UNC Imaging Research Building

Chapel Hill, NC

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AE Senior Thesis l Spring 2010

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Outline

- Existing Building Information
- Project Goals
- Structural Depth Study
- Construction Management Breadth
- Blast Resistant Façade Breadth
- Conclusions
- Acknowledgements
- Questions and Comments

Existing Building Information

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Location

- UNC's Chapel Hill Campus

Building Statistics

- Office/Laboratory/Imaging Equipment
- Size | 325,000 sq. ft.
- Stories | 8 above grade / 2 below grade = 10 Total + Penthouse

Total Project Cost

- $230 million (Estimated)

Perspective from Northwest Corner

Credit: Perkins + Will

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Architectural Design Concept

- Laboratory space and imaging equipment
- South Facade
  - Aluminum and glass curtain wall
  - Horizontal sunshades
- North Facade
  - Bridge to Lineberger Cancer Center
- Concrete stair and elevator cores

South Elevation
Credit: Perkins + Will

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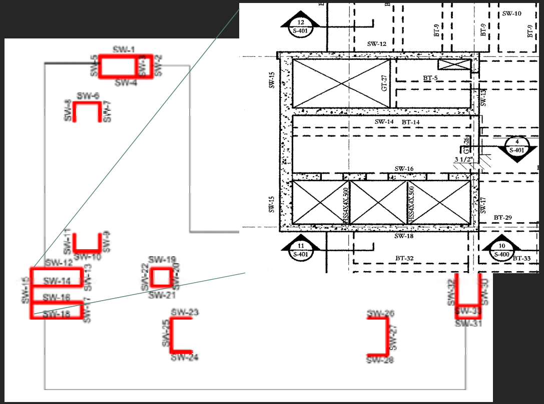
Structural System

- 6” thick one-way cast-in-place concrete slabs
- Spread, continuous and mat slab foundation system
- 12” and 16” thick ordinary reinforced concrete shear walls
- 20”x20” & 24”x24” columns
- 18”x20” T-Beams
- 28”x30” Girders
- Steel mechanical penthouse structure
- Varying concrete strengths – 5 ksi to 10 ksi



Project Goals

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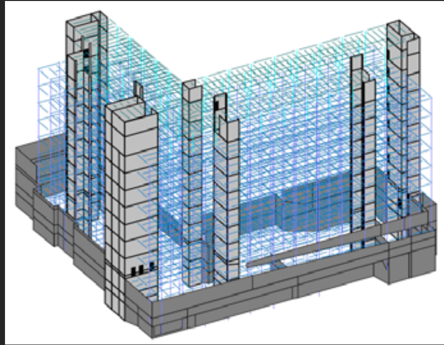
Problem Statement

- Complete concrete structure
- Bulky and heavy
  - Reduced usable floor area
  - Reduced vertical trade space
- Time consuming and costly
  - Formwork
  - Labor
  - Construction schedule



Existing Concrete Structure RAM Model

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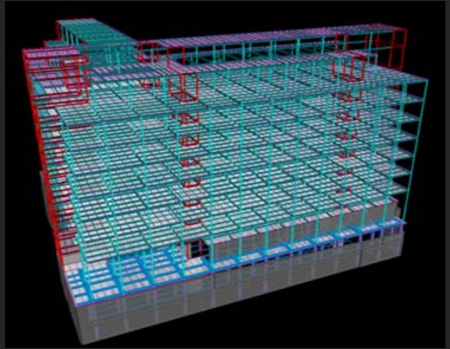
- Structural Depth Study | Gravity system redesign
  - Steel framing with composite floor system
- Structural Depth Study | Lateral system redesign
  - Special concentric braced frames
- Construction Management Breadth
  - Cost analysis
  - Comparison of steel framing to concrete
- Blast Resistant Façade Breadth



Steel Redesign RAM Model

Structural Depth Study

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Design Goals

- To maintain the current column layout as much as possible
- To design the new composite floor system efficiently so that the total depth of the system is less than the original to free up vertical trade space
- Use RAM and confirm designs with hand calculations
- To present a design that has a shorter construction schedule and less cost
- To follow all codes and standards during the redesign

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- Design Loads
  - ASCE 7-05
    - Live load values
    - Superimposed load values
  - Controlling load combination
    - 1.2 D + 1.6L + 0.5 Lr
- Lateral Loads
  - Wind
    - East/West
    - North/South

Table 1 -Gravity Loads		
Description	Mulkey	ASCE 7-05
DEAD (DL)		
Reinforced Normal Weight Concrete	150 pcf	150 pcf
Slab + Deck	65 psf	65 psf
LIVE (LL)		
Roof	30 psf	20 psf
Offices	50 psf	50 psf
Public Areas, Lobbies	100 psf	100 psf
Laboratories	100 psf	60 psf
Corridors, 2nd & Above	100 psf	100 psf
Corridors Ground	100 psf	100 psf
Stairs	100 psf	100 psf
Catwalk	40 psf	40 psf
Storage	125 psf	125 psf
Heavy File Storage	200 psf	250 psf
Mechanical Rooms	150 psf	150 psf
Level B1	150 psf	N/A
SNOW (S)		
Snow	16.5 psf	16.5 psf
SUPERIMPOSED (SDL)		
Finishes, MEP, Partions	25 psf	25 psf
Bathroom Terrazo	40 psf	N/A
Lobby Terrazo	60 psf	N/A
Mechanical Courtyard	300 psf	N/A
3T MRI Room	250 psf	N/A
7T Sheilding	75 psf	N/A
Hot Cells	350 psf	N/A
Water Tank	350 psf	N/A

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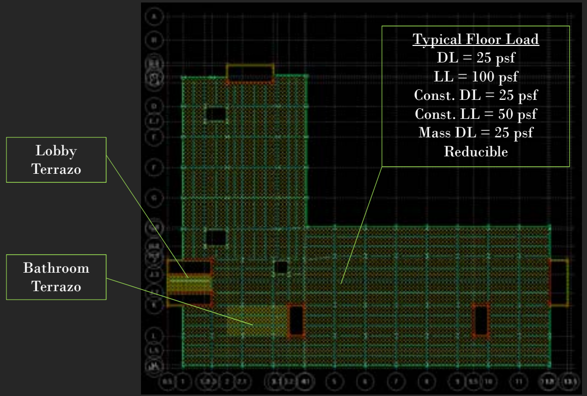
- Design Process
  - Maintain existing column layout
  - Determination of loads
    - Area Loads
    - Line Loads
  - Model in RAM
    - Deck Selection
    - Layout of Framing
    - Braced Frame Locations
  - Hand Calculations



Typical Floor Loads

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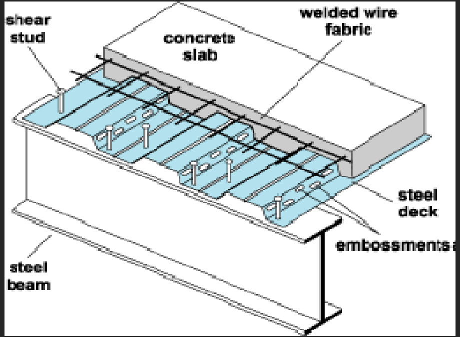
Floor System

- Composite metal deck
- Design governed by load, span
- Vulcraft Product Catalog
  - 2", 20 gage deck with 4 ¼" lightweight concrete
- Benefits
  - Speed of steel construction
  - No shoring
  - Slight increase in thickness
- Drawbacks
  - Shorter spans



Composite Deck Design

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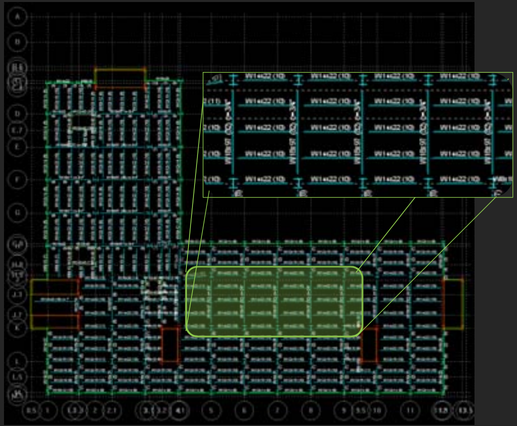
Gravity Framing

- Multiple iterations
- Optimization of beams
  - Repetition was used
  - Typical beam depth– W14's and W12's
- Girders mostly restricted to W18's
  - Problem area – middle bays
    - Optimized shape was a W24 x 68
    - Depth reduced to W18 x 97's w/ c=3/4"



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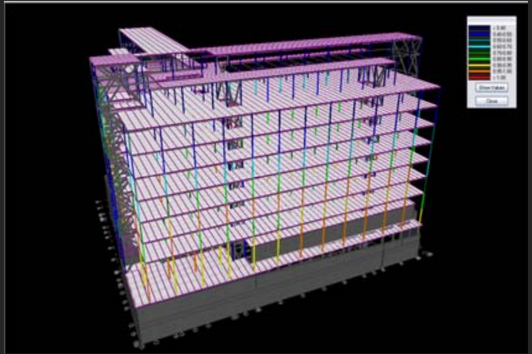
Gravity Framing

- Column layout restricted to current design
  - Columns added at corner of shear walls
- Multiple iterations
- Repetition was used
- Column splices between every other level
- Gravity columns kept to 14" depth
  - Compared to existing 24"x24" and 20"x20" concrete columns



Column Code Check

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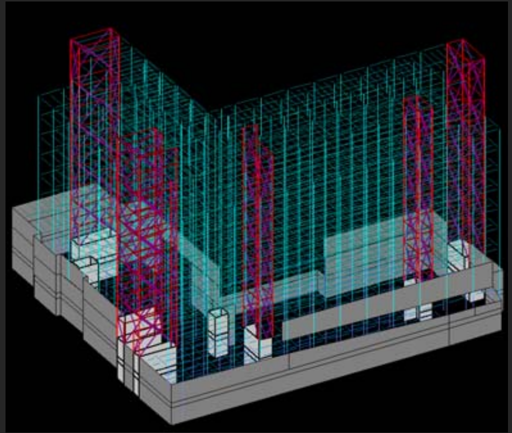
Lateral Framing

- Original design – Ordinary reinforced concrete shear walls
- Considered designing connections to steel frame
- Chose steel lateral system
- Only above grade
- Designed in RAM
- Multiple Iterations
  - Began with moment frames
    - Costly
    - Too flexible, strength and drift concerns
  - Decided to use braced frames



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Lateral Framing
- Assumptions and Criteria:
  - Rigid diaphragm was modeled at every floor with lateral load assigned to diaphragm
  - Load combinations were generated according to relevant codes
  - Braces were assumed pinned at each end
  - P-Delta effects were taken into account
  - Ground level set at floor 1

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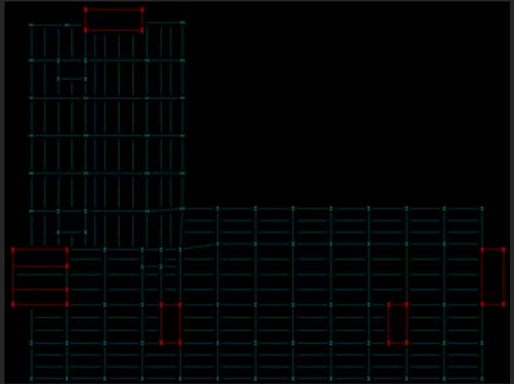
Lateral Framing

- Frame locations originally same as shear walls
- Realized not practical
  - Some frames around mechanical shafts eliminated
- BRBF's vs. OCBF's vs. SCBF's
  - BRBF's
    - Not as common, modeling complexity
  - OCBF's
    - Lower R value, less ductile
    - Benefits - less expensive, less detailing requirements



Lateral Frame Locations

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Lateral Framing

- Special Concentric Braced Frames (SCBF's)
  - R value of 6
  - Benefits
    - Able to reduce number of frames
  - Drawbacks
    - Special detailing requirements, more expensive
- Final Design
  - Modified "X" or 2-story "X"
    - Dissipates energy along height of frame
    - Braces buckle simultaneously at all floors

Lateral Framing

- Repetition
- Beams and Columns
  - W Shapes
- Braces
  - HSS 10x10x1/2"
- Realize does not meet goal of not interfering with architecture
  - Door locations
  - Columns slightly wider than existing shear walls

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Serviceability

- Two criteria
  - Wind: h/400
  - Seismic: 0.020hsx
    - Amplified according to 12.8 ASCE 7-05

$$\delta x = \frac{C_d \, x \, \delta_{xe}}{I}$$

- Drifts taken from RAM Frame
- Inherent Torsion
  - But COM and COR were very close

Table 2 - Story and Overall Drifts for Steel Redesign

Floor	Height Above Ground- z (ft)	Story Height (ft)	Wind North/South Drift (in)		Wind East/West Drift (in)		Wind Allowable Drift (in)		Seismic North/South Drift (in)		Seismic East/West Drift (in)		Seismic Allowable Drift (in)	
			Story	Total	Story	Total	Story	Total	Story	Total	Story	Total	Story	Total
Roof	162.00	14.33	0.38	2.70	0.27	1.93	0.43	4.86	0.20	1.41	0.22	1.49	3.44	38.88
Mech Mez.	148.66	16.66	0.33	2.43	0.24	1.74	0.50	4.46	0.18	1.31	0.20	1.37	4.00	35.68
8	130.00	16.00	0.33	2.06	0.24	1.47	0.48	3.90	0.18	1.08	0.19	1.15	3.84	31.20
7	114.00	16.00	0.33	1.73	0.24	1.23	0.48	3.42	0.18	0.89	0.19	0.96	3.84	27.36
6	98.00	16.00	0.31	1.39	0.22	0.99	0.48	2.94	0.16	0.71	0.17	0.76	3.84	23.52
5	82.00	16.00	0.29	1.06	0.21	0.76	0.48	2.46	0.15	0.53	0.17	0.57	3.84	19.68
4	66.00	16.00	0.24	0.75	0.16	0.54	0.48	1.98	0.12	0.37	0.12	0.40	3.84	15.84
3	50.00	16.00	0.22	0.46	0.17	0.33	0.48	1.50	0.10	0.22	0.12	0.23	3.84	12.00
2	34.00	16.00	0.22	0.22	0.17	0.17	0.48	1.02	0.10	0.10	0.12	0.12	3.84	8.16

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Impact on Foundation

- Initial trials in RAM
- Complete redesign was not warranted
- Spread footings could be reduced under columns
- Mat foundations
  - Support lateral frames and imaging equipment
  - Size controlled by load from imaging equipment
  - Still will encompass over half of building

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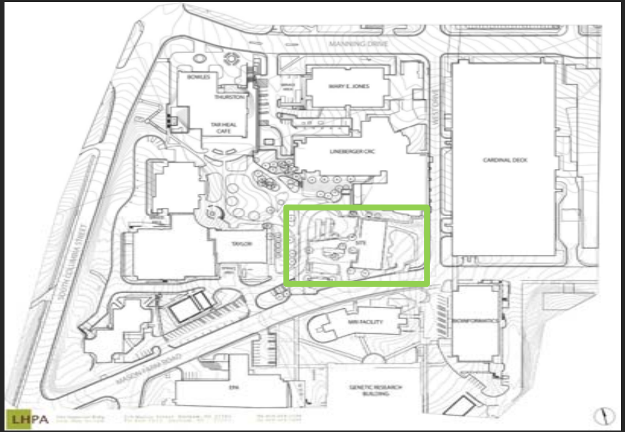
Site

- Small site
- Proximity to Lineberger Cancer Center
  - Concerns during excavation
  - Blasting
- Staging concerns



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Cost Analysis

- Initial square foot cost estimate
  - R.S. Means Construction Cost Data online catalog
  - Not relevant, uniqueness of building
  - "apples to apples" comparison of structure
- Detailed estimate
  - R.S. Means
  - Takeoff from RAM
  - Only beams & girders, columns, and lateral frames

Table 4.2 - Structural Material, Labor, and Equipment Totals		
Steel		
Summary	***Cost Per Square Foot($/SF)***	***Total Cost($)***
Material Total	$40.26	$3,351,091.08
Labor Total	$2.09	$174,227.83
Equipment Total	$1.87	$155,824.62
Total	$44.22	$3,681,143.53
Concrete		
Summary	***Cost Per Square Foot($/SF)***	***Total Cost($)***
Material Total	$24.77	$2,062,368.33
Labor Total	$32.26	$2,685,458.12
Equipment Total	$0.95	$79,250.54
Total	$57.99	$4,827,076.98

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Schedule Analysis

- Compared structural components only
- Above grade
- Linear analysis
- Crews based on RS Means

Steel		Concrete
225 days	<	315 days

- Can be reduced
  - Addition of more crews
  - Overlapping of activities

Blast Resistant Façade Breadth

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Design Process

- Two major codes
  - GSA/Interagency Security Committee Security Design Criteria
  - DoD Unified Facilities Code UFC 4-010-01, Minimum Antiterrorism Standards for Buildings
- Standoff distance = 50 ft
- Equivalent charge weight = 220 lbs
- Using ASTM F 224-08
  - 3-second equivalent design pressure = 250 psf

Device	Description	Charge Weight (TNT Equiv. lbs)
	Pipe Bomb	5
	Suitcase	50
	Compact Sedan	220
	Full Size Sedan	500
	Passenger / Cargo Van	1,000
	Box Truck	4,000
	Semi-Trailer	40,000

USDOT Equivalent Charge Weight

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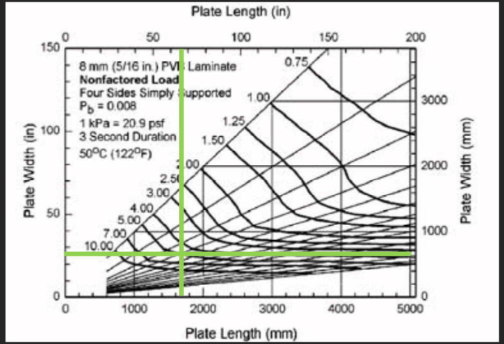
Glass Options

- Heat Strengthened vs. Annealed vs. Fully Tempered
- Load Resistance
  - LR = 2 x 1.8 x NFL > 3-sec design pressure of 250 psf
    - NFL – Non-Factored Load
    - 2 lites, 1.8 for heat strengthened
- Plate size = 66" x 24"
- Multiple Iterations
- 5/16" heat strengthened, laminate insulated glass
  - LR = 18kPA = 376.2 psf > 250 psf
- Mullions and frames deflection limit of L/160
- Connections need to withstand 2 times capacity of glass



Non-Factored Load Chart

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Conclusions

- Reduced Floor System Depth ☑
    - 30" to 24 ¼"
- Designed steel lateral system ☑
- Maintained architectural concepts
    - Reduced columns sizes in gravity framing
    - Redesigned lateral system deeper than existing shear walls
- Cost of steel redesign less than concrete ☑
    - 3.7 vs 4.8 million
- Reduced schedule time to complete superstructure ☑
- Redesigned façade for blast resistance ☑

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Questions and Comments