Project Facts

- Located in Northeast, USA
- 209,000 S.F.
- 2 below grade stories / 7 above grade stories
- Maximum Height: 117'-0"
- Classroom, Laboratories, and Offices
- Construction Cost: $ 80 Million
- August 2007 – December 2009
- LEED GOLD Certification
Thesis Topics

- Existing Structural System
- Problem and Solution
- Gravity Design
- Lateral Design
- Construction Management Study
- Mechanical System Study
Project Team

- **Owner**: Not Release
- **Architect**: Mack Scogin Merrill and Elam
- **General Contractor**: PJ Dick
- **WEB Contractor**: Graziano Construction
- **Structural Engineer**: ARUP – Boston
- **Mechanical Engineer**: ARUP – Boston
- **Electrical Engineer**: ARUP - Boston
- **Civil Engineer**: Civil and Environmental Consultants
Architecture

- Independent from surrounding campus architecture
- Unique Façade:
  - Zinc Panels
  - Aluminum Window Trim
- Multiple Atriums
- Unsymmetrical floor plans
**Existing Structural System**

- **Superstructure (4 – Roof)**
  - Composite Deck on steel framing

- **Foundation (Levels 1-3)**
  - Drilled caissons, strip and column footings
  - Concrete walls and columns
  - 150 car parking garage

- **Lateral System**
  - Dual Shear Walls and Braced Frames
Existing Structural System

- Superstructure (4 – Roof)
  - Composite Deck on steel framing

- Foundation (Levels 1-3)
  - Drilled caissons, strip and column footings
  - Concrete walls and columns
  - 150 car parking garage

- Lateral System
  - Dual Shear Walls and Braced Frames
Roof Elevations

- 6th Level Roof – 61'-0"
- 7th Level Roof – 75'-0"
- 9th Level Roof – 103'-0"
- Mechanical Penthouse – 117'-0"
Problem Statement

- Superstructure Schedule
  - Erection and detailing of steel put project 2 months behind schedule

- Incurred Costs
  - Delayed schedule added general condition costs
  - Change orders were frequent
  - Other trades inherently feel behind schedule
Concrete Structure
- One trade
- No ‘Connections’
- Predictable and efficient schedule

Structural Systems
- Two Way Flat Plate
- Shear Wall-Moment Frame Interactive System

Concrete Design
- Manageable budget and schedule
- Shear wall core
- Moment frames to help reduce torsion

Truss
- Design truss to resist gravity loads on west cantilever
Introduction

**Problem Solution**

**Existing Problem**

**Gravity**

**Lateral**

**Construction**

**Conclusion**

**Questions?**

**Two Way Flat Plate Design**

**spSlab:** Level 6 Equivalent Frame Analysis

**RAM Concept:** Level 6 Longitudinal Design Strips

**RAM Concept:** Level 6 Latitude Design Strips
Two Way Flat Plate Design

ACI § 13.3.8.1 Minimum slab reinforcement extension

RAM Concept: Level 6 Deflection Plan

Δ_{max} = 0.34''
Problem

Solution

Lateral

Construction

Conclusion

Questions?

Introduction

Existing

Gravity

Edge Beam Design

Beam Edge Location

Design Edge Beam Span
**Gravity**

- **Problem**: Edge Beam Design
- **Solution**: Existing Gravity Beam Edge Location
- **Conclusion**: Designed Edge Beam Section

**Design Edge Beam Span**

- (4) #8's
- #4 Stirrups @ 6" o.c

**Beam Edge Location**

- 24" x 24"
Truss Design

West Elevation: Cantilever Highlight

Gravity

Level 6 Truss Plan
Gravity

West Elevation: Cantilever Highlight

Level 6 Truss Plan – Frame GO Highlight

Frame GO: ETABS Analysis

Δ_max = 1.68°
Gravity

Truss Design

West Elevation: Cantilever Highlight

ETABS: 3D Truss

Frame GO: ETABS Analysis

Δ_max = 1.68°
ETABS: 3D Truss

West Elevation: Cantilever Highlight

ETABS: 3D Truss

Cantilever Design Section

Mid-span Design Section

Description of the gravity and lateral design sections of a truss structure, including dimensions and construction details.
Truss Design

West Elevation: Cantilever Highlight

ETABS: 3D Truss
The lateral analysis of the building includes:

- Seismic Design Category “B”
- ASCE7-05 §12.8 Equivalent Lateral Force Procedure
- Shear Wall-Moment Frame Interactive System
- ASCE7-05 §12.3.2.1 Horizontal Irregularity
  - Type 1b: Extreme Torsional Irregularity
- ASCE7-05 §12.5: Directional Loading
  - Orthogonal Loading Only

The forces are as follows:

- Horizontal force (V): 588 kN
- Moment (M): 54,134 ft-k
Lateral System

- Shear Wall-Moment Frame Interactive System
  - Shear Walls
    - 4 - North/South
    - 4 - East/West
  - Moment Frames
    - 4 - North/South
    - 3 - East/West
ETABS Analysis

- **Shear Walls**
  - 8000 psi
  - Membrane
  - $I = 0.35I_g$

- **Moment Frames**
  - 6000 psi
  - $I_{col} = 0.7I_g$
  - $I_{bm} = 0.35I_g$
  - Rigid End Offset = 0.5

- Rigid Diaphragm
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<thead>
<tr>
<th>Introduction</th>
<th>Existing Problem</th>
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</table>

**Shear Wall G7 (N/S)**

- **Design Values**
  - $V_{\text{max}} = 157.5 \, k$
  - $M_{\text{max}} = 9642 \, \text{ft-k}$
  - $P_{\text{max}} = 1704 \, k$

**Shear Wall GG (E/W)**

- **Design Values**
  - $V_{\text{max}} = 196 \, k$
  - $M_{\text{max}} = 15,000 \, \text{ft-k}$
  - $P_{\text{max}} = 960 \, k$
**Existing Problem**

**Solution**

**Gravity**

**Lateral**

**Construction**

**Conclusion**

**Questions?**

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**Introduction**

**Shear Wall G7 (N/S)**

**Shear Wall GG (E/W)**

**Flexural Reinforcement**

<table>
<thead>
<tr>
<th></th>
<th>As, min</th>
<th>As, max</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>5.8 in²</td>
<td>54.6 in²</td>
</tr>
<tr>
<td>As</td>
<td>17.78 in²</td>
<td>72.7 in²</td>
</tr>
</tbody>
</table>

**ε_s**

- 0.01848
- >0.00207
- >0.005
- 0.9

| Mn     | 10,987 ft-k | >9,641.7 ft-k |

- (14) #10s @ Ea End

**Flexural Reinforcement**

<table>
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<th></th>
<th>As, min</th>
<th>As, max</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>10.3 in²</td>
<td>72.7 in²</td>
</tr>
<tr>
<td>As</td>
<td>17.78 in²</td>
<td>72.7 in²</td>
</tr>
</tbody>
</table>

**ε_s**

- 0.0261
- >0.00207
- >0.005
- 0.9

| Mn     | 15,158 ft-k | >15,000 ft-k |

- (14) #10s @ Ea End
Shear Wall Design Section
Moment Frame Column Design

Moment Frame Column Design Section

spColumn: Interaction Diagram
Moment Frame Beam Design

Moment Frame Beam Design Section

Design Beam Section: Exterior Span

Introduction

Existing Problem

Solution

Gravity

Lateral

Construction

Conclusion

Questions?
Schedule Analysis

- **Existing**
  - **Start:** May 5th, 2008
  - **Finish:** November 11th, 2008

- **Proposed**
  - **Start:** May 5th, 2008
  - **Finish:** August 12th, 2008

- **Comparison**
  - 2 months more efficient
Schedule Analysis

- **Existing**
  - Start: May 5th, 2008
  - Finish: November 11th, 2008
- **Proposed**
  - Start: May 5th, 2008
  - Finish: August 12th, 2008
- **Comparison**
  - 2 months more efficient

Cost Analysis

- **Existing**
  - $4,486,006
- **Proposed**
  - $5,281,312
- **Comparison**
  - $(795,306)
Conclusions

- Design
  - Strength and Serviceability Requirements
    - Gravity System OK!
    - Lateral System OK!

- Construction
  - Incurred cost Plausible
  - Shortened Schedule OK!
Acknowledgements

- Dr. Boothby
- Professor Parfitt
- AE Faculty
- Matt Wetzel of PJ Dick
- Bill Hawk of Graziano Construction
- Family
- Friends for reinforcing core structural concepts