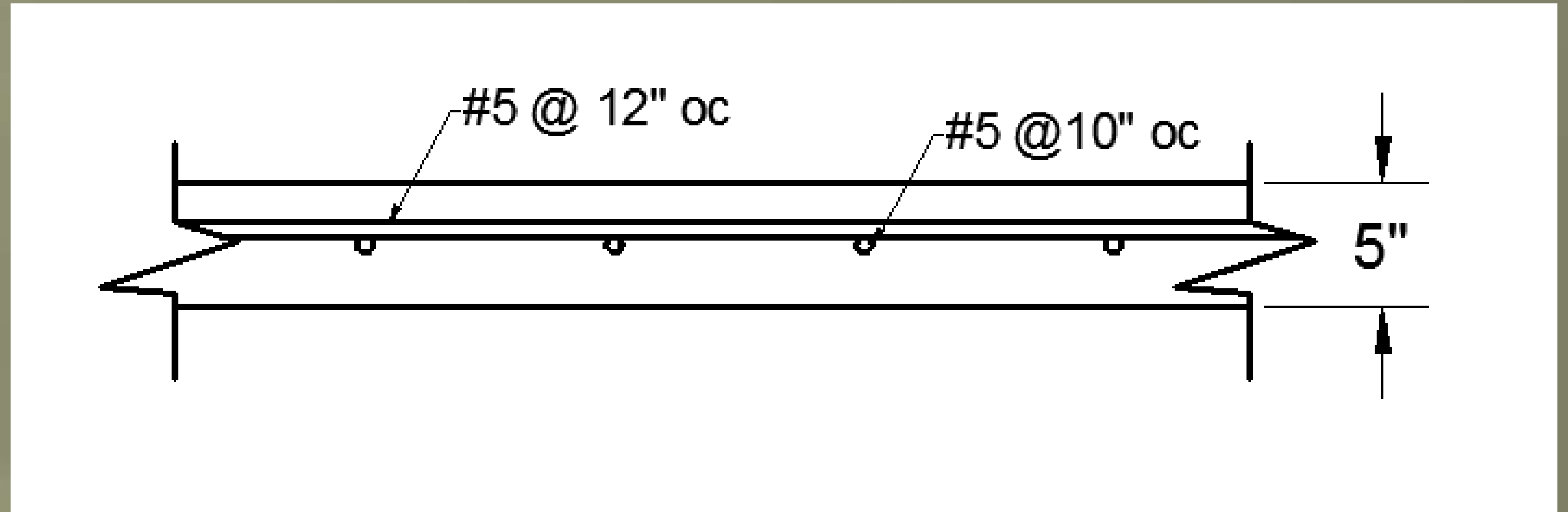
One-way Concrete Slab:
- 5" Slab (Table 9.5a)
- #5 @ 12"oc (flexure)
- #5 @ 10" (crack control)



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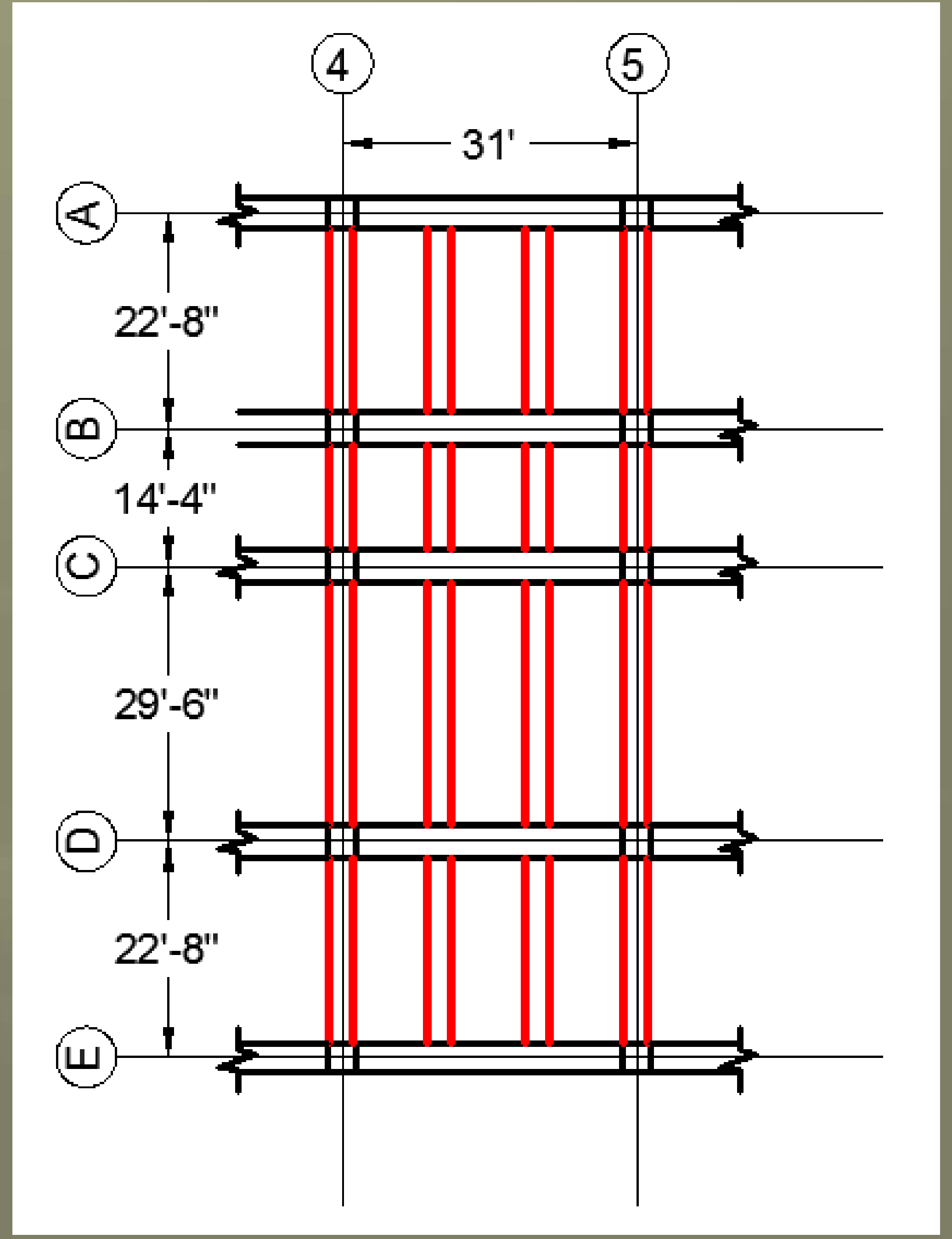
- #5 @ 12”oc (flexure)
- #5 @ 10” (crack control)

Beams :
- Support slab
- Run N-S
- Supported by girders, edge beams, & Columns
- Flexure & shear controlled design
- #5 in corners for cage construction
- Consistent concrete cross section



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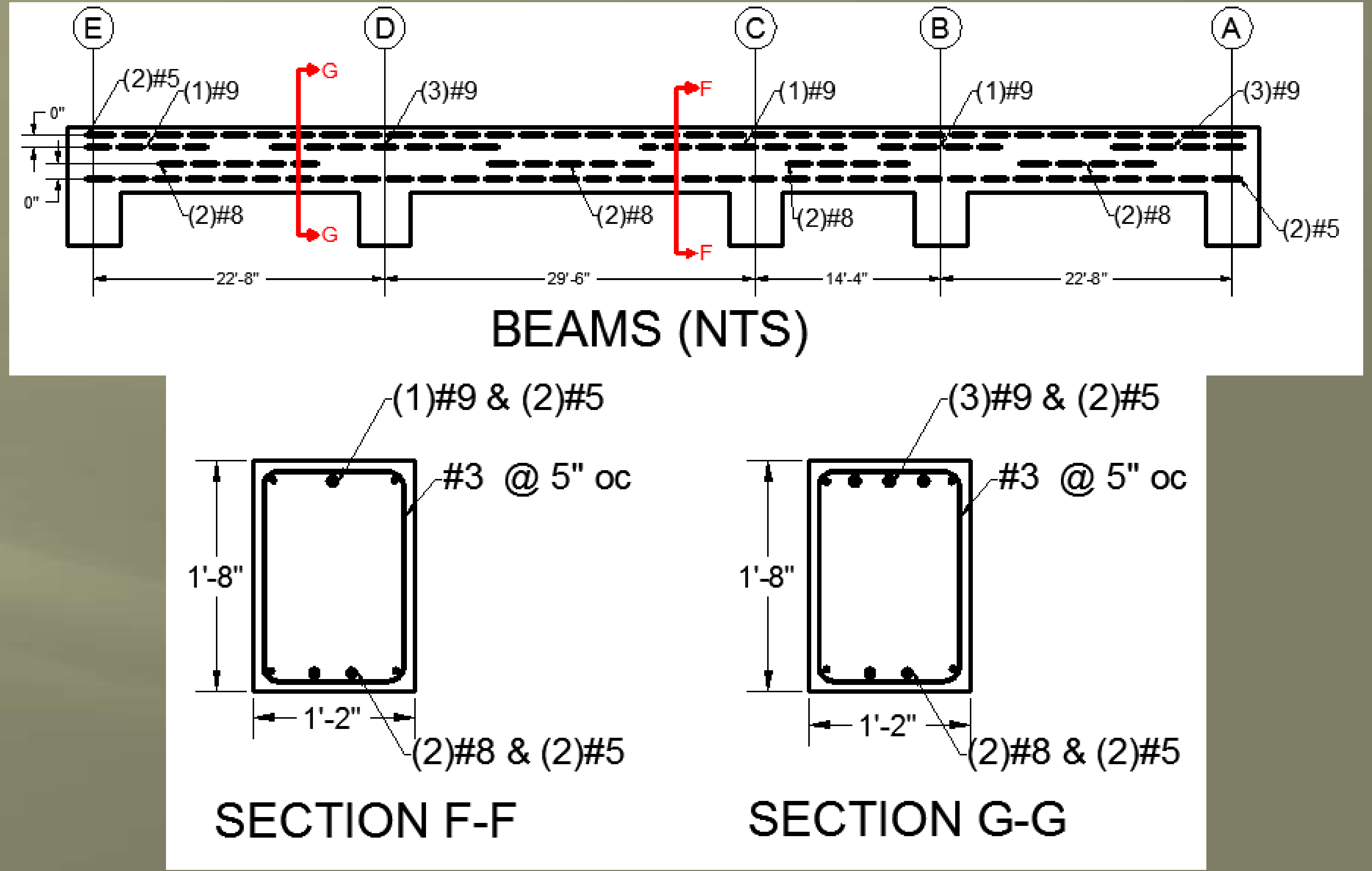

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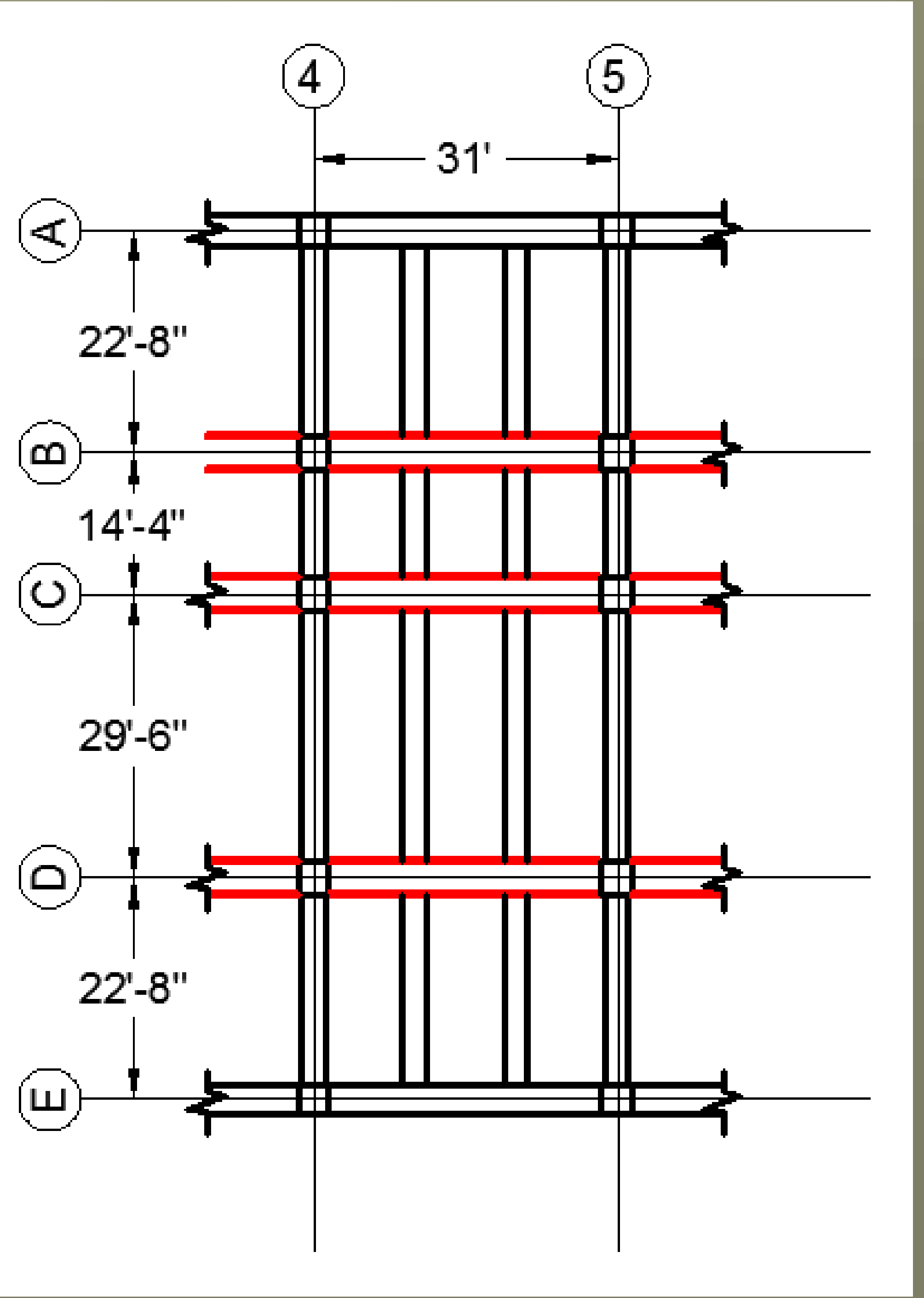
Structural Depth - Gravity

Girders:

- Run E-W
- Supported by columns at both ends
- Concentrated loads produce large moments
- 2” shallower than existing steel structure
- Assumed 50% sustained live load for deflections



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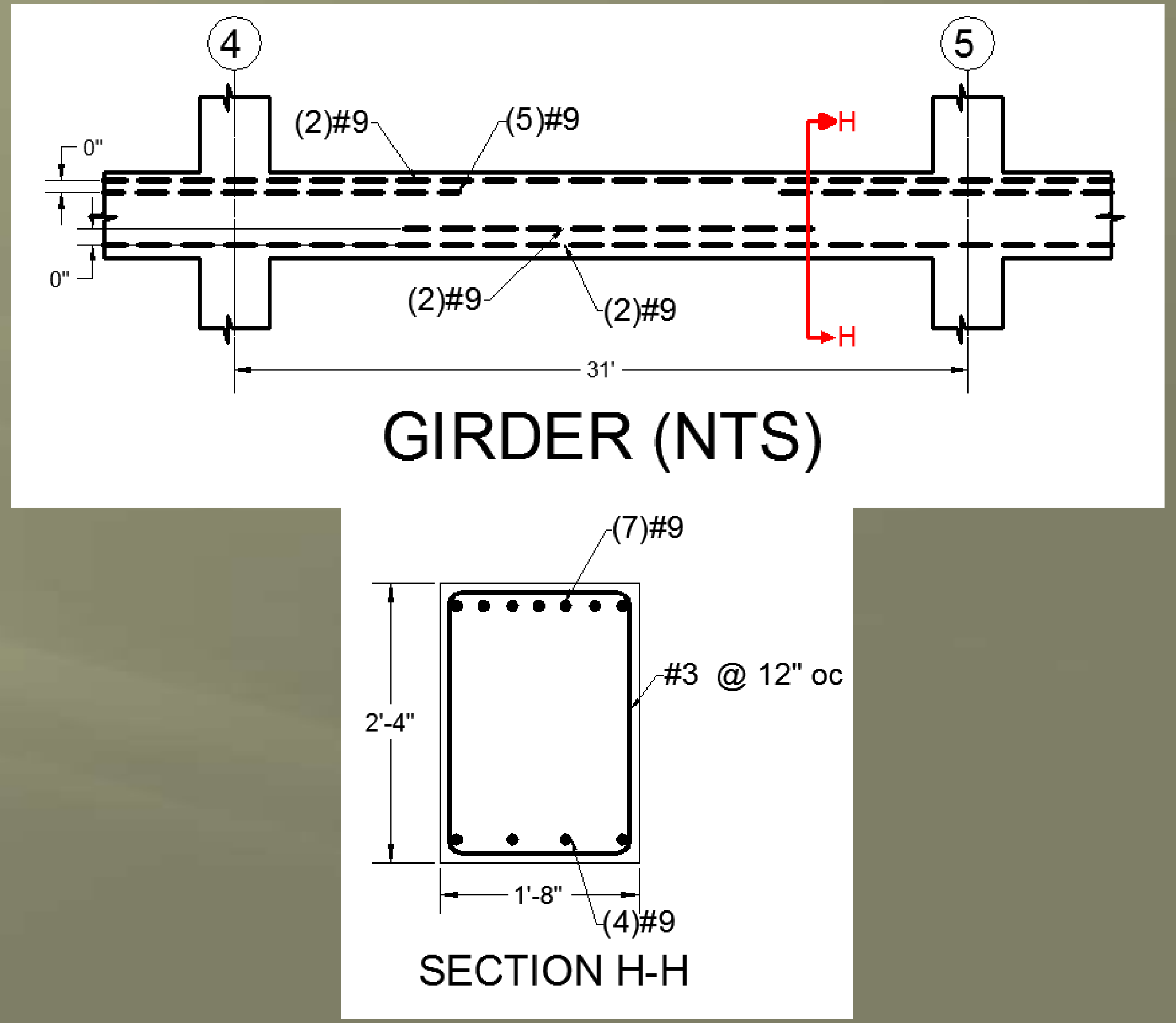

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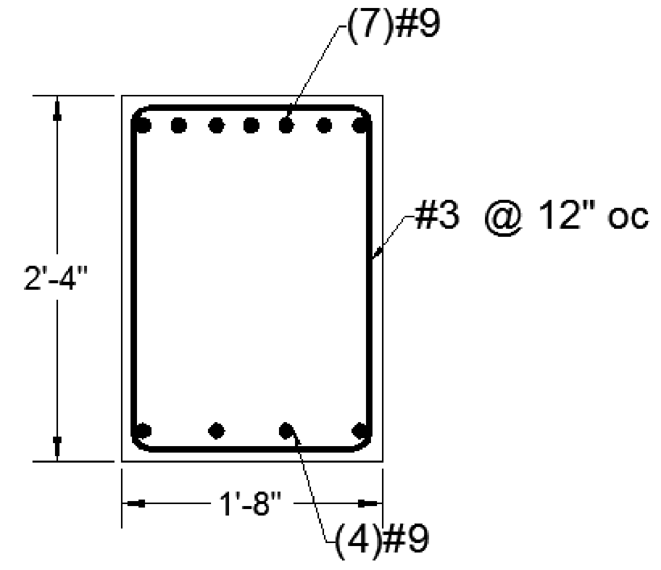
Girder Deflections				
	Actual	Allowable		Pass?
Δi(d+l)	0.11 in	L/240	1.55 in	Yes
Δi(live)	0.06 in	L/360	1.03 in	Yes
Δ long	0.2 in	L/240	1.55 in	Yes



SECTION H-H

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Structural Depth - Gravity

Girders:
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- Concentrated loads produce large moments
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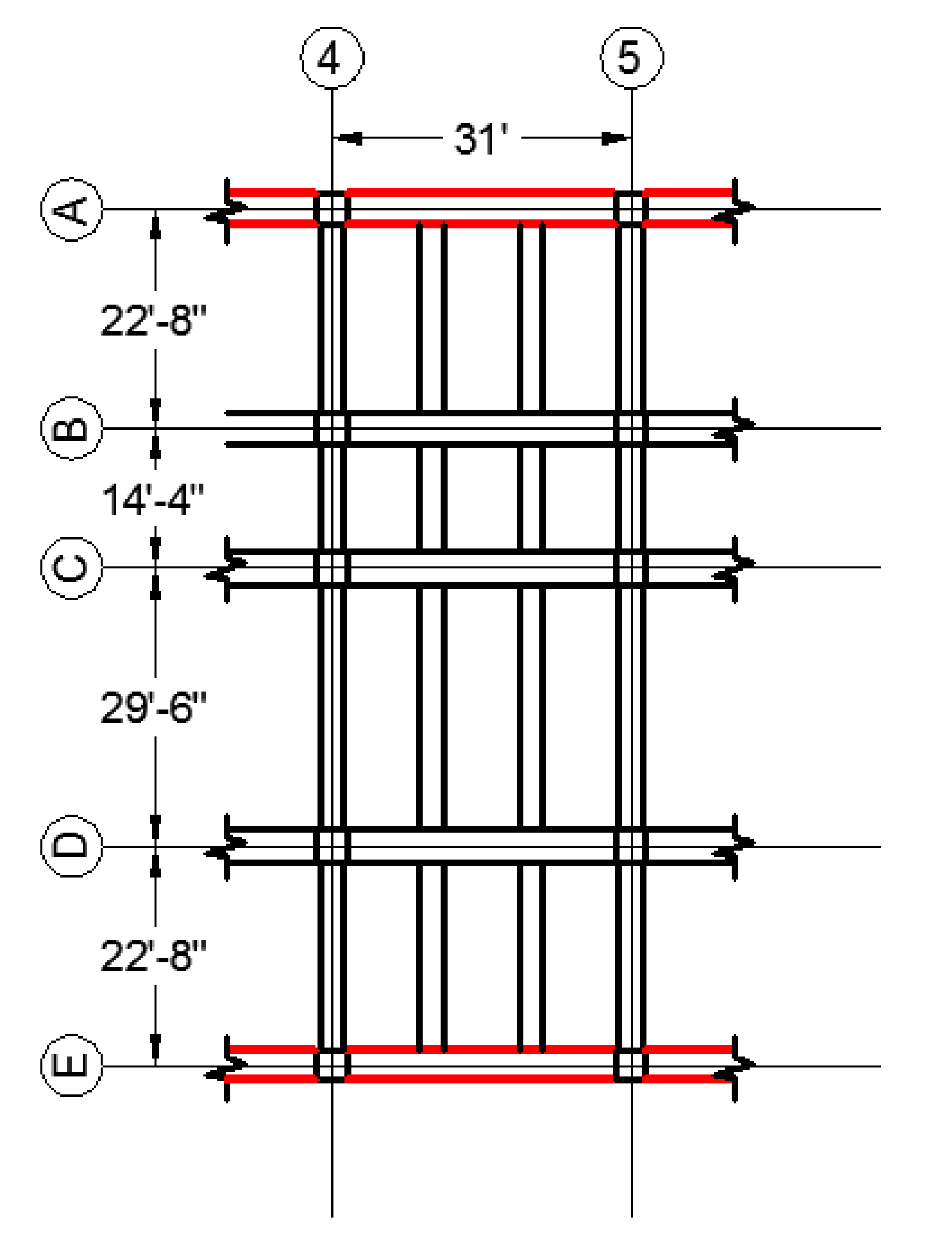
Edge Beam:
- Run perimeter of BBH Building
- Concentrated load produces torsion
    - Added longitudinal & transverse reinforcement
- Supports masonry



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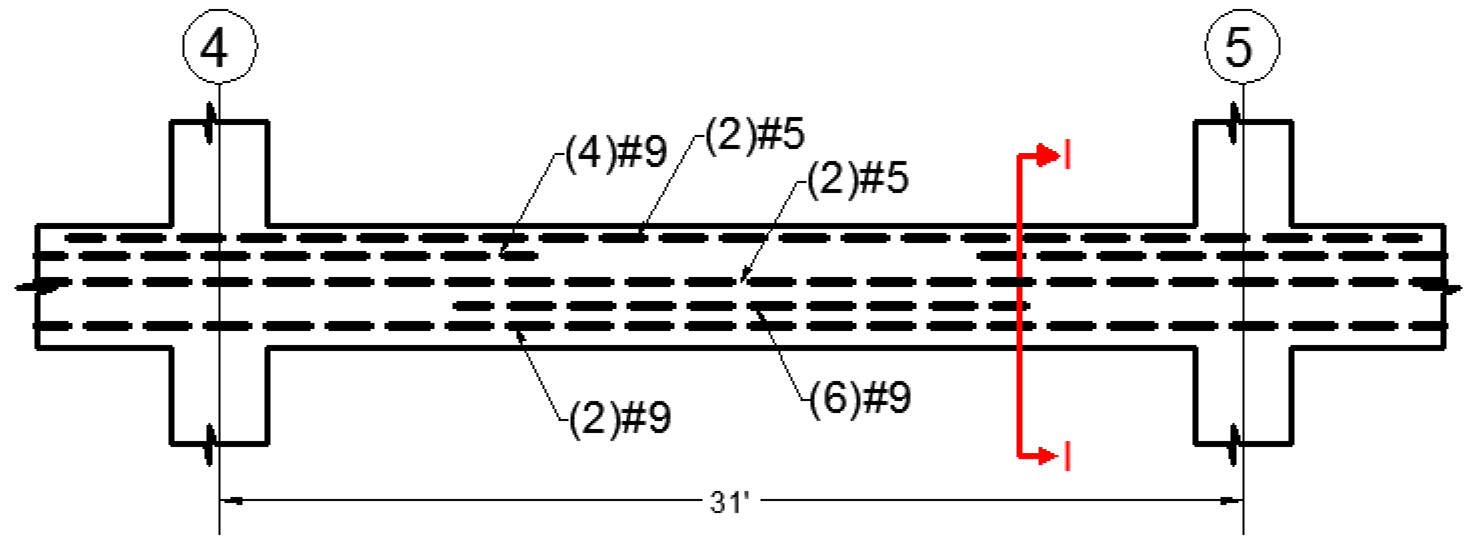
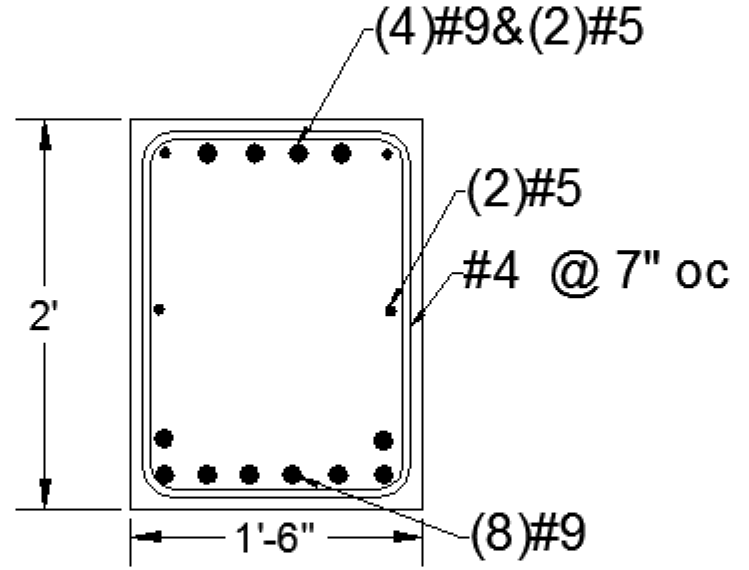


EDGE BEAM (NTS)



SECTION I-I

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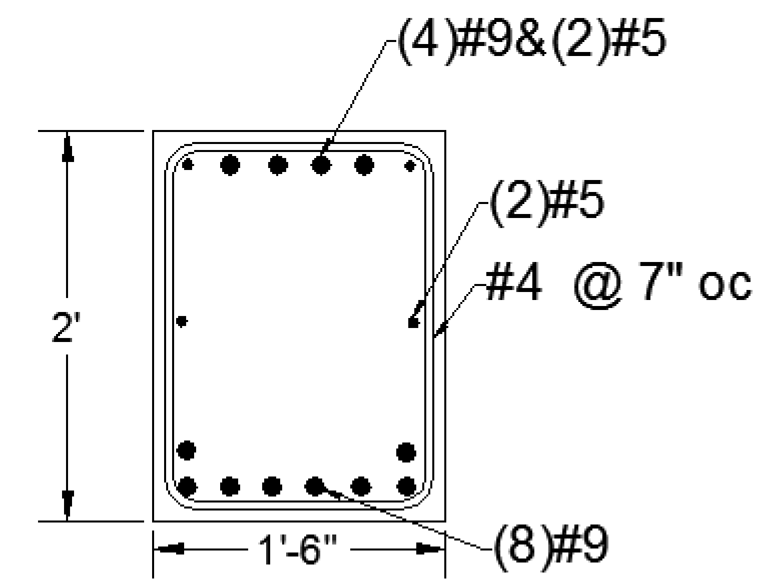
Edge Beam Deflections				
	Computed	Allowable		Pass?
Δi(d+l)	0.29 in	L/600	0.62 in	Yes
Δi(live)	0.06 in	L/360	1.03 in	Yes
Δ long	0.58 in	L/600	0.62 in	Yes



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Structural Depth - Lateral

Concrete Moment Frame:

- Does not affect interior architecture.
- Stiff beam to column connection

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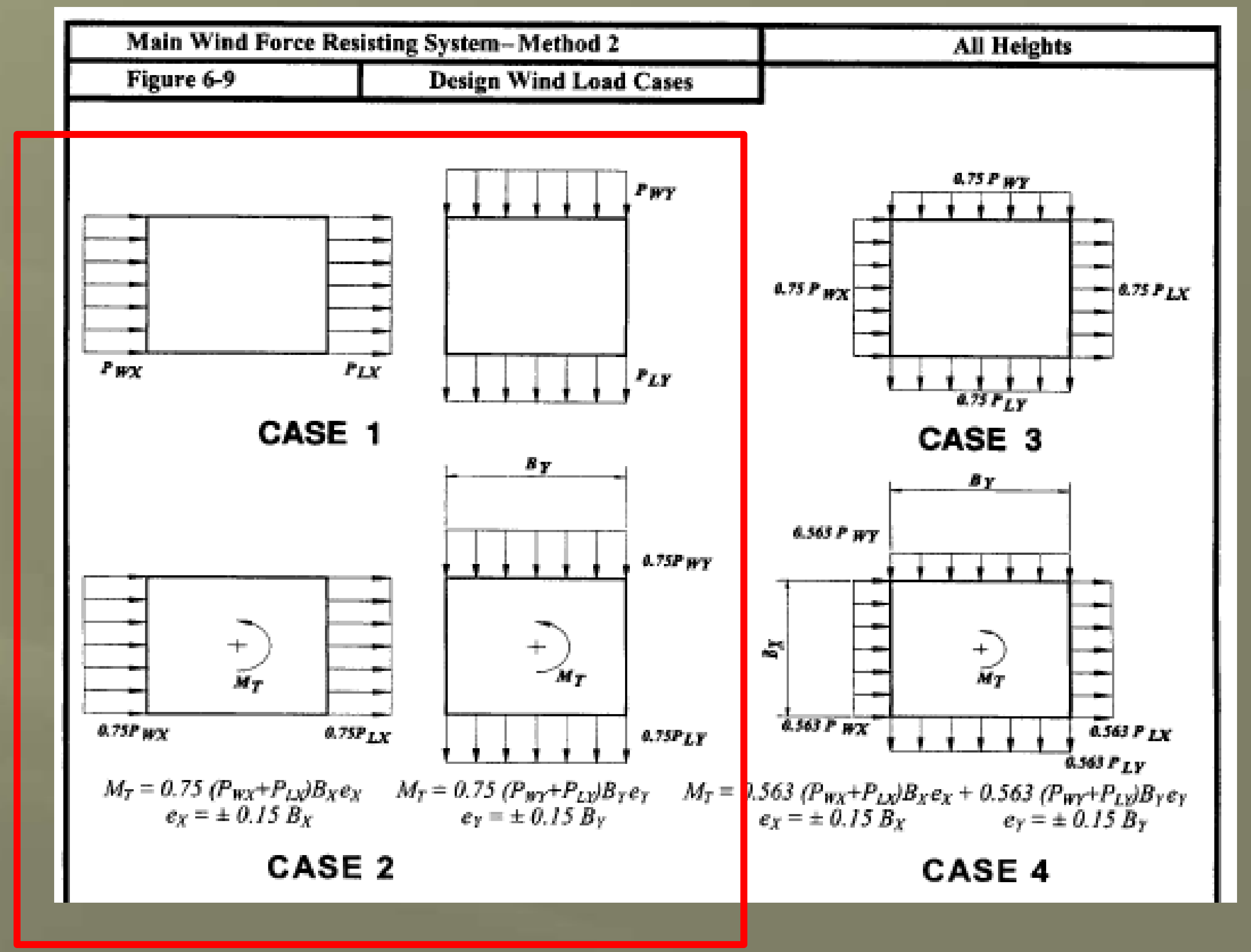
<u>Wind Loads:</u>

- Case 1 & Case 2 Controlled



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Wind Loads:
- Case 1 & Case 2 Controlled

Relative Stiffness:
- 1 kip load applied to each frame
- Calculated relative stiffness based on deflection.
- Distribution of wind loads

Frame	K (k/in)	$\sum K_{NS}$ (k/in)	$\sum K_{EW}$ (k/in)	Direct shear (kip)	d (in)	Kd^2	∑Kd^2	Torsional Moment Shear (kip)	Total shear (kip)
B	0.5502	0.00	4.23	0.00	32.50	581.15	17444.38	1.04	1.04
C	1.2902	0.00	4.23	0.00	18.20	427.38	17444.38	1.36	1.36
D	1.3881	0.00	4.23	0.00	-11.30	177.25	17444.38	-0.91	-0.91
E	1.0000	0.00	4.23	0.00	-34.00	1156.00	17444.38	-1.97	-1.97
1	0.1972	3.51	0.00	6.32	-106.00	2215.32	17444.38	-1.21	5.10
2	0.2560	3.51	0.00	8.20	-84.70	1836.50	17444.38	-1.26	6.94
3	0.3437	3.51	0.00	11.01	-61.30	1291.35	17444.38	-1.22	9.79
4	0.4860	3.51	0.00	15.57	-30.70	458.02	17444.38	-0.86	14.70
5	0.5848	3.51	0.00	18.73	0.30	0.05	17444.38	0.01	18.74
6	0.5309	3.51	0.00	17.00	31.30	520.08	17444.38	0.96	17.97
7	0.4180	3.51	0.00	13.39	55.90	1306.04	17444.38	1.35	14.74
8	0.2922	3.51	0.00	9.36	85.00	2111.43	17444.38	1.44	10.80
9	0.2248	3.51	0.00	7.20	106.00	2525.70	17444.38	1.38	8.58
10	0.1727	3.51	0.00	5.53	128.20	2838.10	17444.38	1.28	6.81

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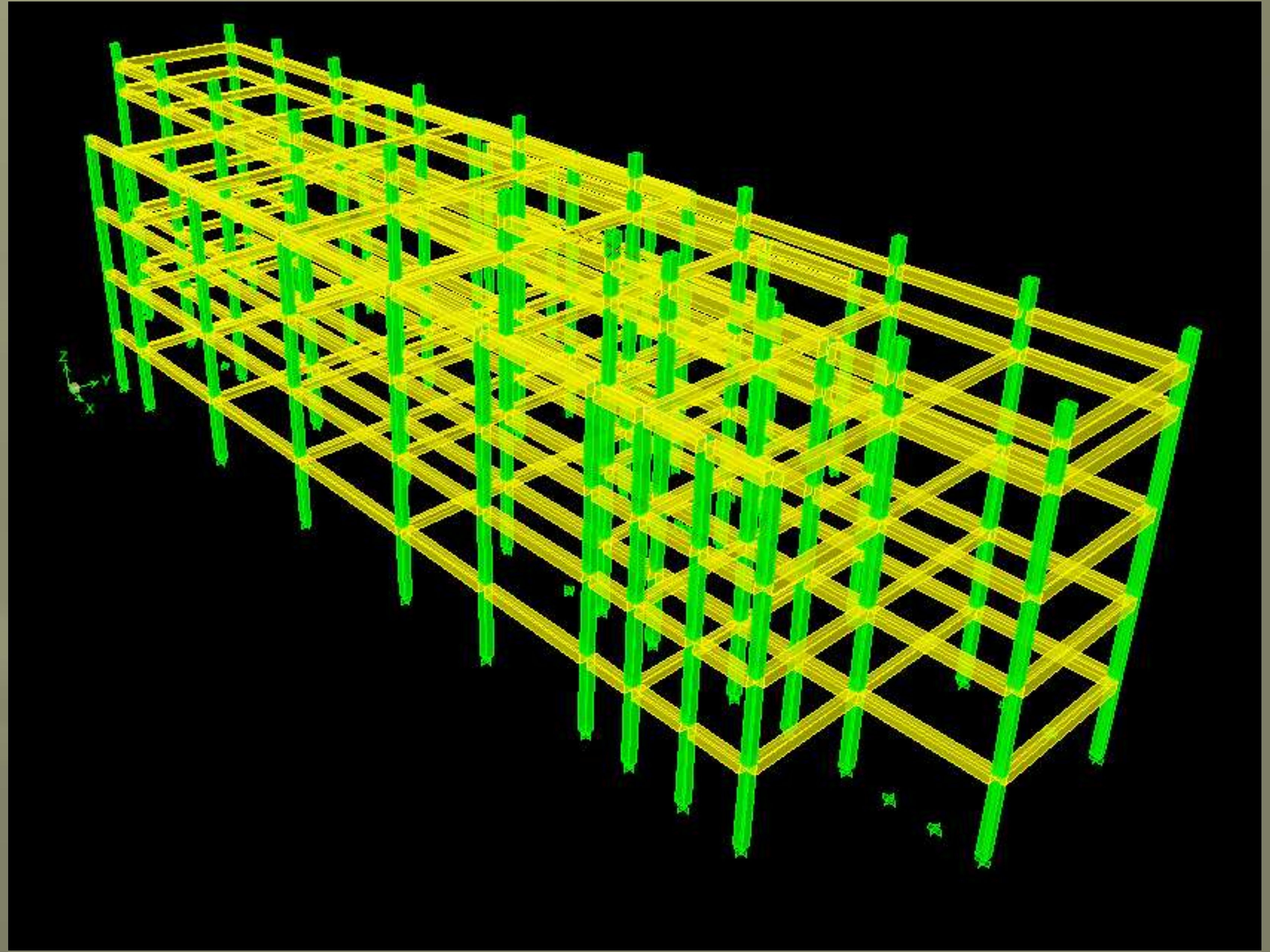
<u>Relative Stiffness:</u>
- 1 kip load applied to each frame
- Calculated relative stiffness based on deflection.
- Distribution of wind loads

<u>ETABS:</u>
- Line elements with proper material & section properties
- Columns – 0.70*Ig
- Beams – 0.35*Ig
- Verified output with hand calculations



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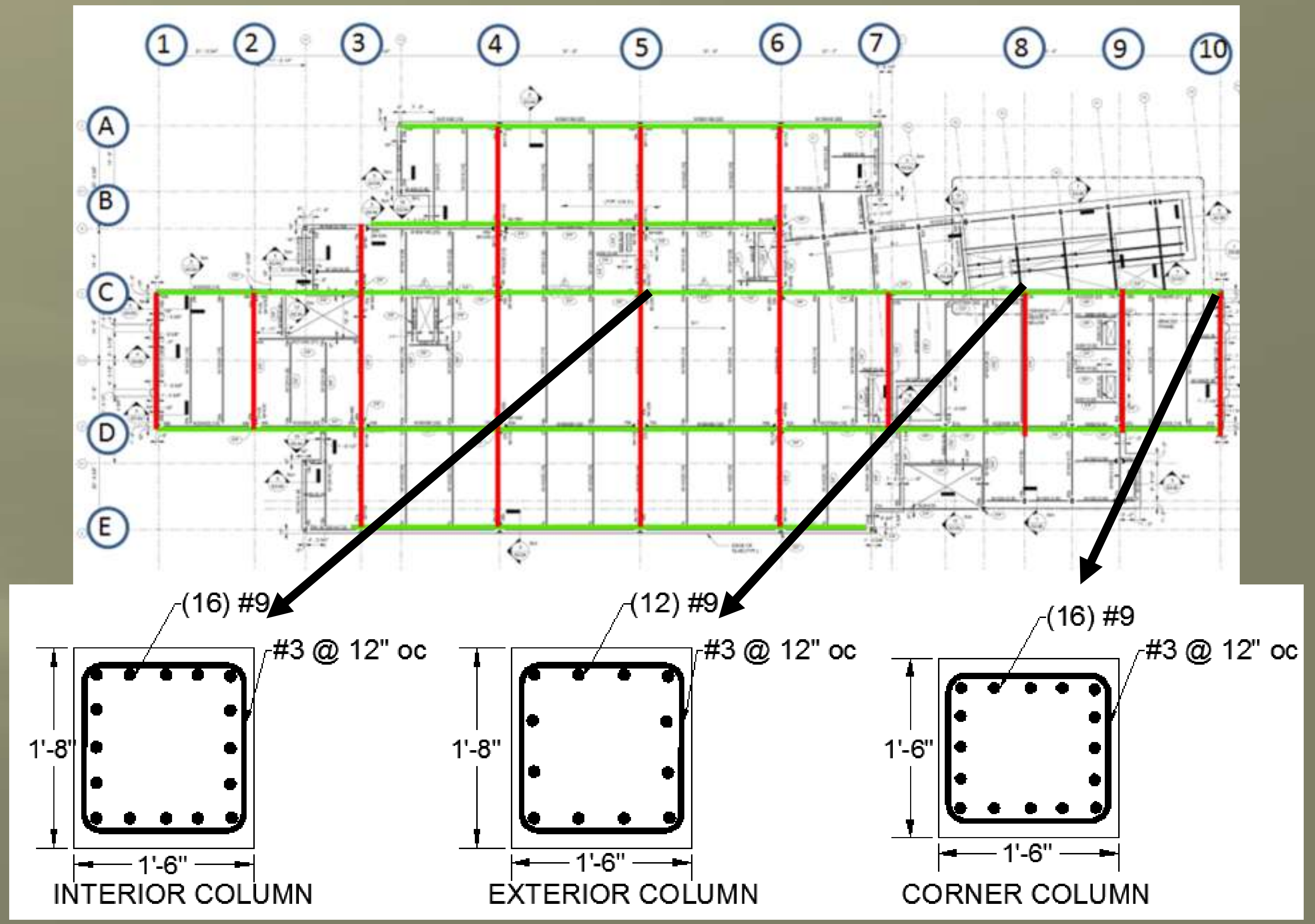
Structural Depth - Lateral

<u>Column Design:</u>

- Corner, Interior, & Exterior
- Resists axial & flexural loads



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<u>Design Checks:</u>
- Lateral Displacement < H/400
  - 0.9D+L+W

Displacement - X Direction					
Story	Height	Story Height	Displacement	H/400	Pass?
	(ft)	(ft)	(in)	(in)	Yes
PH	57	15	0.18	1.71	Yes
4	42	14	0.15	1.26	Yes
3	28	14	0.11	0.84	Yes
2	14	14	0.05	0.42	Yes

Displacement - Y Direction					
Story	Height	Story Height	Displacement	H/400	Pass?
	(ft)	(ft)	(in)	(in)	Yes
PH	57	15	1.6	1.71	Yes
4	42	14	1.25	1.26	Yes
3	28	14	0.82	0.84	Yes
2	14	14	0.31	0.42	Yes

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Structural Depth – Cost Impact

Steel		Concrete	
Structural steel	$297,025	Beams	$220,000
Metal Deck	$49,345	Columns	$94,504
1" Spray on Fireproofing	$12,968	Slab	$141,000
Concrete fill	$48,183	Total	$455,504
Total	$407,521		
% increase	12%		
Cost Diff	$47,984		

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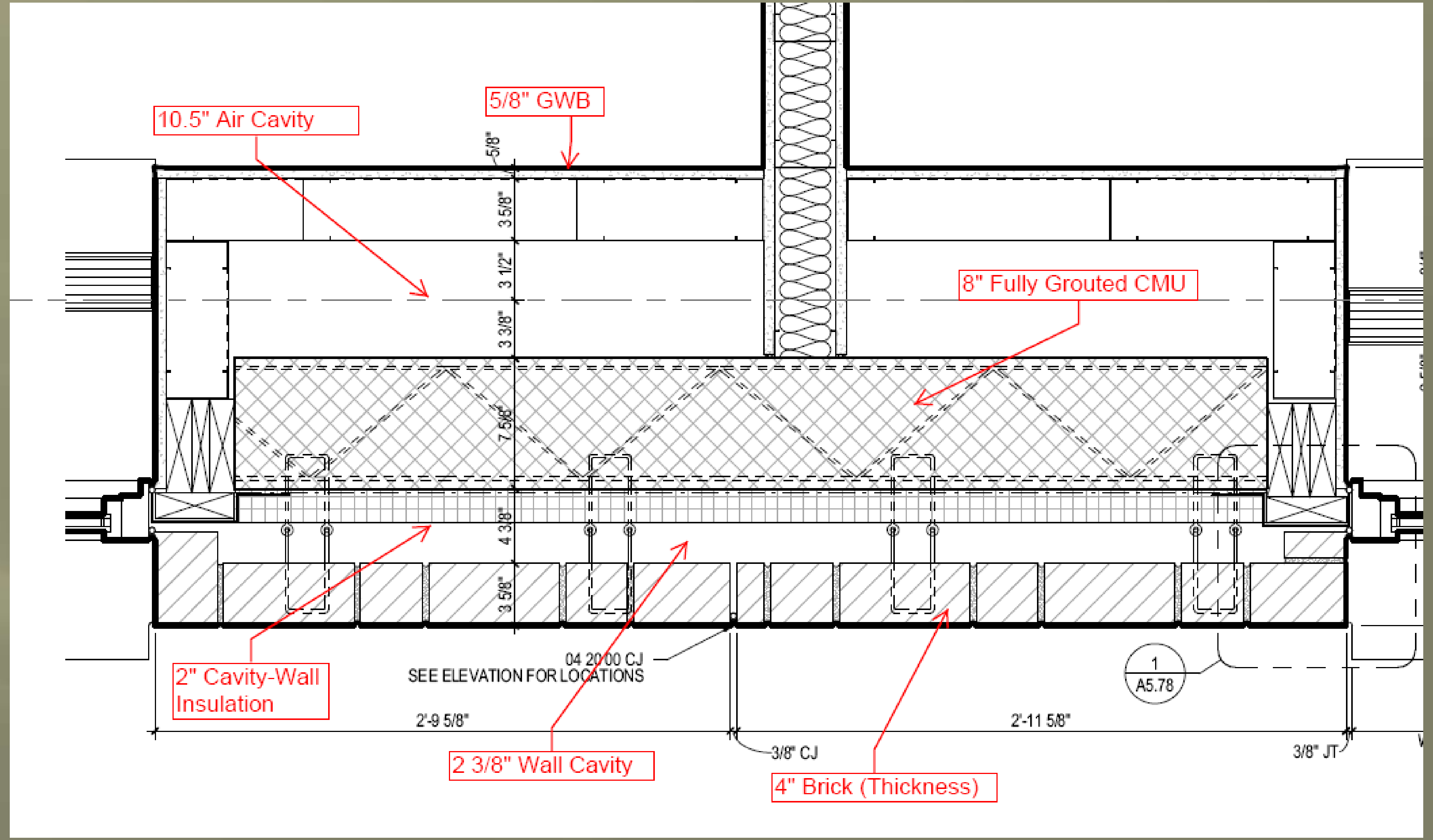
Façade Study Breadth

<u>Existing Façade:</u>

- Traditional hand placed brick & limestone
- Held back by 8” fully grouted CMU
- Flashing, weep holes, & air barrier
- Heavy & Expensive



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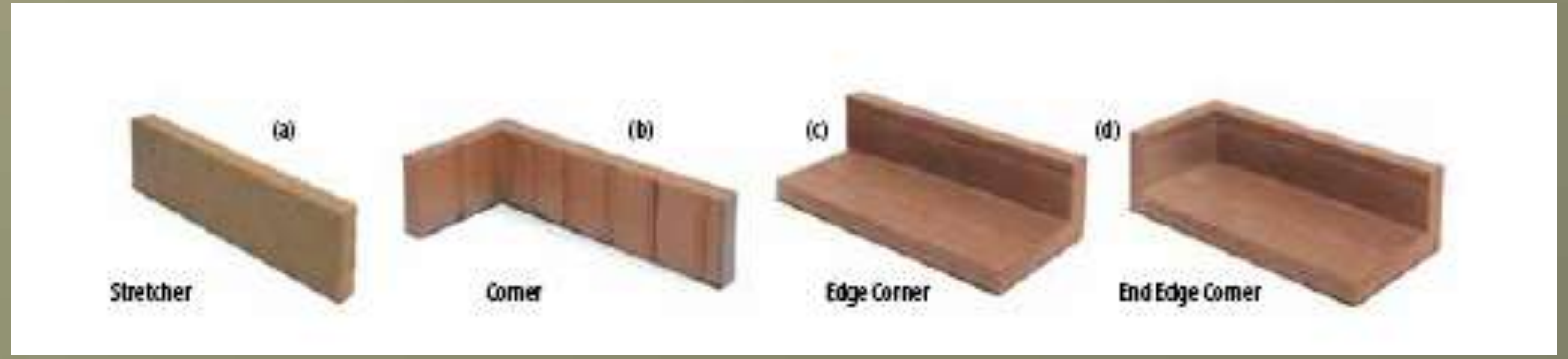
- Traditional hand placed brick & limestone
- Held back by 8” fully grouted CMU
- Flashing, weep holes, & air barrier
- Heavy & Expensive

<u>Alternative Façade:</u>

- Thin brick precast panels
- Made in controlled conditions
- Faster Construction

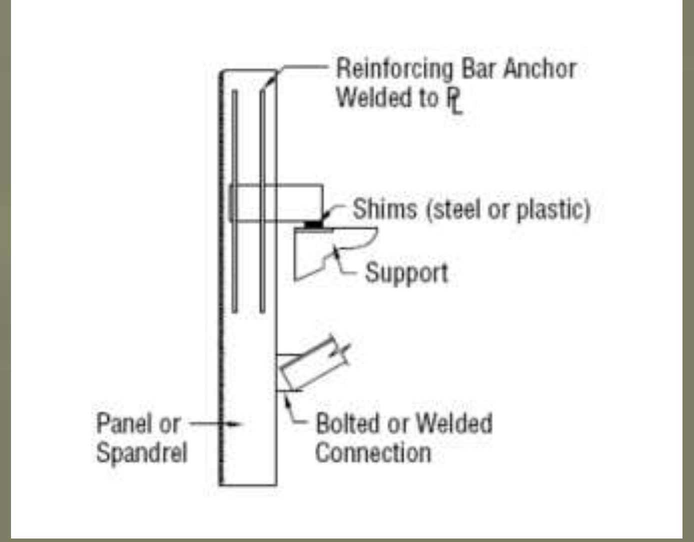


Presentation Outline

Façade Study Breadth

Thin Brick Precast:

- Typical Layout
- Hung from edge beams
- Kickback provide lateral support



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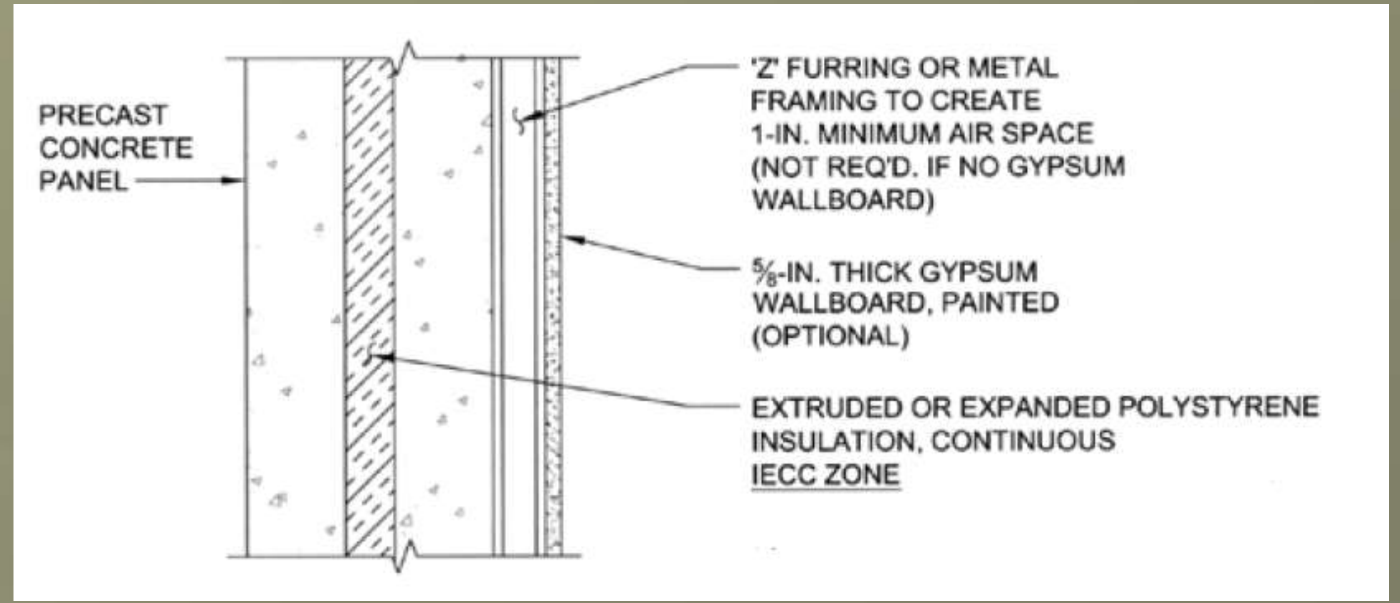
Façade Study Breadth

<u>Thin Brick Precast:</u>
- Typical Layout
- Hung from edge beams
- Kickback provide lateral support

<u>Thermal & Moisture Resistance:</u>
- Sandwich Wall
    - Provides rain barrier & thermal resistance



Existing Wall			Precast Wall		
Material	Thickness (in)	R-Value	Material	Thickness (in)	R-Value
Brick	4	0.4	Thin Brick	1	0.1
Air Cavity	2.375	1	Sandwich Panel Walls	4	4.4
Rigid Insulation	2	4.35	Air Cavity	18.5	1
Fully Grouted CMU	8	2.3	Wall Insulation Between Studs(Total R=13)	4	5.1
Air Cavity	10.5	1	GWB	0.625	0.45
GWB	0.625	0.45	Total Resistance		11.05
Total Resistance		9.5			

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Façade Study Breadth

Cost Impact:

Traditional Masonry		Precast Panels	
Brick	$156,142	Brick	$336,938
CMU	$86,289	Cornice	$81,250
Cleaning & Repointing	$57,526	Total	$418,188
Grouting	$152,185		
Reinf	$8,000		
Scaffolding	$12,500		
Total	$472,642		

% decrease	40%
Cost Diff	$54,454

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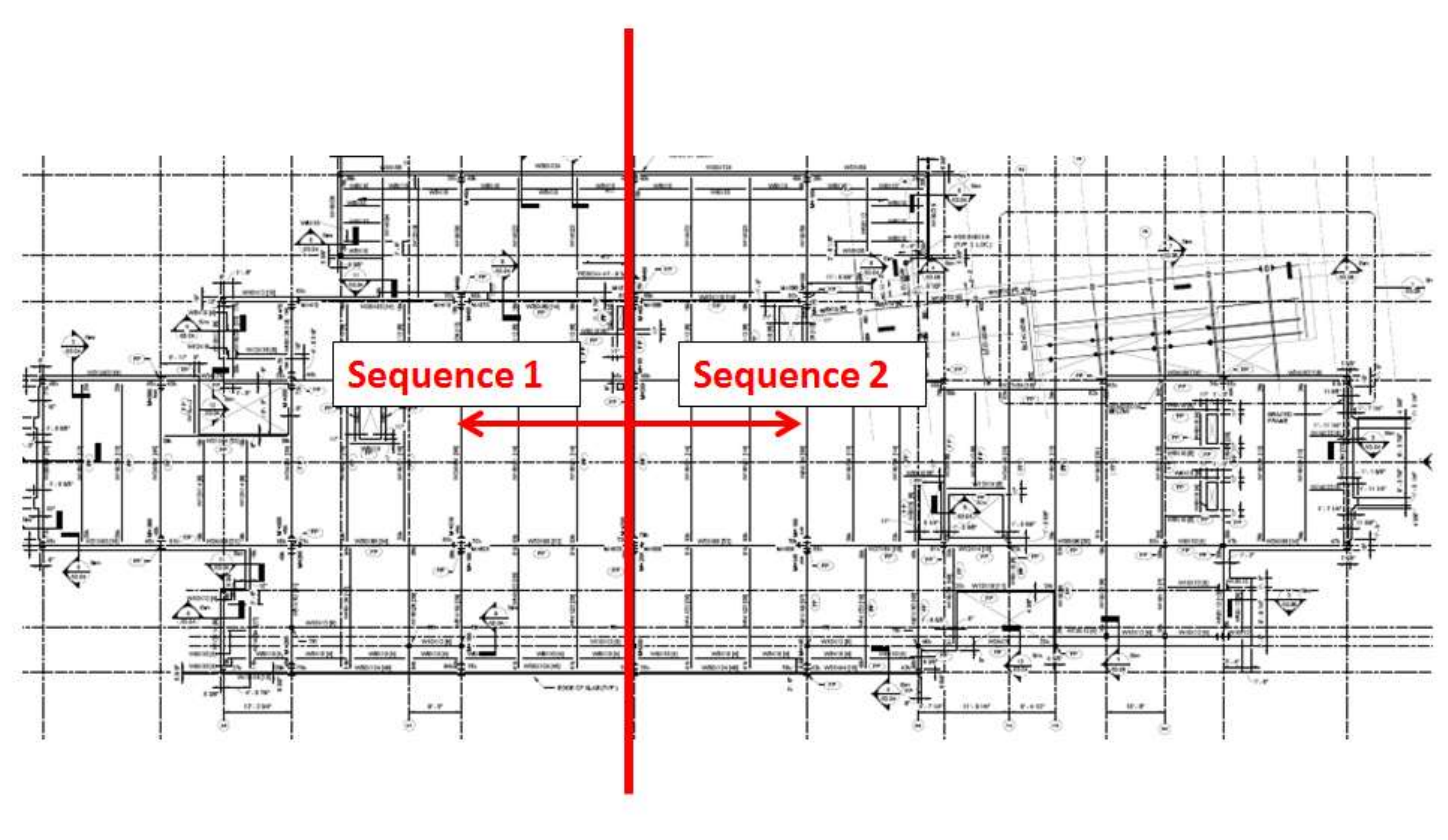
Schedule Impact Breadth

Construction Sequencing:

- Sequence 1: Col Line 1-5
- Sequence 2: Col Line 5-10



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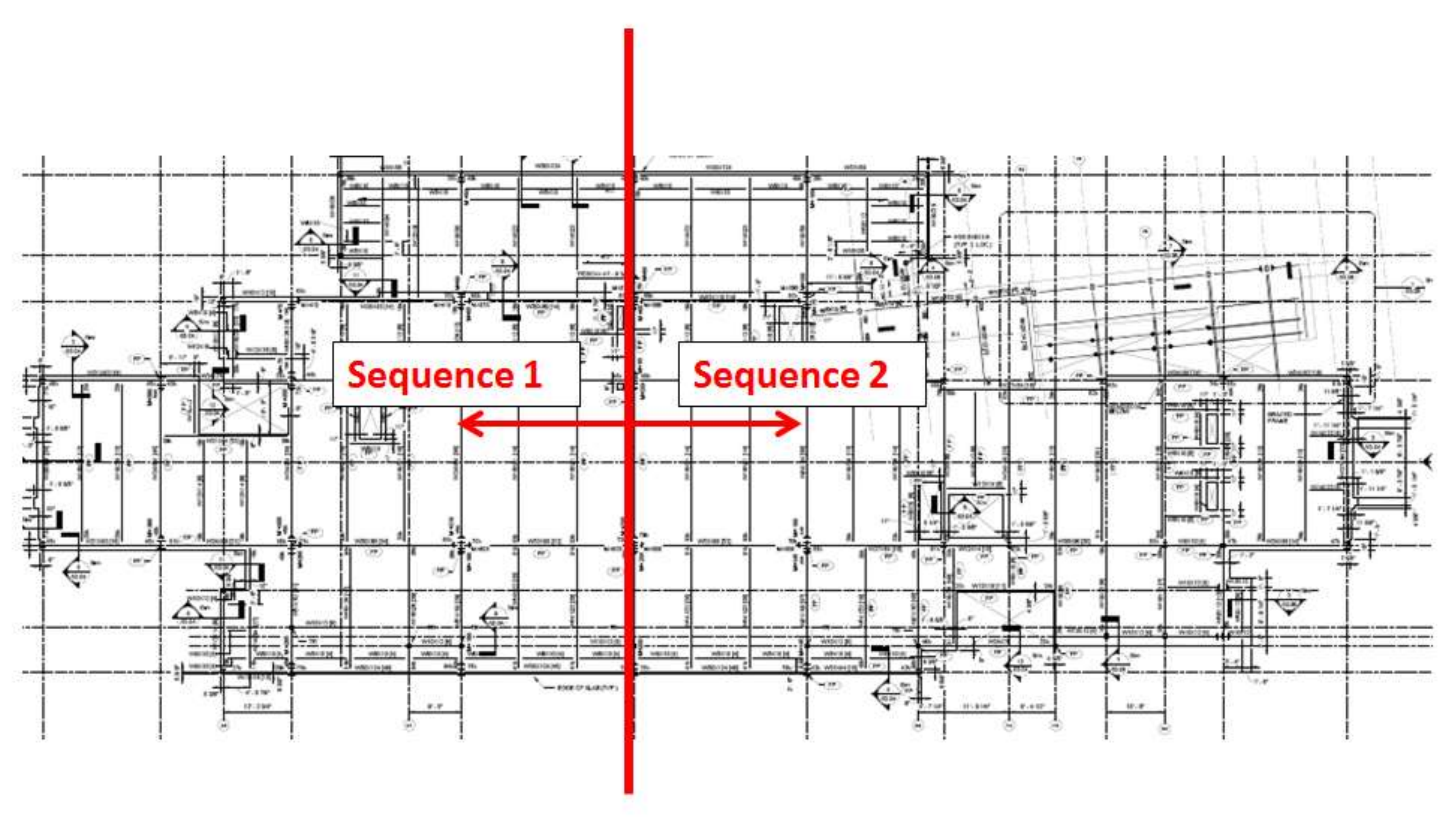
Schedule Impact Breadth

Construction Sequencing:
- Sequence 1: Col Line 1-5
- Sequence 2: Col Line 5-10

Assumptions:
- Reinforcement starts 1-3 days after forming starts
- Wait 7 days for concrete cure before construction on next floor



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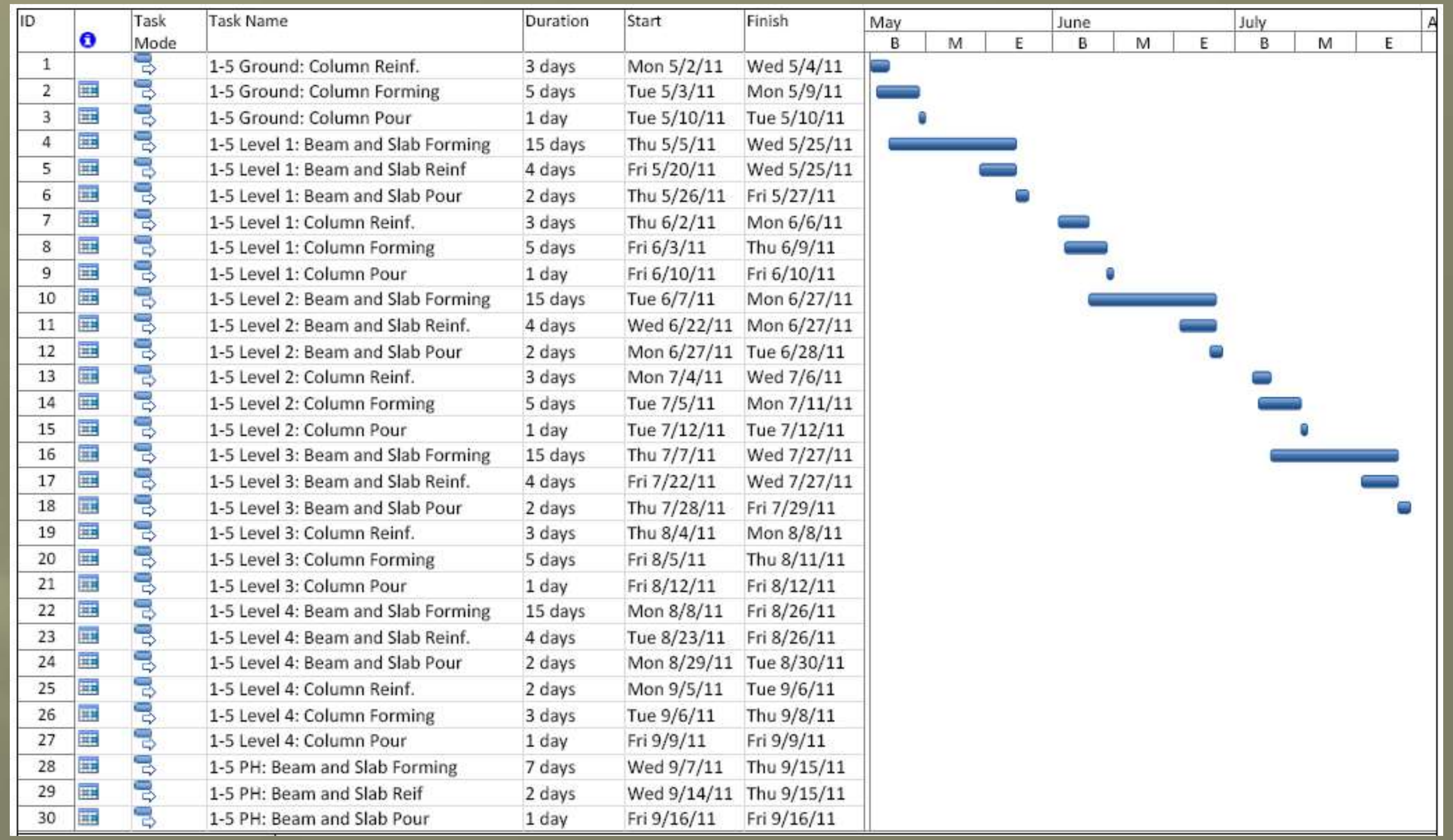
Schedule Impact Breadth

<u>Construction Sequencing:</u>
- Sequence 1: Col Line 1-5
- Sequence 2: Col Line 5-10

<u>Assumptions:</u>
- Reinforcement starts 1-3 days after forming starts
- Wait 7 days for concrete cure before construction on next floor

<u>Key Completion Dates:</u>
- Concrete redesign: Feb 3, 2012 (+3 months)
- Alternative precast façade: Mar. 15, 2012 (-6 months)



ID	Task Name	Duration	Start	Finish
1	1-5 Ground: Column Reinf.	3 days	Mon 5/2/11	Wed 5/4/11
2	1-5 Ground: Column Forming	5 days	Tue 5/3/11	Mon 5/9/11
3	1-5 Ground: Column Pour	1 day	Tue 5/10/11	Tue 5/10/11
4	1-5 Level 1: Beam and Slab Forming	15 days	Thu 5/5/11	Wed 5/25/11
5	1-5 Level 1: Beam and Slab Reinf	4 days	Fri 5/20/11	Wed 5/25/11
6	1-5 Level 1: Beam and Slab Pour	2 days	Thu 5/26/11	Fri 5/27/11
7	1-5 Level 1: Column Reinf.	3 days	Thu 6/2/11	Mon 6/6/11
8	1-5 Level 1: Column Forming	5 days	Fri 6/3/11	Thu 6/9/11
9	1-5 Level 1: Column Pour	1 day	Fri 6/10/11	Fri 6/10/11
10	1-5 Level 2: Beam and Slab Forming	15 days	Tue 6/7/11	Mon 6/27/11
11	1-5 Level 2: Beam and Slab Reinf.	4 days	Wed 6/22/11	Mon 6/27/11
12	1-5 Level 2: Beam and Slab Pour	2 days	Mon 6/27/11	Tue 6/28/11
13	1-5 Level 2: Column Reinf.	3 days	Mon 7/4/11	Wed 7/6/11
14	1-5 Level 2: Column Forming	5 days	Tue 7/5/11	Mon 7/11/11
15	1-5 Level 2: Column Pour	1 day	Tue 7/12/11	Tue 7/12/11
16	1-5 Level 3: Beam and Slab Forming	15 days	Thu 7/7/11	Wed 7/27/11
17	1-5 Level 3: Beam and Slab Reinf.	4 days	Fri 7/22/11	Wed 7/27/11
18	1-5 Level 3: Beam and Slab Pour	2 days	Thu 7/28/11	Fri 7/29/11
19	1-5 Level 3: Column Reinf.	3 days	Thu 8/4/11	Mon 8/8/11
20	1-5 Level 3: Column Forming	5 days	Fri 8/5/11	Thu 8/11/11
21	1-5 Level 3: Column Pour	1 day	Fri 8/12/11	Fri 8/12/11
22	1-5 Level 4: Beam and Slab Forming	15 days	Mon 8/8/11	Fri 8/26/11
23	1-5 Level 4: Beam and Slab Reinf.	4 days	Tue 8/23/11	Fri 8/26/11
24	1-5 Level 4: Beam and Slab Pour	2 days	Mon 8/29/11	Tue 8/30/11
25	1-5 Level 4: Column Reinf.	2 days	Mon 9/5/11	Tue 9/6/11
26	1-5 Level 4: Column Forming	3 days	Tue 9/6/11	Thu 9/8/11
27	1-5 Level 4: Column Pour	1 day	Fri 9/9/11	Fri 9/9/11
28	1-5 PH: Beam and Slab Forming	7 days	Wed 9/7/11	Thu 9/15/11
29	1-5 PH: Beam and Slab Reif	2 days	Wed 9/14/11	Thu 9/15/11
30	1-5 PH: Beam and Slab Pour	1 day	Fri 9/16/11	Fri 9/16/11

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Structural Depth;

- Successful concrete redesign
- Met all serviceability requirements
- Minimal impact interior architecture & layout

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Structural Depth;

- Successful concrete redesign
- Met all serviceability requirements
- Minimal impact interior architecture & layout

Façade Study Breadth:

- Matched existing thermal & moisture protection
- Cheaper
- Fast Construction

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Structural Depth;

- Successful concrete redesign
- Met all serviceability requirements
- Minimal impact interior architecture & layout

Façade Study Breadth:

- Matched existing thermal & moisture protection
- Cheaper
- Fast Construction

Schedule Impact Breadth:

- Develop an adjusted schedule
- Structure: + 3 months
- Façade: -6 months

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Acknowledgments

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- Tim Jones
- Jim Kephart
- Keith Smith

Robert Silman Associates:

- Dipa Makim

The Entire Penn State Faculty

Family & Friends

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Appendix

Snow Load Type	Uniform (psf)
Flat Roof Load	21
Sloped Roof Load	24

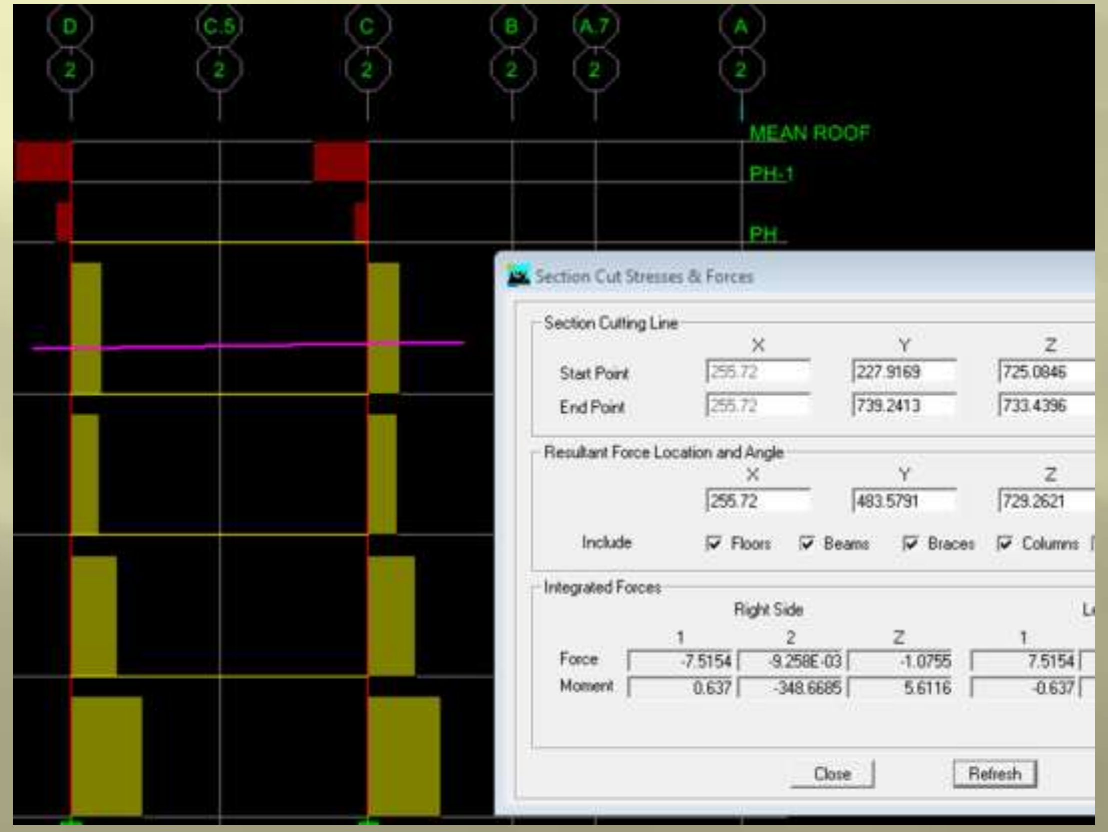
Lvl 2	Area	DL	Weight
Slab	16600	46	763600
superimposed	16600	5	83000
Steel	16600	5	83000
Façade	8663	45	389812.5
CMU	8663	83	719029
Int Brick	2590	40	103600
Stone Floor	1700	10	17000
Total	16600		2,159,042
Lvl 3	Area	DL	Weight
Slab	16600	46	763600
superimposed	16600	5	83000
Steel	16600	5	83000
Façade	8820	45	396900
CMU	8820	83	732060
Int Brick	1400	40	56000
Stone Floor	1700	10	17000
			2,131,560
Lvl 4	Area	DL	Weight
Slab	16600	46	763600
superimposed	16600	5	83000
Steel	16600	5	83000
Façade	9293	45	418162.5
CMU	9293	83	771319
Int Brick	1500	40	60000
Stone Floor	1700	10	17000
			2,196,082
PH	Area	DL	Weight
Slab	6000	46	276000
Roof Deck	4700	3.3	15510
superimposed	10700	5	53500
Steel	10700	5	53500
Façade	9000	45	405000
CMU	9000	83	747000
Green Roof	4700	25	117500
			1,668,010
Roof	Area	DL	Weight
Slate	7310	10	73100
steel	7310	5	36550
superimposed	7310	5	36550
			146,200
Bld weight (lbs)			8,300,893

Weight Comparison

Lvl 2	Area	DL	Weight
Slab	16600	63	1037500
superimposed	16600	5	83000
Steel	16600	0	0
Façade	8663	100	866250
Int Brick	2590	4.7	12086.667
Total	16600		2,032,837
Lvl 3	Area	DL	Weight
Slab	16600	63	1037500
superimposed	16600	5	83000
Steel	16600	0	0
Façade	8820	100	882000
CMU	8820	0	0
Int Brick	1400	4.7	6533.3333
Stone Floor	1700	20	34000
			2,043,033
Lvl 4	Area	DL	Weight
Slab	16600	63	1037500
superimposed	16600	5	83000
Steel	16600	0	0
Façade	9293	100	929250
CMU	9293	0	0
Int Brick	1500	4.7	7000
Stone Floor	1700	20	34000
			2,090,750
PH	Area	DL	Weight
Slab	6000	63	375000
Roof Deck	4700	63	293750
superimposed	10700	5	53500
Steel	10700	0	0
Façade	9000	100	900000
CMU	9000	0	0
Green Roof	4700	25	117500
			1,739,750
Roof	Area	DL	Weight
conc slab	7310	63	456875
Slate	7310	10	73100
steel	7310	0	0
superimposed	7310	5	36550
			566,525
Bld weight (lbs)			8,472,895

Overturning Moment			
Level	ht (ft)	Wind Force (K)	Moment (k-ft)
Roof	67	40.83	2736
Parapet	63	15.68	988
PH	57	55.79	3180
4	42	74.23	3118
3	25	67.12	1678
2	14	61.48	861
		Overturning Moment=	12,560 k-ft

Resisting Moment
M_{resist}=8,473k x 89'/2 x .67 = 252,622 k-ft



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PH Level					
N-S	ft	E-W	ft		ft
CR=	34	CR=	106	.15By=	36
CM=	32	CM=	115	.15Bx=	13
CR-CP=	2.00	CR-CP=	-9.00		

W1: Case 1 NS			
F_{NS} (kip)	112.3	e_{NS} (ft)	9
F_{EW} (kip)	0	e_{EW} (ft)	0
M_{NS} (k-ft)	1010.7		
M_{EW} (k-ft)	0		

Frame	K (k/in)	$\sum K_{NS}$ (k/in)	$\sum K_{EW}$ (k/in)	Direct shear (kip)	d (in)	Kd^2	∑Kd^2	Torsional Moment Shear (kip)	Total shear (kip)
B	0.5502	0.00	4.23	0.00	32.50	581.15	17444.38	1.04	1.04
C	1.2902	0.00	4.23	0.00	18.20	427.38	17444.38	1.36	1.36
D	1.3881	0.00	4.23	0.00	-11.30	177.25	17444.38	-0.91	-0.91
E	1.0000	0.00	4.23	0.00	-34.00	1156.00	17444.38	-1.97	-1.97
1	0.1972	3.51	0.00	6.32	-106.00	2215.32	17444.38	-1.21	5.10
2	0.2560	3.51	0.00	8.20	-84.70	1836.50	17444.38	-1.26	6.94
3	0.3437	3.51	0.00	11.01	-61.30	1291.35	17444.38	-1.22	9.79
4	0.4860	3.51	0.00	15.57	-30.70	458.02	17444.38	-0.86	14.70
5	0.5848	3.51	0.00	18.73	0.30	0.05	17444.38	0.01	18.74
6	0.5309	3.51	0.00	17.00	31.30	520.08	17444.38	0.96	17.97
7	0.4180	3.51	0.00	13.39	55.90	1306.04	17444.38	1.35	14.74
8	0.2922	3.51	0.00	9.36	85.00	2111.43	17444.38	1.44	10.80
9	0.2248	3.51	0.00	7.20	106.00	2525.70	17444.38	1.38	8.58
10	0.1727	3.51	0.00	5.53	128.20	2838.10	17444.38	1.28	6.81

Case 2 NS + .15By

$.75F_{NS}$ (kip)	84.225	e_{NS} (ft)	45
$.75F_{EW}$ (kip)	0	e_{EW} (ft)	0
M_{NS} (k-ft)	3790.125		
M_{EW} (k-ft)	0		

Frame	K (k/in)	$\sum K_{NS}$ (k/in)	$\sum K_{EW}$ (k/in)	Direct shear (kip)	d (ft)	Kd^2	∑Kd^2	Torsional Moment Shear (kip)	Total shear (kip)
B	0.5502	0.00	4.23	0.00	32.50	581.15	17444.38	3.89	3.89
C	1.2902	0.00	4.23	0.00	18.20	427.38	17444.38	5.10	5.10
D	1.3881	0.00	4.23	0.00	-11.30	177.25	17444.38	-3.41	-3.41
E	1.0000	0.00	4.23	0.00	-34.00	1156.00	17444.38	-7.39	-7.39
1	0.1972	3.51	0.00	4.74	-106.00	2215.32	17444.38	-4.54	0.20
2	0.2560	3.51	0.00	6.15	-84.70	1836.50	17444.38	-4.71	1.44
3	0.3437	3.51	0.00	8.26	-61.30	1291.35	17444.38	-4.58	3.68
4	0.4860	3.51	0.00	11.67	-30.70	458.02	17444.38	-3.24	8.43
5	0.5848	3.51	0.00	14.05	0.30	0.05	17444.38	0.04	14.09
6	0.5309	3.51	0.00	12.75	31.30	520.08	17444.38	3.61	16.36
7	0.4180	3.51	0.00	10.04	55.90	1306.04	17444.38	5.08	15.12
8	0.2922	3.51	0.00	7.02	85.00	2111.43	17444.38	5.40	12.42
9	0.2248	3.51	0.00	5.40	106.00	2525.70	17444.38	5.18	10.58
10	0.1727	3.51	0.00	4.15	128.20	2838.10	17444.38	4.81	8.96

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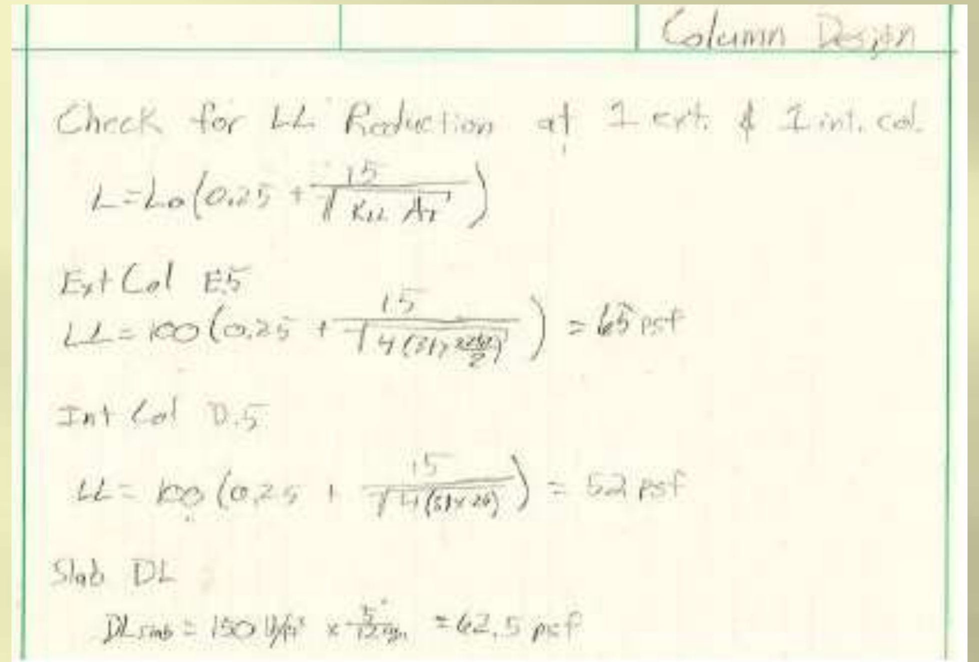


Column Design

Check for LL Reduction at 1 ext. & 1 int. col.

$L = L_o\left(0.25 + \frac{15}{\sqrt{K_{LL} A_T}}\right)$

Ext Col E5

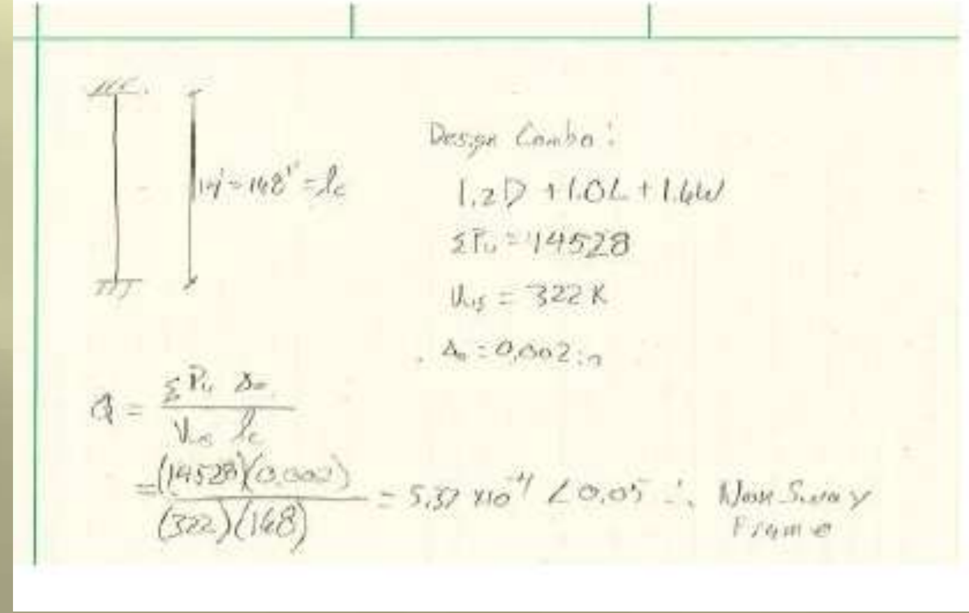
$LL = 100\left(0.25 + \frac{15}{\sqrt{4(31 \times \frac{28}{2})}}\right) = 65\ psf$

Int Col D.5

$LL = 100\left(0.25 + \frac{15}{\sqrt{4(31 \times 28)}}\right) = 52\ psf$

Slab DL

$DL_{slab} = 150\ lb/ft^3 \times \frac{5''}{12\ in} = 62.5\ psf$



$14' = 168'' = l_c$

Design Combo:

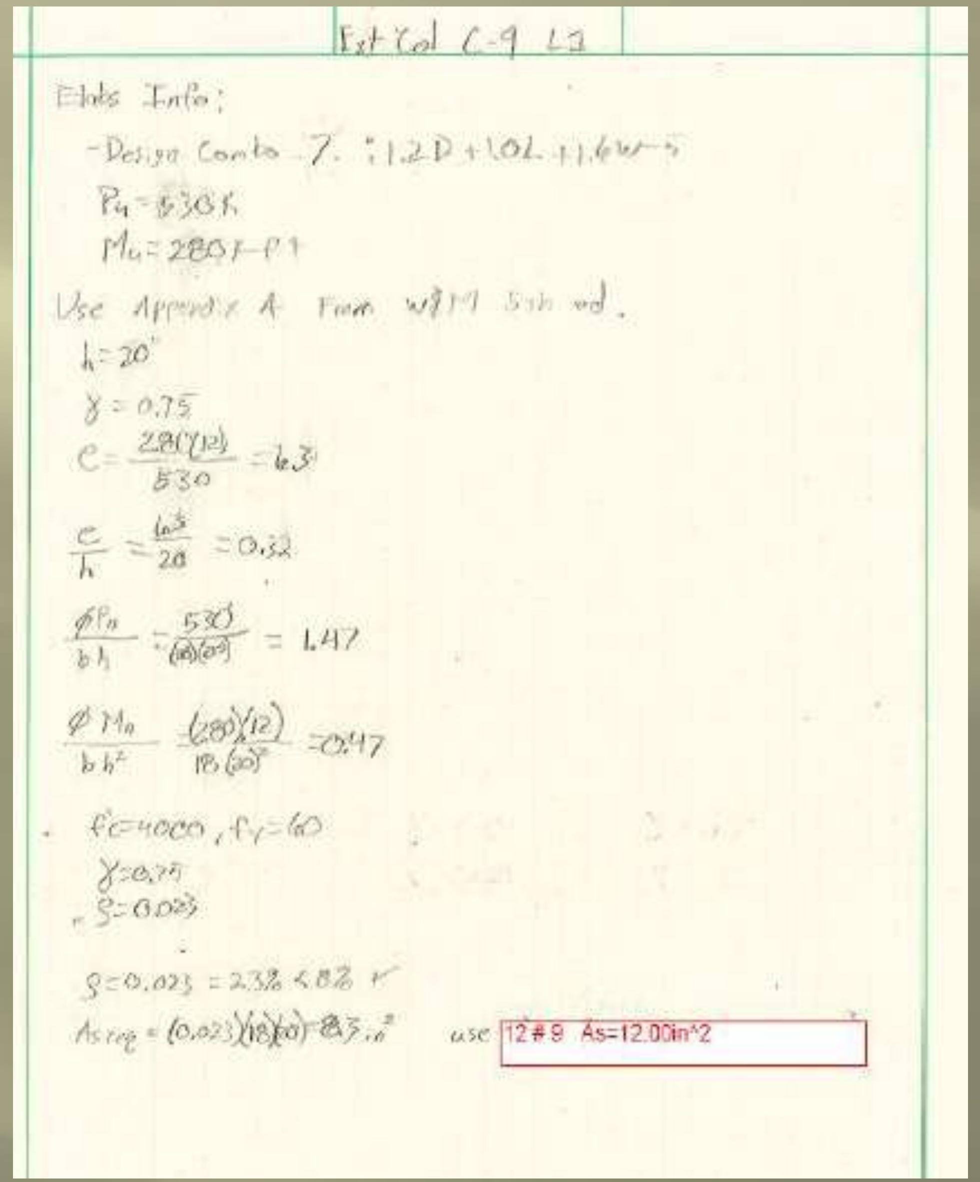
$1.2D + 1.0L + 1.6W$

$\Sigma P_u = 14528$

$V_{us} = 322\ K$

$\Delta_o = 0.002\ in$

$Q = \frac{\Sigma P_u \Delta_o}{V_{us} l_c} = \frac{(14528)(0.002)}{(322)(168)} = 5.37 \times 10^{-4} < 0.05$ ∴ Non Sway Frame



Ext Col C-9 L1

Etabs Info:

- Design Combo 7: $1.2D + 1.0L + 1.6W$

$P_u = 530\ K$

$M_u = 280\ K\text{-}ft$

Use Appendix A Form w/ #9 Sth wd.

$h = 20''$

$\gamma = 0.75$

$e = \frac{280(12)}{530} = 6.3$

$\frac{e}{h} = \frac{6.3}{20} = 0.32$

$\frac{\phi P_n}{bh} = \frac{530}{(18)(20)} = 1.47$

$\frac{\phi M_n}{bh^2} = \frac{(280)(12)}{18(20)^2} = 0.47$

$f'_c = 4000,\ f_y = 60$

$\gamma = 0.75$

$\rho = 0.023$

$\rho = 0.023 = 2.3\% < 8\%$ ✓

$A_{s\,req} = (0.023)(18)(20) = 8.3\ in^2$ use 12#9 As=12.00in^2

Per floor

Column Reinforment	6.80	6.8 TONS	2.3		3.0		Starts 7 days after beam and slab pour
Column Forming	1235	1235 SF	238		5.2		Starts 1 day after Column Reinf
Pour Columns	37	37 CY	92		0.4		
Beam Forming	6200	6200 SF	650		9.5	use 2 crews	Beam and Slab form starts 2 days after column form
Beam Reinf	10.1	10.1 TONS	2.7		3.7		beam reif starts 4 days befor beam and slab form ends
Slab Forming	5500	5500 SF	1100		5.0	use 2 crews	
Slab Reinf	4.1	4.1 TONS	2.9		1.4		
Pour Slab and Beams	210	210 CY	120		1.8		
				15 total per			
Precast Panels	4107	4107 SF	3000	sequence			

28. How many panels can be installed in a day?

Depending on site access and the orientation of panels on a building, between 3,000 to 4,500 square feet of wall area can be installed each day.