North Mountain
Integarted Medical Services
Office Building

Phoenix, Arizona

Integration of Sustainable Structural Elements and Evaluating Mechanical System Effects

Mike Hopple
Structural Option
AE Senior Thesis – Spring 2008
Penn State University

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Presentation Outline

1. North Mountain Background
2. As Designed Conditions
3. Project Objective/Design Goals
4. Sustainable Architecture Breadth
5. Mechanical Breadth
6. Structural Depth
7. Conclusions and Recommendations
8. Questions and Comments

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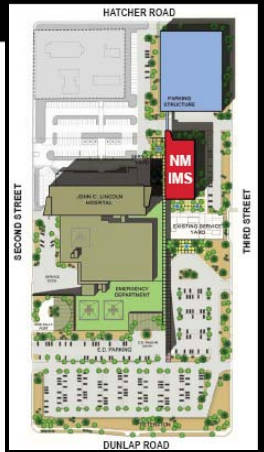
North Mountain Background

- Part of John C. Lincoln Hospital
- Ground floor features state-of-the-art imaging center and an outpatient ambulatory surgery center
- Remaining three floors encompass over 92,000 square feet of rentable office space
- Four floors total 124,000 square feet
- Floor to floor height of 14’ and total building height of 60’
- Estimated Cost: $10 million
- Design – Build contract
- Construction began June 2007



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Gravity System As Designed

- Double Tees
  - 44’ – 54’ long, 24” deep, 10’ wide
  - Stems contain (6) ½” diameter 270 ksi low relaxation strand (typ.)
- Inverted Tee Girders
  - Span 28’ between columns, 24” deep, 32” wide
  - Contains (22) prestressing strands
- Columns
  - 56’ in length, 24” x 24”
  - One connection to complete erection
- Foundations
  - Drilled piers up to 30’ deep and 6’ in diameter
  - Grade beams span over piers and support exterior wall panels

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Lateral System As Designed

- Load bearing precast concrete shear walls
  - 30'-0" x 14'-0" x 11"-15"
  - f'c = 5000 psi
  - Reinforced with #4 bars at 12" o.c. (typ.)
  - Responsible for gravity, wind and seismic loads
  - Also provides the building enclosure

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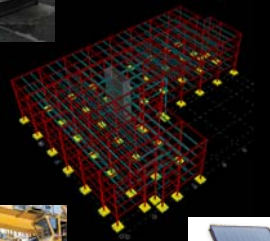
Project Objective / Design Goals

- Sustainable Architecture Breadth
  - Environmental effects of steel vs. concrete building frames
  - Addition of a green roof
  - Evaluate thermal properties of precast concrete sandwich panels
- Mechanical Breadth
  - Heating and cooling load reduction
- Structural Design Depth
  - Change precast structure to steel framing
  - Design precast concrete sandwich panels



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Sustainable Architecture Breadth

- Environmental Effects of Steel vs. Concrete Building Frames
  - Life-cycle Assessment (LCA)
    - **Material Extraction and Manufacturing**
      - Structural steel contains 95% recycled content
      - Steel sizes are made to exact specifications; production waste is minimal
      - Welding releases volatile organic compounds (VOCs) and heavy metals into the atmosphere
      - Industrial by-products like fly-ash, slag cement and silica fume can be used in cement
      - Formwork creates construction waste
      - Precast concrete shop setting minimizes waste

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Sustainable Architecture Breadth

- Environmental Effects of Steel vs. Concrete Building Frames
  - Life-cycle Assessment (LCA)
    - **Building Construction**
      - Transportation largest issue
      - Steel frame requires less truck mileage
      - Steel members are much lighter
      - Concrete frames contain more embodied energy due to temporary formwork
    - **Building Use and Maintenance**
      - Negligible environmental impacts between each frame system

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Sustainable Architecture Breadth

- Environmental Effects of Steel vs. Concrete Building Frames
  - Life-cycle Assessment (LCA)
    - **Building End-of-life**
      - Includes demolition and transportation of debris off site
      - Concrete frame requires more trucks to remove debris due to its large mass
      - Almost 100% of structural steel is recyclable
      - Concrete can be recycled into aggregate for road bases and fill
  - Energy required by frame construction accounts for up to 10% of total energy required throughout building life span
  - Overall differences between steel and concrete minimal
  - More research is needed to quantify environmental impacts

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Sustainable Architecture Breadth

- Green Roof Benefits
  - Reduces heat island effect
  - Reduces energy requirements for the building
  - Gives back land area that the building footprint occupies
- Green Roof Concerns
  - Phoenix averages only 7 inches of rain a year
  - Landscape architects consider plant selection proprietary information
  - Desert plants have large root systems

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Sustainable Architecture Breadth

- Green Roof Vegetation
  - **Trailing Rosemary:** As one of the best and toughest plants for arid growing zones, trailing rosemary does well in poor or shallow soils. It tolerates great heat and blazing sun as well as cold climates.
  - **Damianita :** This ground cover is a star performer in the arid Southwest. This plant has a long bloom period, but flowers are most profuse in the spring and fall.
  - **Prickly Pear :** Easily grown in dry, sandy or gravelly, well-drained soils in full sun.
  - **Hedgehog Cactus :** A small barrel-shaped cactus. Flowers are scarlet red, with many petals, and are cup-shaped. This is the first cactus to bloom in the spring.

Trailing Rosemary

Damianita

Prickly Pear

Hedghog Cactus

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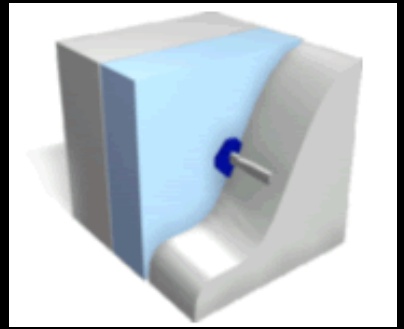
Sustainable Architecture Breadth

- Precast Concrete Sandwich Panels
  - Selected to increase thermal efficiency
  - Uses 3” Polyisocyanurate insulation
  - Maintains original building aesthetic exterior
  - Panels provide required insulation value
  - Windows changed from single pane to 1” IGU
  - Increased R-value by 247%



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Mechanical Design Breadth

- Heating and Cooling Load Reduction
  - Computed heating and cooling loads using TRACE 700
  - Entered new u-values for roof and exterior walls
  - Cooling load was reduced by 35%
    - Direct effect of added insulation and reduced solar gain
  - Heating load increased by 1%
    - Accounted for by the reduction of solar gain and thermal mass

Design and Calculated Loads

	Heating (Btu/h)	Cooling (tons)
Design Professional	641,650	341
Calculated Exisiting	670,678	394
Calculated Redesign	681,226	256

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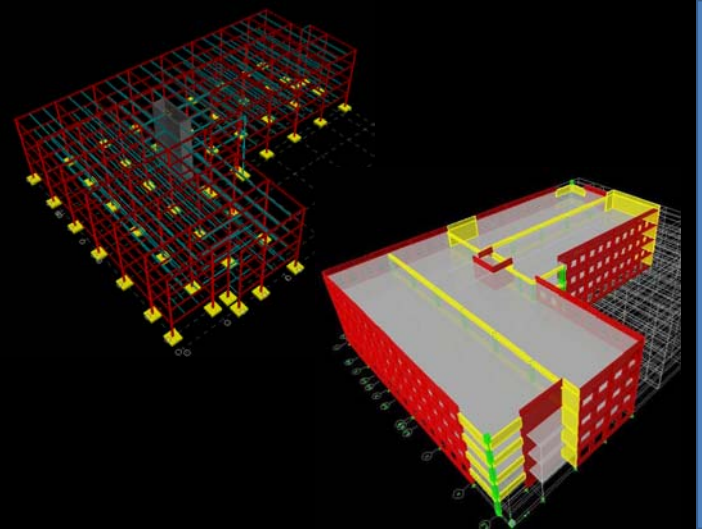
Structural Design Depth

- Precast to Steel Framing
  - Gravity system redesign
  - Lateral system redesign
  - Foundation system redesign
  - Building enclosure design



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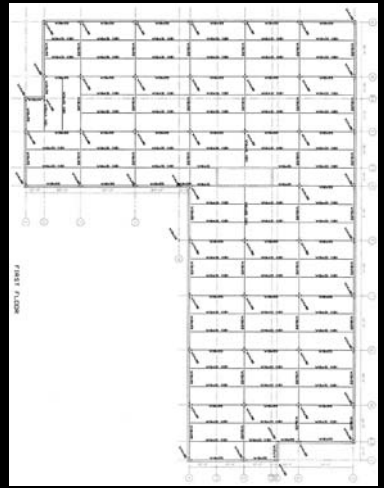
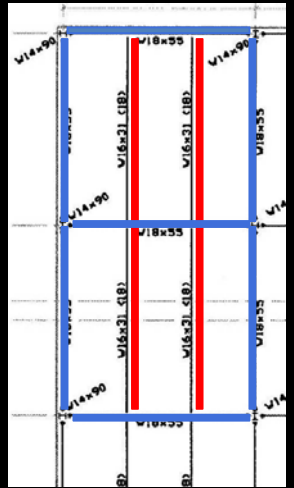
Structural Design Depth

- Gravity System
  - System consists of infill beams only
  - Beams are spaced at 10'-0" o.c. and span 30'-0"
  - Shear studs ensure composite action with floor slab
  - Typical sizes:
    - W16x31 beams (18 studs) for office floors
    - W18x35 beams (22 studs) for roof
  - Loading:

Roof Live Load	20 psf
Floor Live Load	80 psf
Partition Live Load	20 psf
Superimposed Roof Dead Load	15 psf
Green Roof Dead Load	100 psf
Superimposed Floor Dead Load	15 psf





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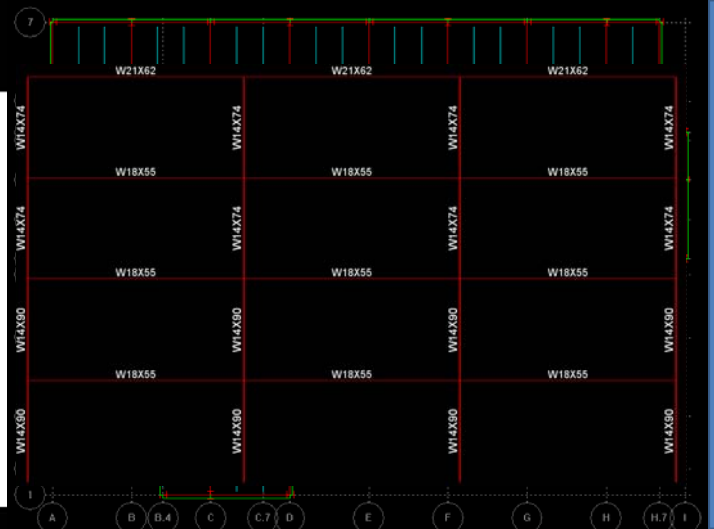
Structural Design Depth

- Lateral System
  - Ordinary steel moment frames
  - Arranged in a space frame configuration
  - All girder column connections designed as rigid
  - Typical sizes
    - W18x55 girders for office floors
    - W21x62 girders for roof
    - W14x90 columns supporting first and second floor
    - W14x74 columns supporting third floor and roof



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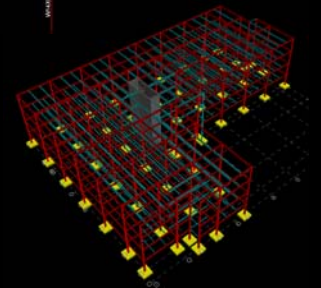
Structural Design Depth

- Lateral System
  - Loading
    - Original seismic base shear 1627 kips
    - Redesigned seismic base shear 730 kips
    - Wind load base shear 285 kips
  - Lateral Drift

	Allowable Drift (in.)	Actual Drift (in.)	
		North-South	East-West
Level 1	1.26	0.60	0.60
Level 2	2.52	1.49	1.49
Level 3	3.78	2.47	2.46
Roof	5.04	3.16	3.14



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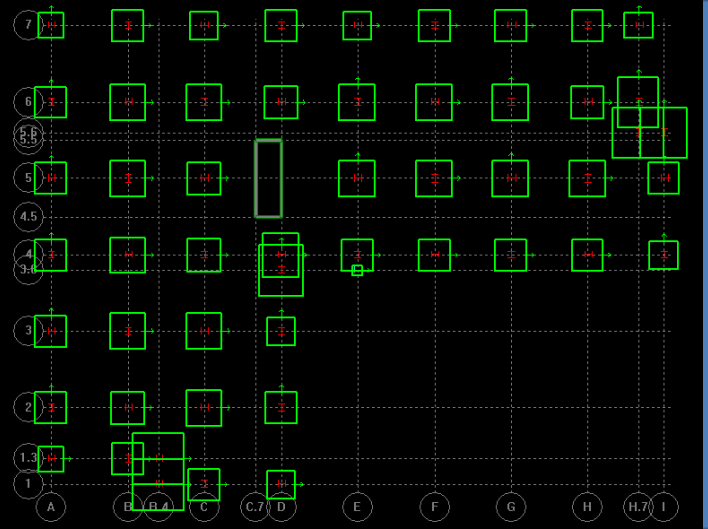
Structural Design Depth

- Foundation System
  - Deep foundations no longer required due to lighter column loads
  - Spread footings designed by RAM
  - Shallow foundation system saves 10% concrete material



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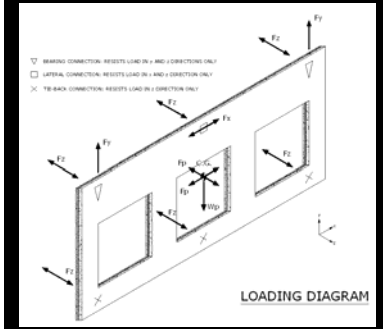
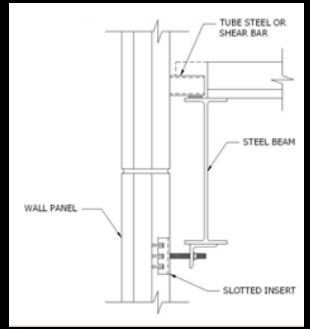
Structural Design Depth

- Precast Concrete Sandwich Panels
  - Non-load bearing panels
  - Must resist wind and earthquake loads on itself
  - Designed as a composite panel
    - Fiber reinforced connectors provide shear transfer to each wythe
  - Stripping and handling forces control design
  - Connected to edge beams using bearing, lateral and tie-back connections





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Conclusions

- North Mountain IMS Office Building provides safe environment for all occupants
- Design meets owner's needs and goals
- Changing structural system will add construction time
- Sustainable features will add cost to the project
- Steel framing is a viable option for the structural system

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Recommendations

- "Green Engineering"
  - Similar to "value engineering"
  - Evaluates design for introduction of sustainable aspects
  - Conducted near the end of the design phase
  - Not to eliminate early collaboration, but to be used as a catch all
- Construction industry can not wait to implement sustainable design and construction practices on a regular basis

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Questions and Comments

Credits and Acknowledgements

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