Hospital Patient Tower

Presented by:
Matthew Peyton

AE Faculty Consultant:
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The Department of Architectural Engineering
The Pennsylvania State University
April 13th 2011

Presentation Outline

- ❑ Introduction
  - ❑ Building Stats and Features
  - ❑ Location
  - ❑ Existing Structural Design
- ❑ Structural Depth Analysis
  - ❑ Proposal Review
  - ❑ Gravity System
  - ❑ Lateral System
- ❑ Breadth Topics
  - ❑ Proposal Review
  - ❑ Construction Management
  - ❑ Acoustical Study
- ❑ Recommendations & Conclusion
- ❑ Acknowledgments & Questions

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Building Stats

Size: 216,000 s.f.
Number of stories: 12 Above Grade
Cost: $161 Million
Construction duration: Summer 2010 – Fall 2011

Building Features

- 174 private intensive care and medical/surgical rooms.
- 360º patient access for improved care.
- Two story atrium connected to the lobby with a living roof.
- Cantilevered aluminum lovers with glazing as lobby canopy.

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Building Location

- Existing Hospital Campus
- Northern Virginia
- Outside the Capital Beltway

Figure1: Campus Arial View

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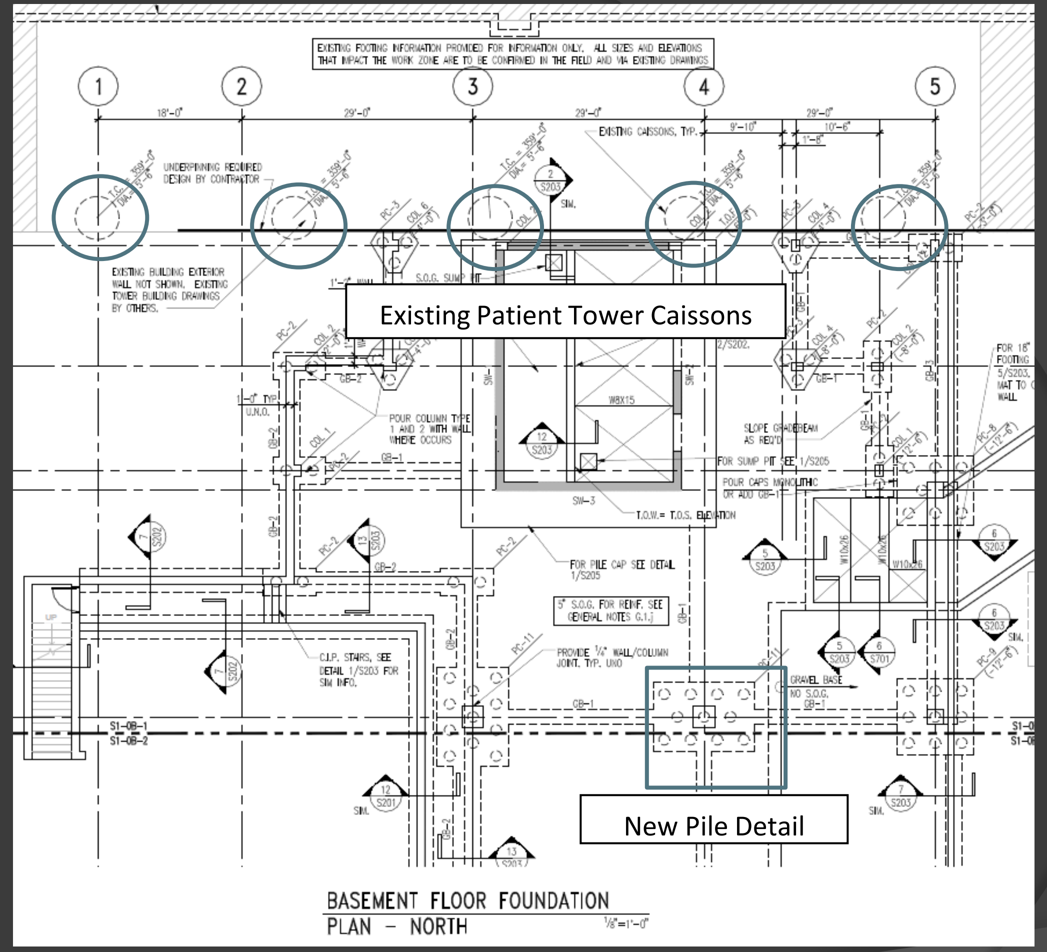
Existing Structural System

Foundation

- Piles
  - Drilled piles from 2 – 12 per column
  - Pile caps pored monolithic with Slab.
- Grade beams
  - 24” to 36” deep
- 5” Slab On Grade



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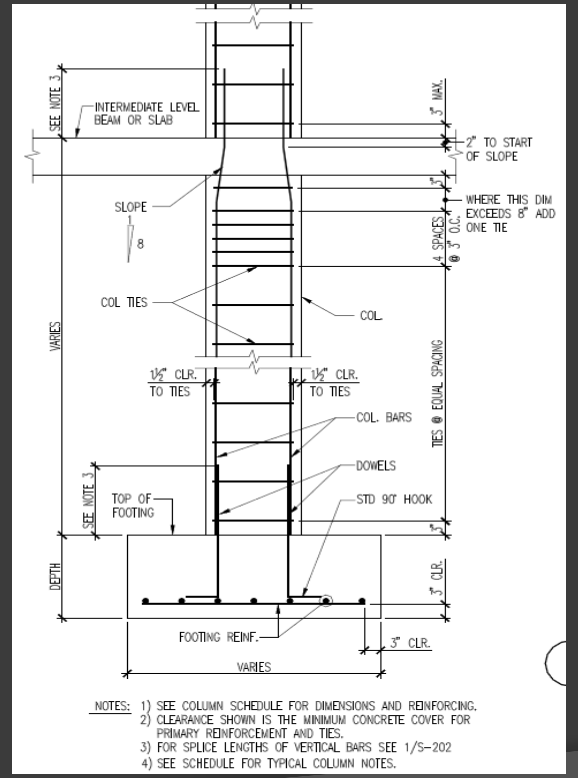
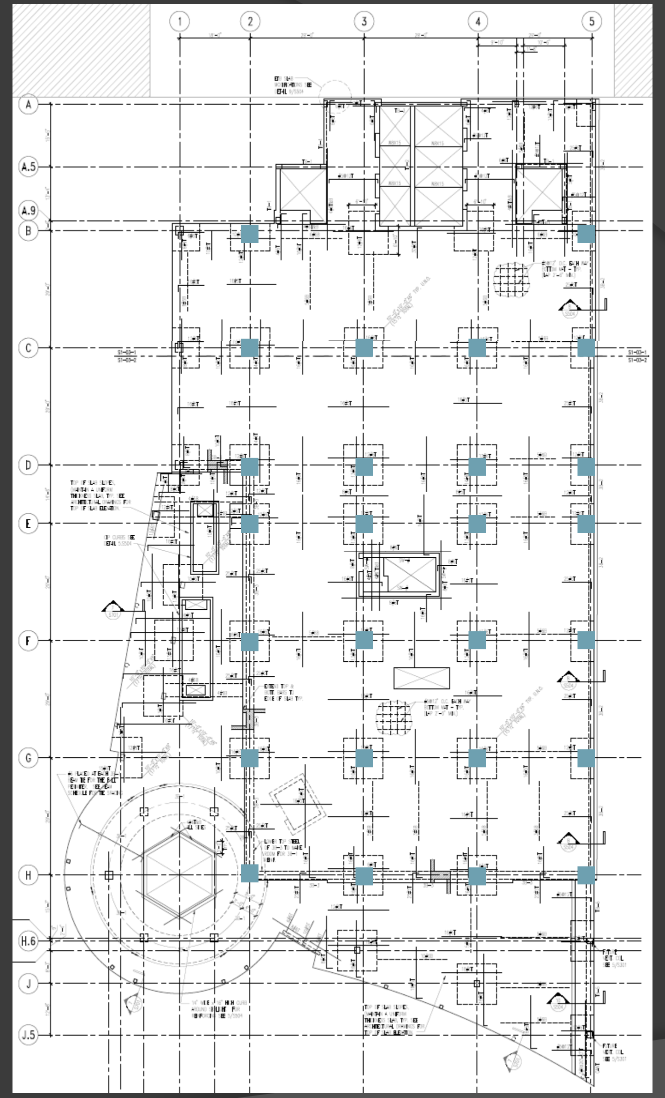
Existing Structural System

Gravity System

- ❑ Columns
  - ❑ Typical size 24” x 24”
  - ❑ 7,000 psi concrete floors 1 – 4
  - ❑ 5,000 psi concrete floors 5 – roof
  - ❑ 6” deep column capitals





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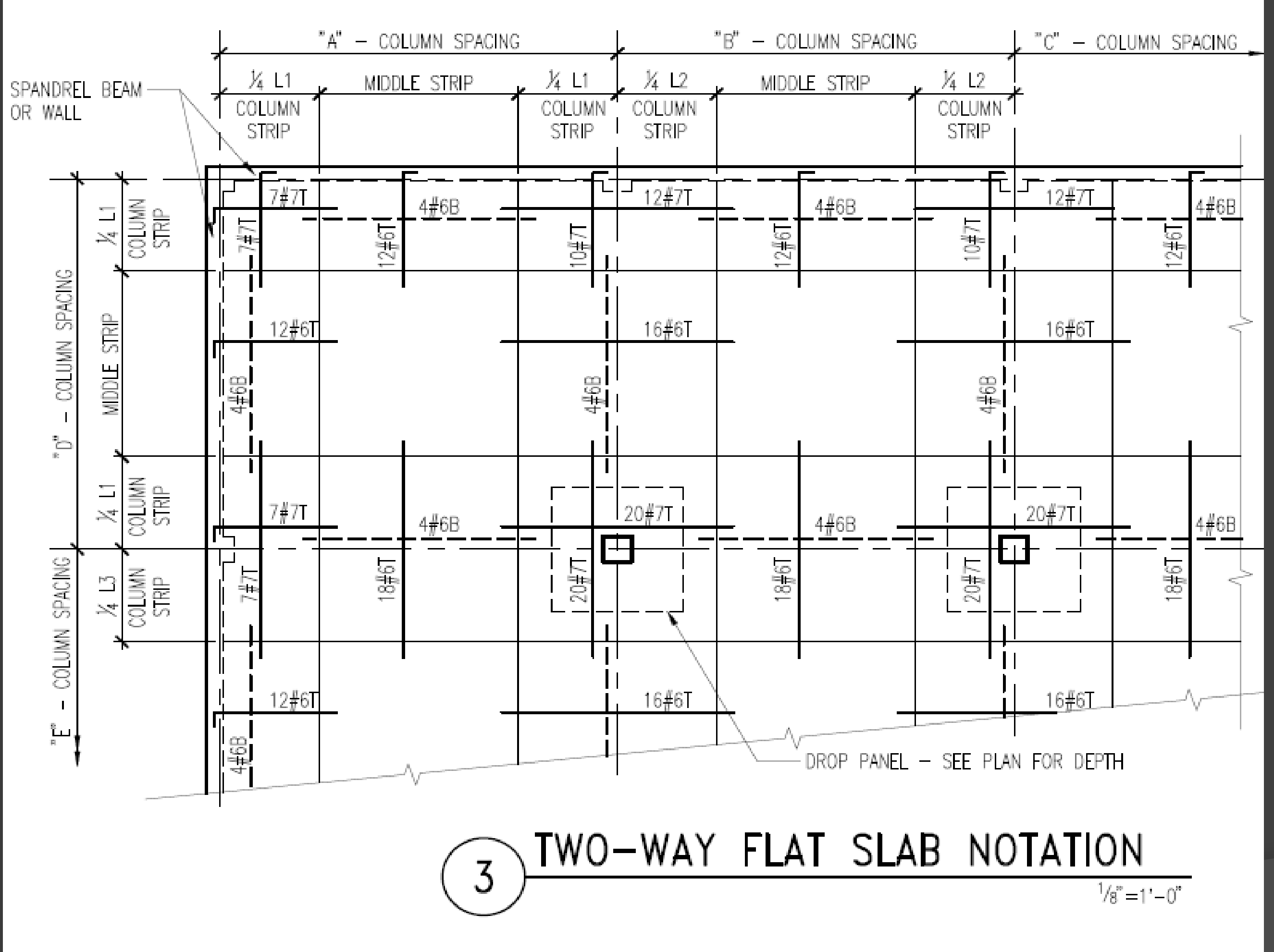
Existing Structural System

Gravity System

- Floor Slab
  - 29’ x 29’ bays
  - 9.5” 2- Way flat plate.
  - 5,000 psi concrete floors 1 – 4
  - 4,000 psi concrete floors 5 – roof
  - 10.5” thick slab for mechanical floor



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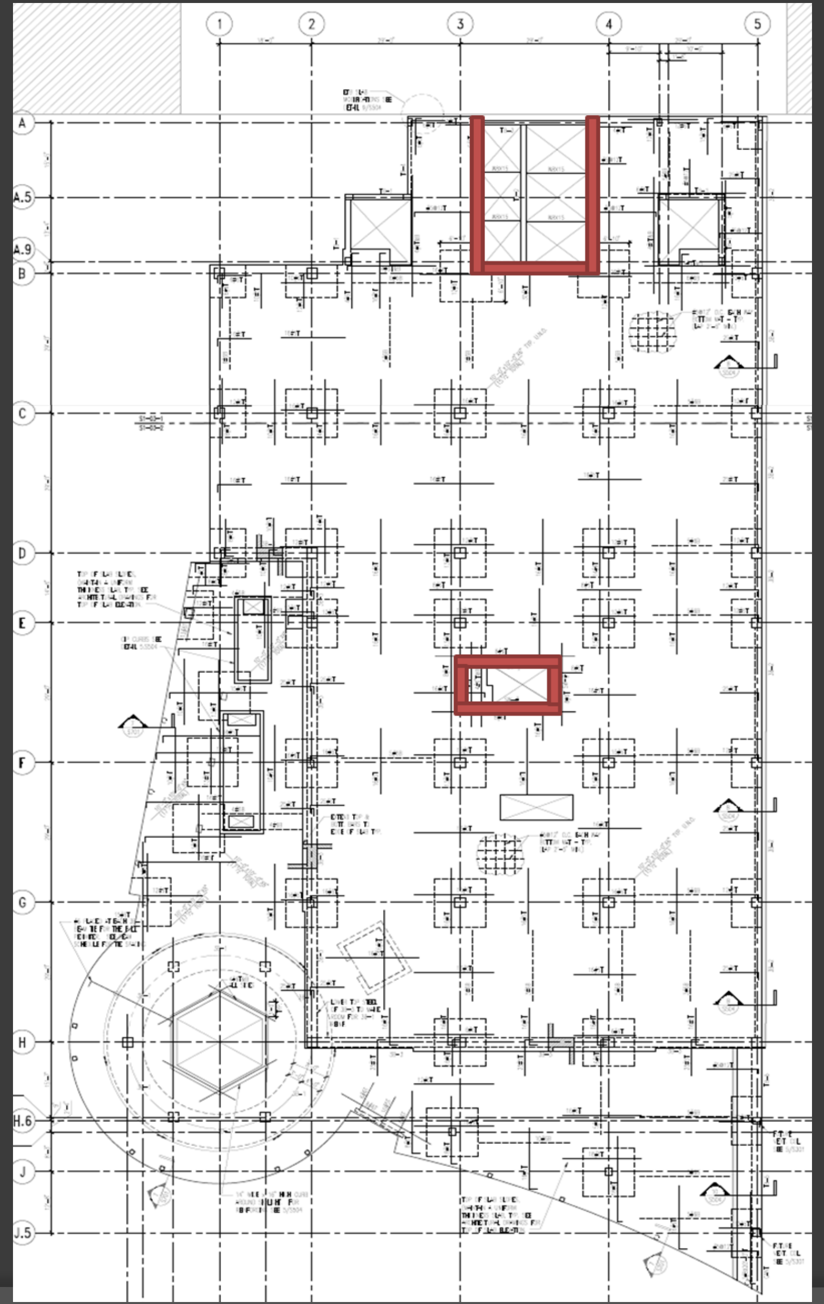

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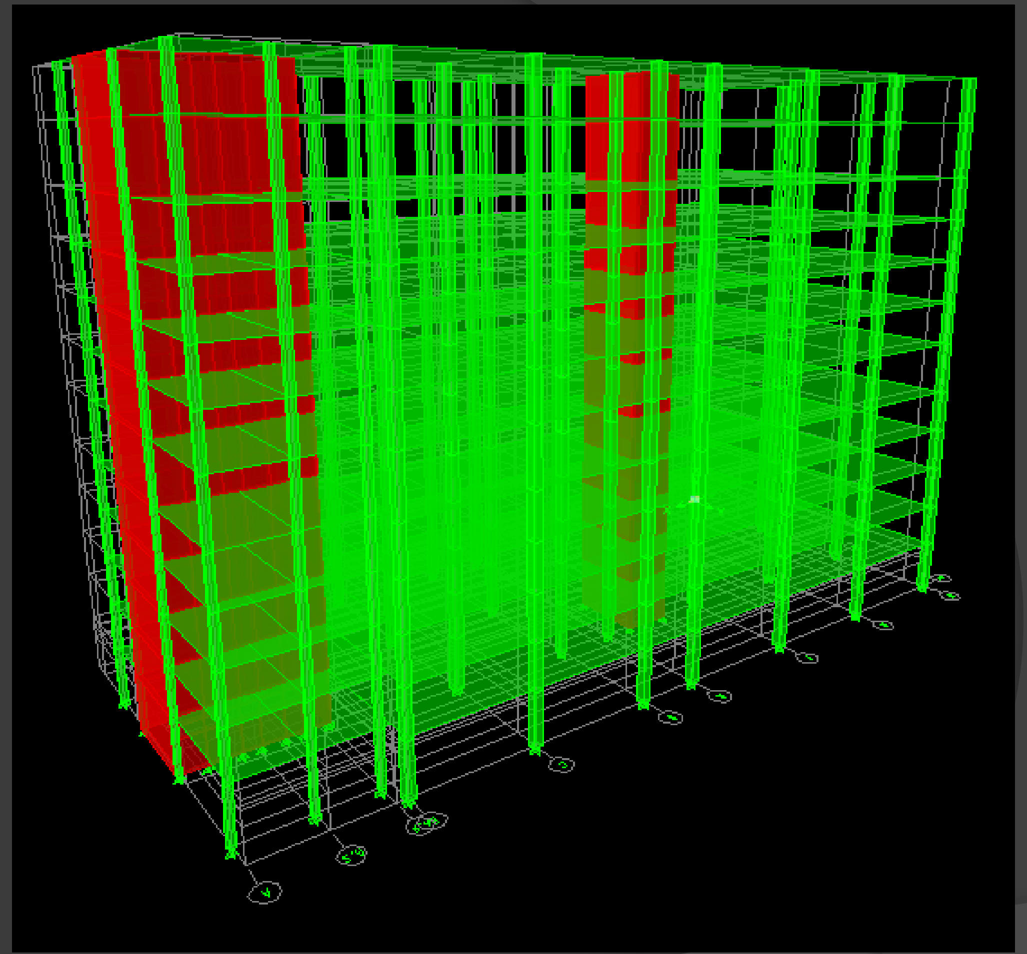
Existing Structural System

Lateral Force Resisting System

- Concrete moment frame
  - Typical 24” x 24” concrete columns
  - 9.5” Two-way slab
- Reinforced concrete shear cores
  - 2 Shear cores
    - Surrounding the stairs and the elevator
  - 12” thick reinforced concrete



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Structural Depth Analysis

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Proposal Review

Design a Steel Frame System with Composite Beam and Hollow core plank and lateral X bracing

- Goals
  - Decrease construction time
  - Decrease building weigh
  - Decrease total cost
  - Maintain the low floor to floor height

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Gravity System Redesign - Column

- ❑ W12 Steel Columns
- ❑ Live loads in accordance with ASCE 7-10
- ❑ Splices every 2 or 4 stories
- ❑ Only W12's to increase shape redundancy
- ❑ Designed by hand and checked with an Etabs model

Interior Column Sizing

Floor	Column Size
Roof	W12 x 50
11	W12 x 50
10	W12 x 50
9	W12 x 50
8	W12 x 79
7	W12 x 79
6	W12 x 79
5	W12 x 79
4	W12 x 120
3	W12 x 120
2	W12 x 120
1	W12 x 120

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Gravity System Redesign - Column

- Advantages
  - Lighter than concrete
  - Quicker erection than concrete
- Disadvantage
  - Requires Fireproofing
  - More columns per floor

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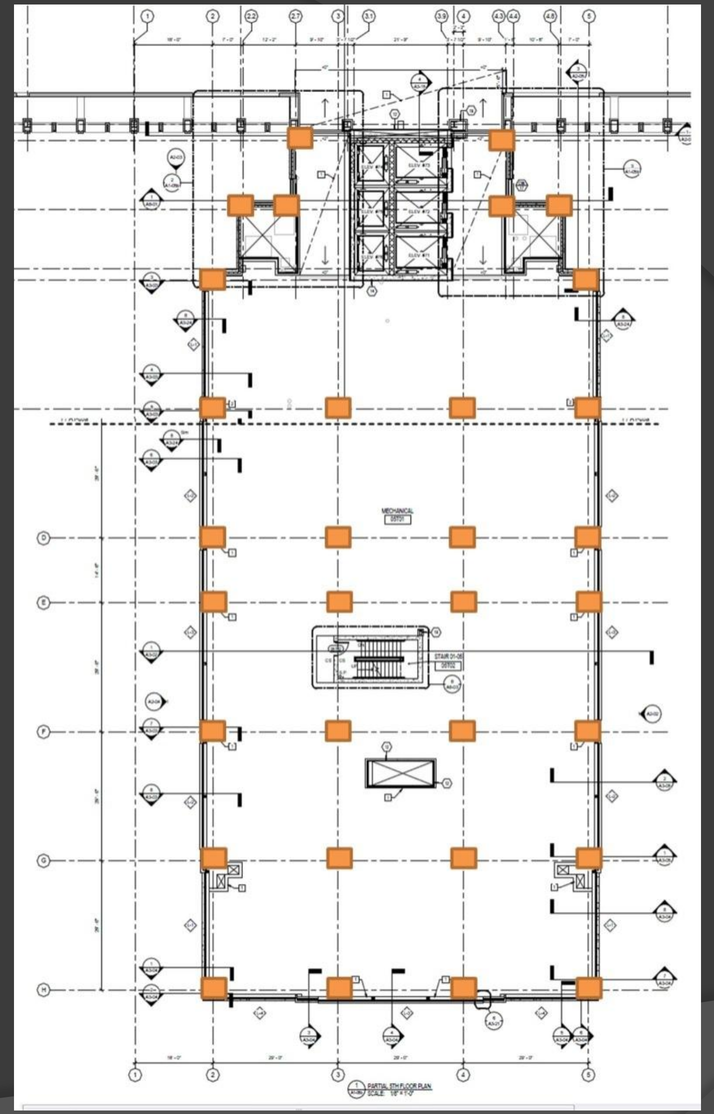

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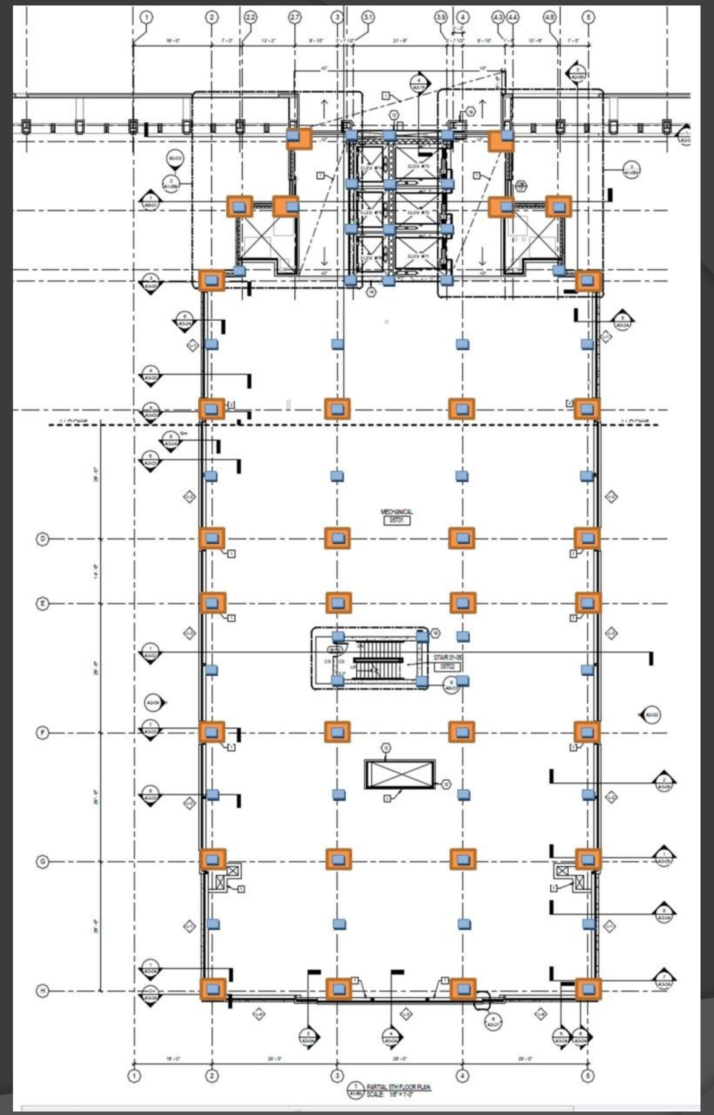

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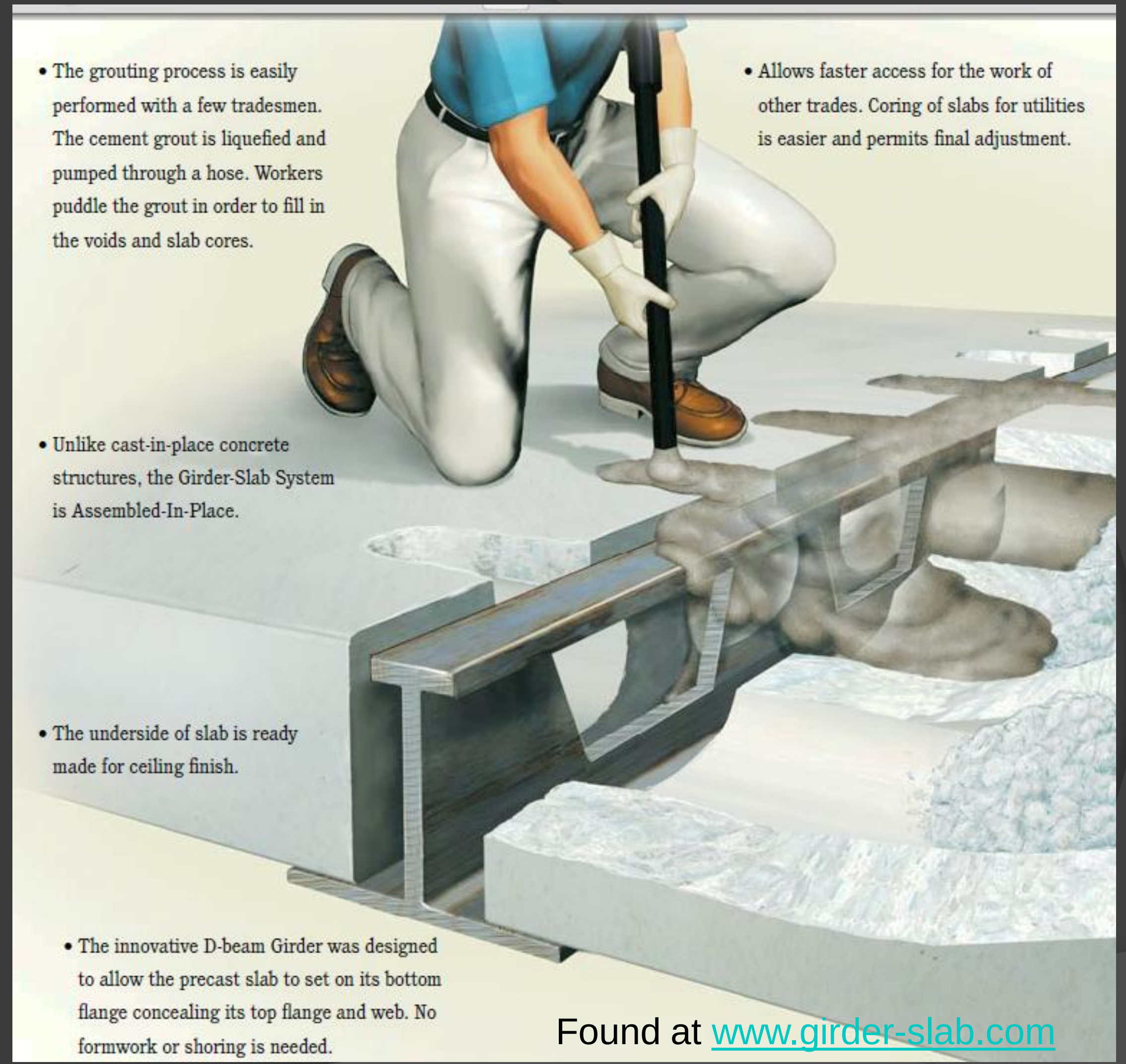
Gravity System Redesign – Floor Slab

- Girder Slab system
- Composite action
- 8” Hollow core plank
- 2” Concrete topping
- Modified W flanges and top flange



Found at www.girder-slab.com

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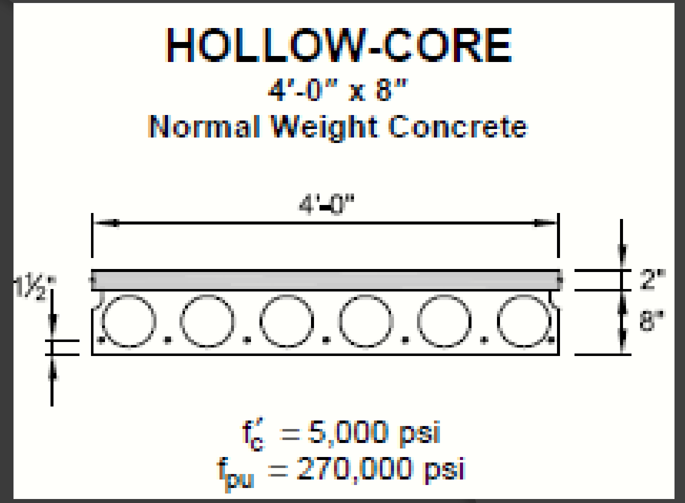
Hollow core plank design

- Live load = 80psf
- Dead Load = 10psf
- SDL = 25
- Max span = 29”
- Normal weight concrete
- 2” concrete topping



Results from PCI Design Handbook

- 78 – S
  - 7 strands at 8/16” dia.

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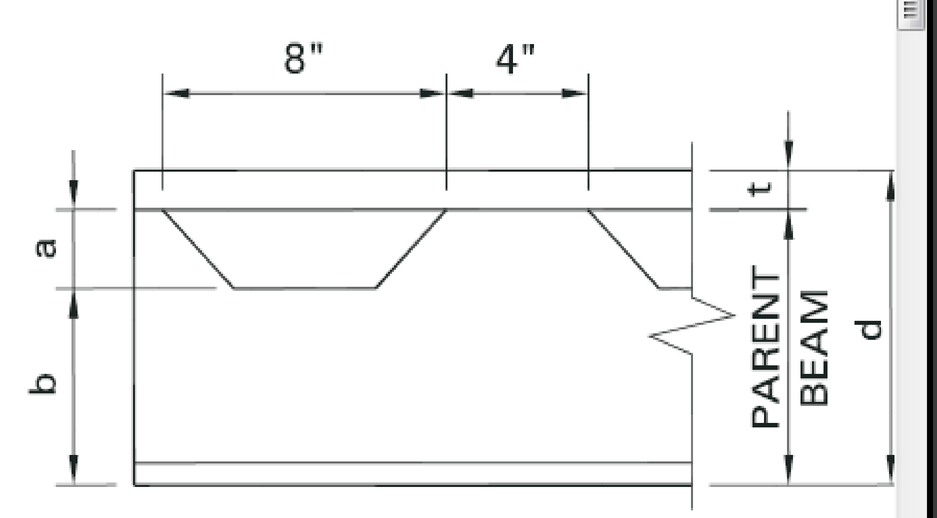
Gravity System Redesign - Floor Slab



D-Beam® Reference Calculator is Available on Website. www.girder-slab.com

- ❑ Girder Slab system
- ❑ Composite action
- ❑ 8” Hollow core plank
- ❑ 2” Concrete topping
- ❑ Modified W flanges and top flange

Designation	Web Included		Depth	Web	Parent Beam			Top Bar
	Weight	Avg. Area	d	Thickness t_w	Size	a	b	w x t
	lb/ft	in^2	in	in		in	in	in x in
DB 8 x 35	34.7	10.2	8	.340	W10 x 49	4	3	3 x 1
DB 8 x 37	36.7	10.8	8	.345	W12 x 53	2	5	3 x 1
DB 8 x 40	39.8	11.7	8	.340	W10 x 49	3	3.5	3 x 1.5
DB 8 x 42	41.8	12.3	8	.345	W12 x 53	1	5.5	3 x 1.5
DB 9 x 41	40.7	11.9	9.645	.375	W14 x 61	3.375	5.25	3 x 1
DB 9 x 46	45.8	13.4	9.645	.375	W14 x 61	2.375	5.75	3 x 1.5

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D-beam design

- Initial Load - Pre-composite
  - M_{DL}= 45.7ft-k < 84 ft-k
- Total Load - Composite
  - M_{sup}= 92.5
  - M_{tl}= 138.2
  - S_{req}= 55.3 < 68.6
- Superimposed Compressive Stress on Concrete
  - F_c= 2.25ksi > f_c=2.25ksi
- Bottom Flange Tension Stress - Total Load
  - F_b= 45ksi > f_b= 24.6
- Shear Check
  - F_v=20ksi > f_v= 17.7ksi

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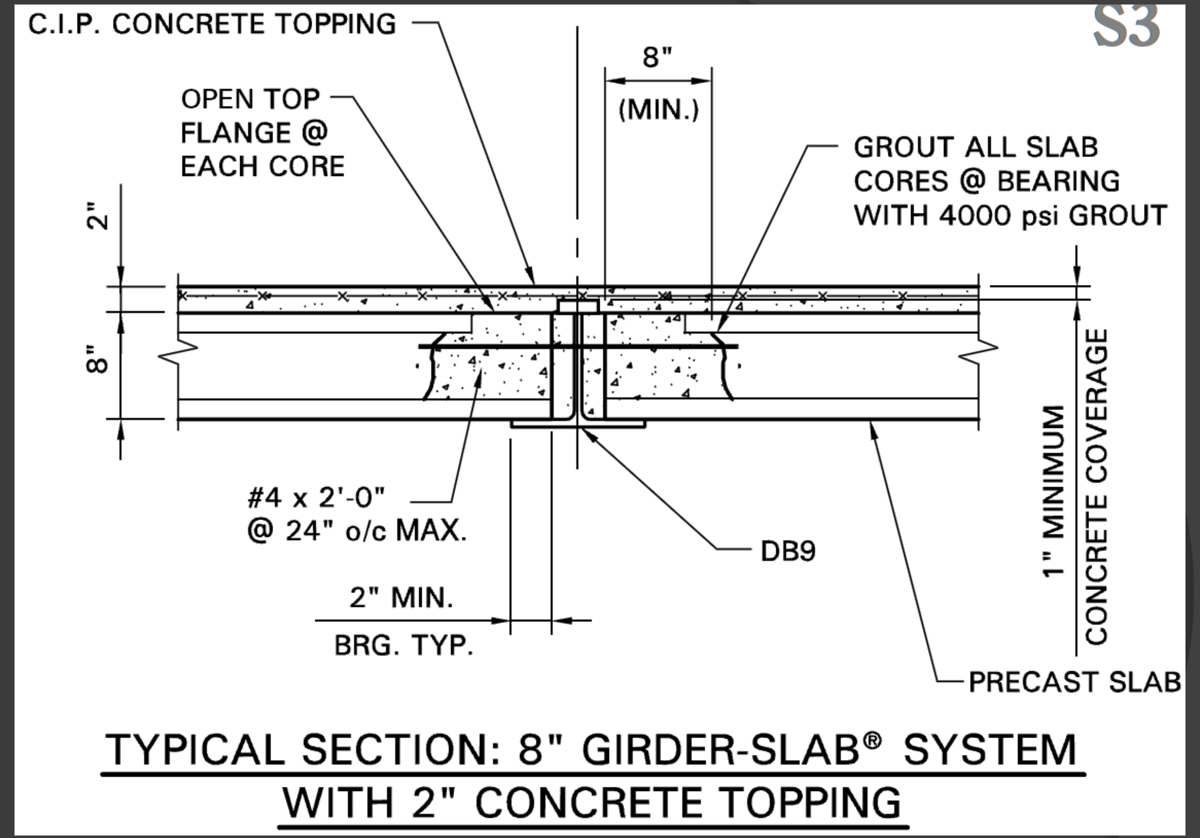
Gravity System Redesign – Floor Slab

- Advantages
  - Composite action
  - Low structural depth
- Disadvantage
  - Short beam spans



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Lateral System Redesign – Wind loads

Location Parameters for Northern Virginia

Table 5 - Wind Load Parameters	
Wind directionality factor (k_d)	0.85
Exposure Category	B
Topographic Factor (K_{zt})	1.0
Gust Effect Factor (G)	0.85
Basic Wind Speed	120 mph

- ASCE 7-10 chapter 27
  - MWFRS Directional Procedure (Table 27.2-1)

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Lateral System Redesign – Seismic loads

Dead weight comparison

- Decrease in building dead weight from concrete to steel frame

Total Building Weight Comparison (kips)	
Concrete Frame with Shear walls	Steel Frame with Hollow core plank
44,000	30,000

Ground Parameters for site location

General Seismic Information		
Occupancy		III
Site Class		D
Seismic Design Category		B
Short Period Spectral Response	S_s	13.5 % g
Spectral Response (1 Sec.)	S_1	5.5% g
Maximum Short Period Spectral Response	S_{MS}	0.216
Maximum Spectral Response (1 Sec.)	S_{M1}	0.132
Design Short Spectral Response	S_{DS}	0.144
Design Spectral Response (1 Sec.)	S_{D1}	0.088
Response Modification Coefficient	R	3.25
Seismic Response Coefficient	C_S	0.0218

- ASCE 7-10 chapter 11,12, 20-22

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Lateral System Redesign

Controlling Lateral Load Case

- East – West direction Wind Case 1 controls
- North – South direction Seismic controls

Lateral Load Cases							
Cases	Location	Load	Base Shear, V_x (k)	Base Shear, V_y (k)	Torsional Moment, M_z (ft-k)	Overturning Moment, M_x (ft-k)	Overturning Moment, M_y (ft-k)
Case 1	Base	WX	-441.6	0	230515.2	0	-437029
Case 1	Base	WY	0	-744.4	-851966	746575.2	0
Case 2	Base	WX	-332	0	119652	0	-329248
Case 2	Base	WY	0	-559	-831764	559398	0
Case 3	Base	WXY	-332	-559	-466472	559398	-329248
Case 4	Base	WXY	-248	-419	-453902	419822	-245568
Seismic	Base	QX	-649.9	0	373398.9	0	-783801
Seismic	Base	QY	0	-649.9	-790728	783800.6	0

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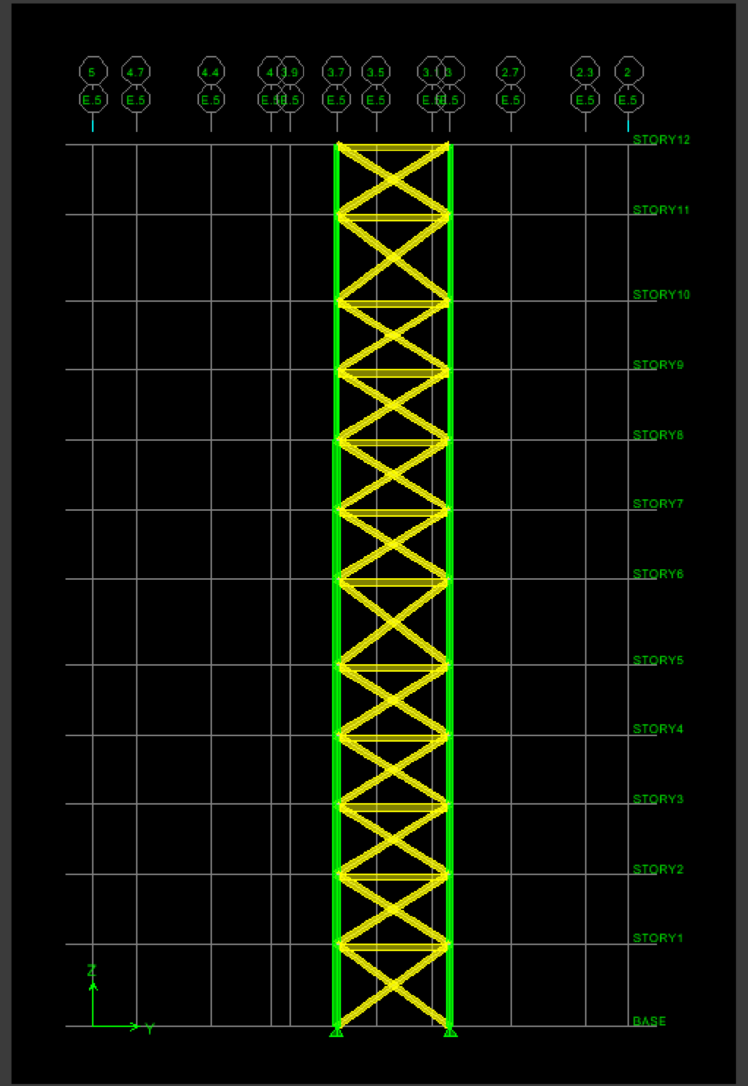

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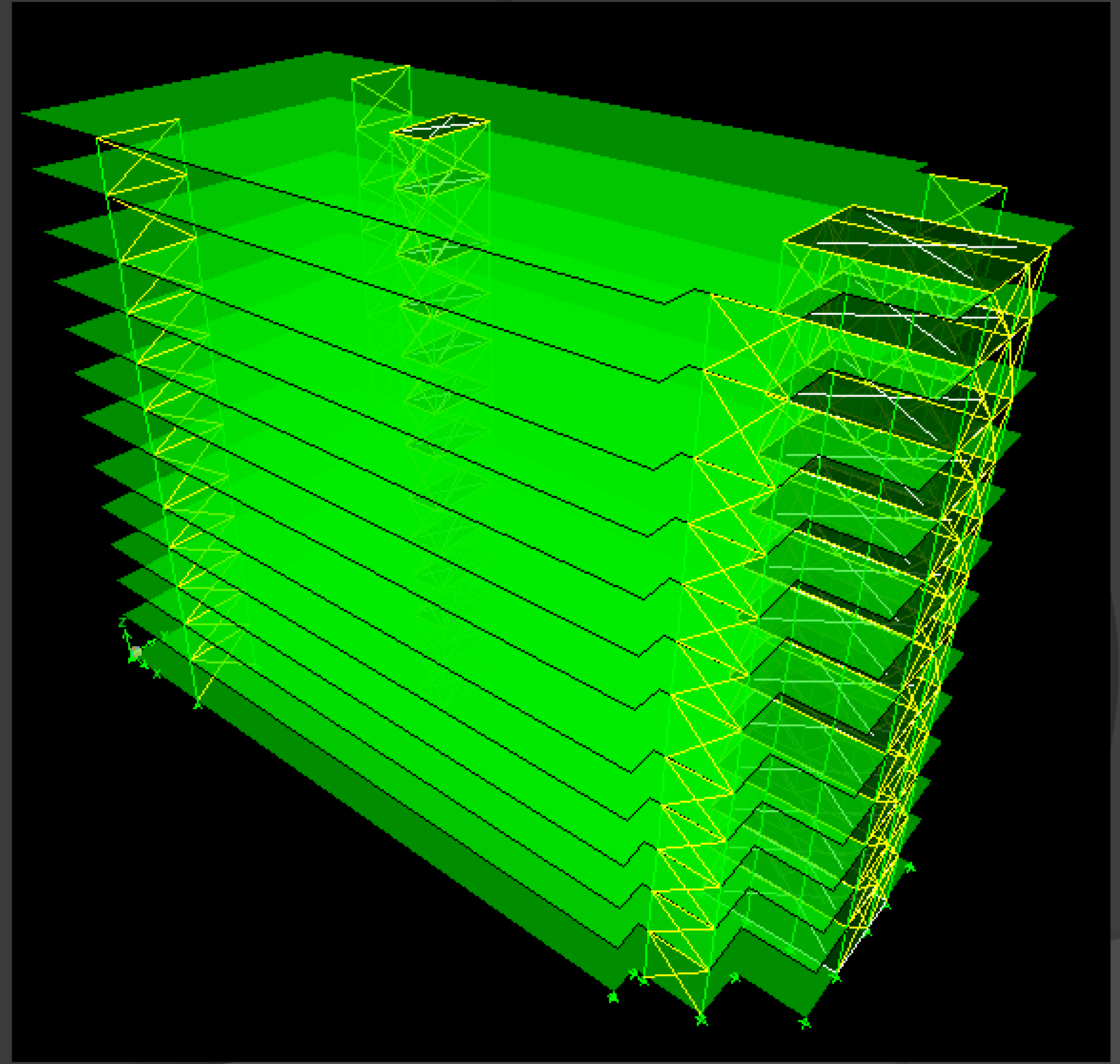
Lateral System Redesign

ETABS Model

- ❑ Assumptions
  - ❑ Braced frames will take full lateral loads
  - ❑ Floors modeled as rigid diaphragms
  - ❑ Lateral loads distributed based on relative stiffness of each wall
  - ❑ Gravity loads added as additional area mass to the diaphragms



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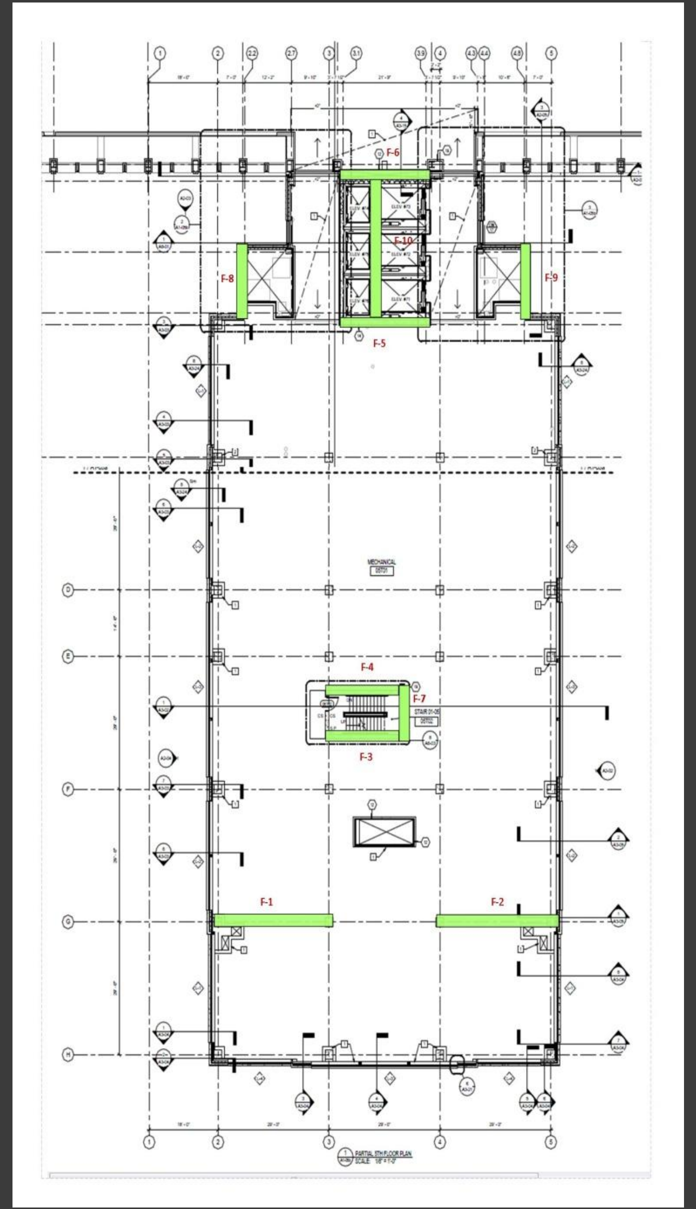

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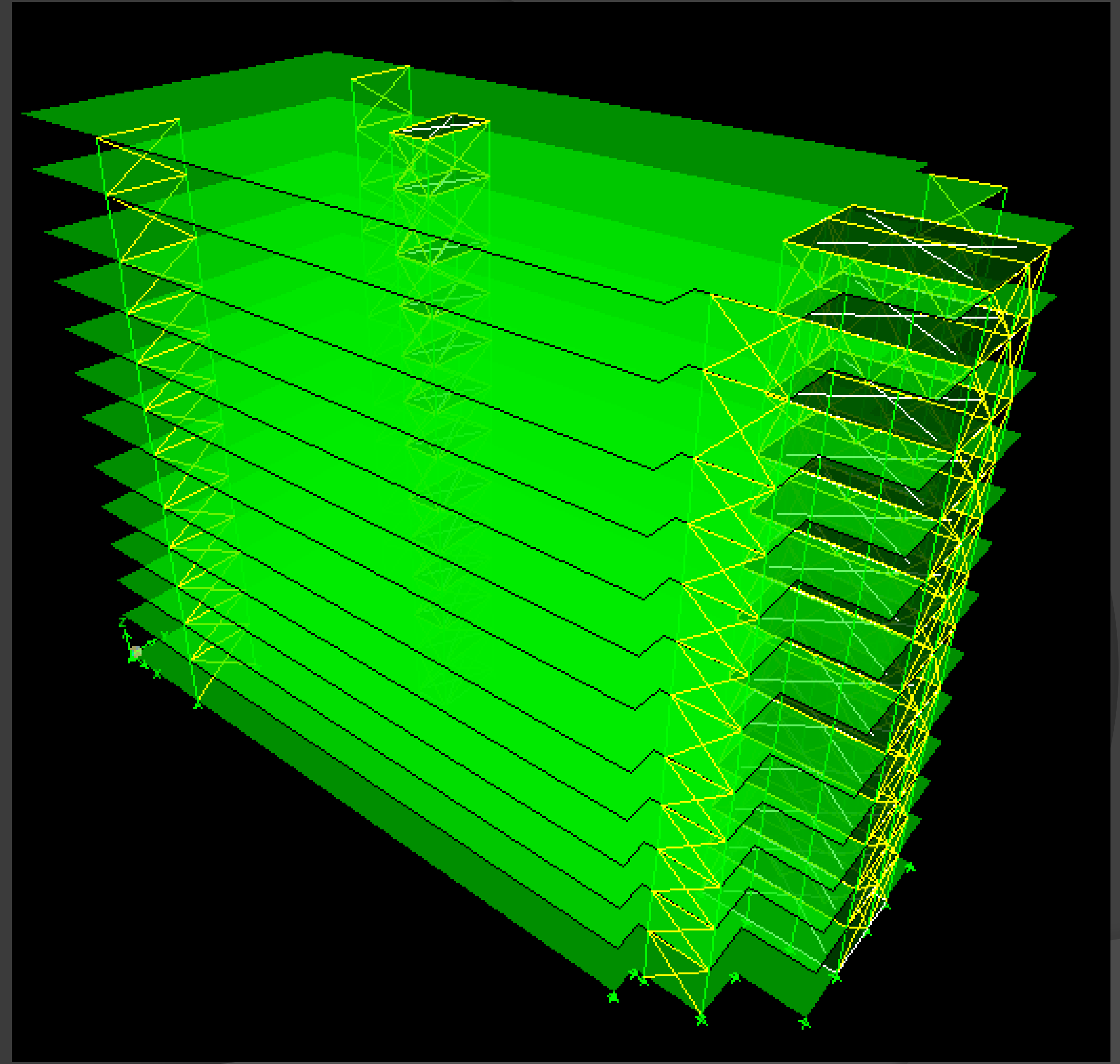
Lateral System Redesign

- 10 Braced Frames
- Columns
  - Range from W12 x 120 – W12 x 50
- Beams
  - W12 x 22
- X Bracing
  - HSS 10” x 12” x 0.5”

- Designed and checked with ETABS model
  - Hand check of relative stiffness



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Lateral System Redesign

Lateral Drift

- Drift Limitations
  - Wind – H/400
  - Seismic – 0.02h
- Controlling load combination
  - 0.9D + 1.0E

Diaphragm CM Displacements

Edit View

Diaphragm CM Displacements

Story	Diaphragm	Load	UX	UY	UZ
STORY12	D1	COMB1	-0.0026	-0.0145	0.0000
STORY12	D1	COMB2	-0.0022	-0.0124	0.0000
STORY12	D1	COMB3	0.7116	-0.0214	0.0000
STORY12	D1	COMB4	-0.0140	1.8134	0.0000
STORY12	D1	COMB5	1.4254	-0.0304	0.0000
STORY12	D1	COMB6	-0.0258	3.6392	0.0000
STORY12	D1	COMB7	2.7230	0.0153	0.0000
STORY12	D1	COMB8	-0.0170	4.0237	0.0000
STORY12	D1	COMB9	1.4260	-0.0273	0.0000
STORY12	D1	COMB10	-0.0253	3.6423	0.0000
STORY12	D1	COMB11	2.7235	0.0184	0.0000
STORY12	D1	COMB12	-0.0164	4.0268	0.0000
STORY12	D1	COMB13	-0.0022	-0.0124	0.0000
STORY11	D1	DEAD	[illegible]	[illegible]	[illegible]

Breadth Topics

Proposal Review

- Analysis steel frame construction schedule
- Compare structural system costs
- Check the acoustical criteria for the Intensive care units

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Schedule of Phase 1

Task Mode	Task Name	Duration	Start	Finish
	Column lines H-E L1-4	2 days	Tue 3/1/11	Wed 3/2/11
	Column lines D-A L1-4	2 days	Thu 3/3/11	Fri 3/4/11
	Beam Level 1	1 day	Mon 3/7/11	Mon 3/7/11
	Beam Level 2	1 day	Tue 3/8/11	Tue 3/8/11
	Beam Level 3	1 day	Wed 3/9/11	Wed 3/9/11
	Beam Level 4	1 day	Thu 3/10/11	Thu 3/10/11
	Plank Level 1	4 days	Tue 3/8/11	Fri 3/11/11
	Plank Level 2	4 days	Fri 3/11/11	Wed 3/16/11
	Plank Level 3	2.5 days	Mon 3/14/11	Wed 3/16/11
	Plank Level 4	2.5 days	Wed 3/16/11	Fri 3/18/11

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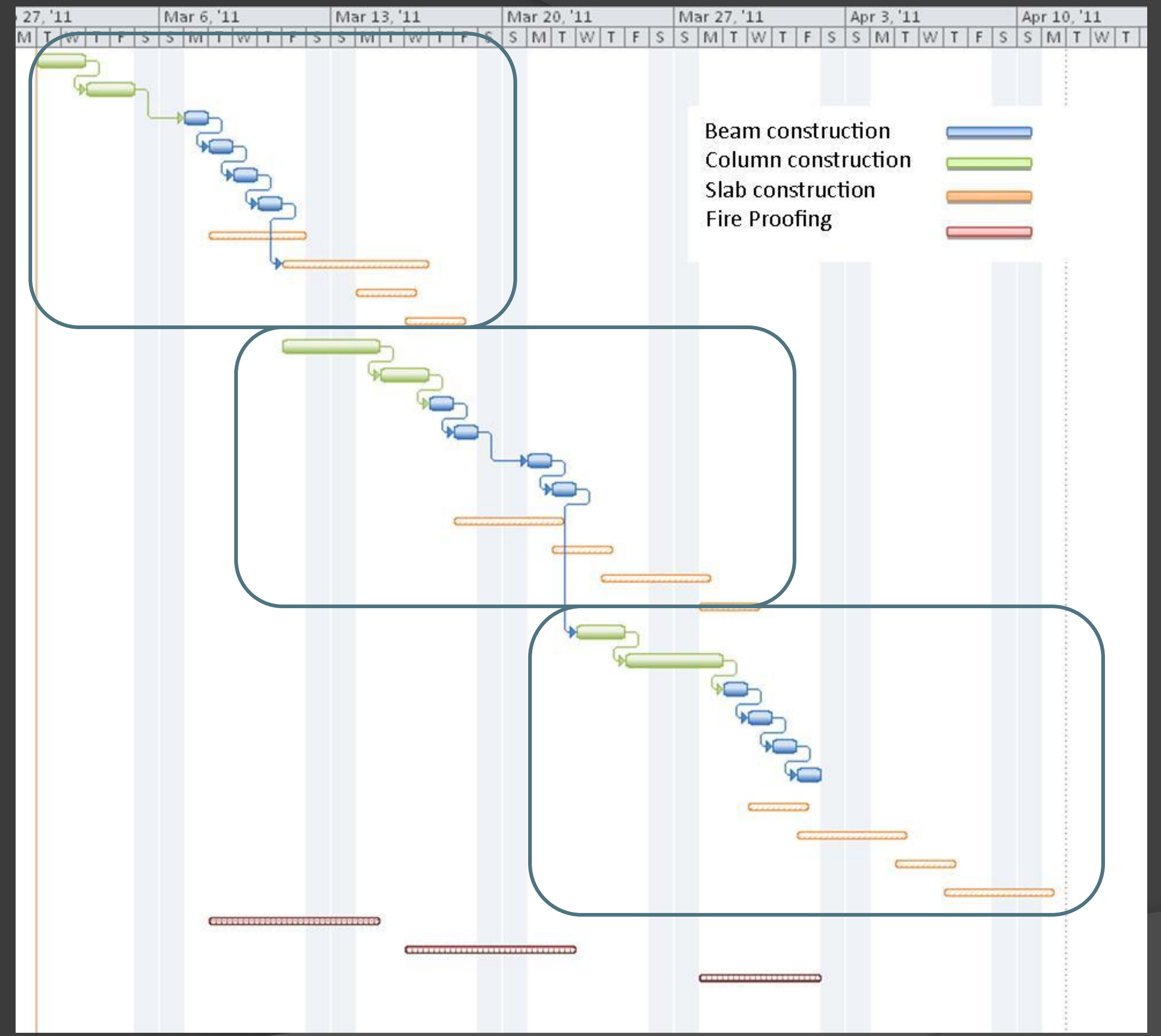
Construction Management – Schedule

- ❑ Scheduled using RS means 2011 Data
- ❑ Constructed in 3 Phases
- ❑ 2 Erection crews
- ❑ Task overlapping

Structural Erection Time comparison (# days)	
Concrete Frame with Shear walls	Steel Frame with Hollow core plank
97	24

3.5 month decrease in construction time



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Construction Management – Cost

- Cost using RS means 2011 Assemblies Data
  - 2 way reinforced concrete slab
  - Hollow core plank and steel beams

Systems Cost Comparison	
Concrete Frame with Shear walls	Steel Frame with Hollow core plank
$ 18/sf	$ 27/sf
$ 4,000,000	$ 6,000,000

$9.00 per s.f. increase in the cost of the structure
2 million dollar increase in total cost.

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Construction Management – Summary

Summary

- ❑ 2 million dollar increase in up front cost
- ❑ 3.5 month decrease in construction time
- ❑ Average revenue for a hospital would at least match the up front cost

Recommendations & Conclusion

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Goals

- Decease construction time ✓
- Decrease building weight ✓
- Decrease total cost =
- Maintain the low floor to floor height ✓

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Conclusion

After much consideration I feel that the proposed steel frame and girder slab system would be a feasible alternative to the existing cast in place concrete structure but I don't not feel that either system is with out its cons.

Acknowledgments & Questions

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Acknowledgment's

Professor Bob Holland – Senior Thesis Instructor
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Lastly, I would like to extend my gratitude to my family and friends for their unconditional support and encouragement.

Questions ??

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