Pennsylvania College Of Technology
Dauphin Hall
Williamsport, Pennsylvania

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Structural Option
AE Senior Thesis- 2011
Thesis Advisor: Dr. Boothby
Introduction

Existing Structural System

Thesis Proposal

Structural Depth
  ▪ Proposed Solution
  ▪ Slab Design
  ▪ Reinforced masonry Design

Architectural Breadth

Conclusion
Building Introduction

- **Location:** Williamsport, PA
- **Owner:** Penn College of Technology
- **Architect:** Murray Associates Architects, PC
- **General Contractor:** IMC Construction, Inc.
- **Number of Stories:** 4 Above Grade (70 feet tall, 316 feet long and 210 feet wide)
- **Seize:** 123,676 GSF
- **Cost:** $26,000,000
- **Construction:** October 2008 – August 2010
- **Delivery Method:** Design-Bid-Build
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Existing Structural System

Foundation:
- Shallow Foundation
- Stone Piers (18” – 36”)
- (8) #8’s
Gravity System:
- 4” Light Weight Concrete Slab, reinforced with 1 ½” – 20 gage Vulcraft composite deck
- Open Web K-series bar Joists @ 2'-0” O.C.
- Exterior walls: non-loadbearing CMU with brick Veneer
- Interior Partitions: 4” Clay Brick
- Columns: W8’s – W10’s
- Beams: W18’s – W24’s

Existing Structural System

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Lateral System:
- Wind Moment Connections in Both East/West and North/South Direction
- 22 Total per floor

Existing Structural System

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Thesis Proposal

- **Structural Depth**
  - Redesign structure using reinforced concrete masonry loadbearing walls
  - Precast Hollow core planks
  - Design for seven stories

- **Construction Management Breadth**
  - Compare cost of existing versus proposed design
  - Generate project schedules

- **Architectural Breadth**
  - Modify existing floor plans
  - Propose an efficient layout that promotes student collaboration
Solution:

- **Gravity System:**
  - Precast hollow core planks
  - Reinforced masonry loadbearing walls
  - 4” Clay brick partitions

- **Lateral System:**
  - Reinforced masonry walls as shear walls

- **Three additional floors**
  - 70 feet tall

- **Proposed Shear Wall Layout**

Precast Hollow Core Planks

- Typical (Max.) Span = 19 feet
- Dead & Live loads from IBC 2009
- Selection from catalog (Nitterhouse)
  - Total Factored Loads
    - \( W = 190 \text{ psf} \leq 214 \text{ psf} \rightarrow \text{OK} \)
- Check Deflection:
  - \( \Delta_{\text{Actual}} = 0.16'' \leq \Delta_{\text{Limit}} = \frac{L}{360} = 0.63'' \)
  \( \therefore \text{OK} \)

Use 4-1/2'' Strand 8'' x 4'-0'' hollow core planks with 2'' normal weight concrete topping
PreCast Hollow Core Planks Connection Details

Structural Depth – Floor Design

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Courtesy of NCMA

Courtesy of NCMA

Courtesy of NCMA

NOTES: TOPPING IS REQUIRED. JOINTS MUST BE GRouted FIRST. NON-RESIN BAND & CEMENT MIXTURE IN JOINTS.

SEALANT BACKER ROD

SEALANT BACKER ROD

SEALANT BACKER ROD

CONTINUOUS BEARING STRIP

EXPERIENCE NOTED MAY BE REQUIRED AND INSTALLED AT OTHER MOUNTING POINTS TO ENSURE THE PLANKS MEET.
Reinforced masonry loadbearing walls:

- Mostly Corridor and Exterior walls

**Structural Depth – Shear Wall Design**

**Assumptions:**

- $f' m = 6000$psi
- $8"$ thickness
- $F_s = 24000$ psi
- $F_y = 60000$ psi
Reinforced masonry loadbearing walls:
- Designed under gravity loads first
- At level 1 (base)
- Load Combination (ASD): D + L
- Max. Loads P,M = (27.3 kips, 36.40 ft-kips)

**Final Design**
- Area steel required: As = 0.85 in²
- Use (1) # 9 @ 16” O.C.*
- Or use (2) # 6’s @ 16” O.C.

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Structural Depth – Shear Wall Design

**ASD Interaction Diagram**

Area steel required: As = 0.85 in²
- Use (1) # 9 @ 16” O.C.*
- Or use (2) # 6’s @ 16” O.C.
Wind Loading:
- Same as existing structure (no change in story height)
- ASCE 7-05 Wind load cases applied
- Controlling Case: Load Case 1
- Longitudinal direction controls
- Base Shear = 263.6 Kips
- Overturning Moment = 11,285 ft-kips
Seismic Loading:
- Base shear recalculated due to additional weight of building
- Original response modification factor $R = 3$
- Intermediate reinforced masonry shear walls $R = 3.5$
- Accidental torsional effects = $\pm 0.05\%$
- Drift checked against 0.001hsx

### Structural Depth – Shear Wall Design

<table>
<thead>
<tr>
<th></th>
<th>Base Shear (Kips)</th>
<th>Overturning Moment (ft-kips)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind</td>
<td>273.6</td>
<td>11,285</td>
</tr>
<tr>
<td>Seismic</td>
<td>1663</td>
<td>81,574</td>
</tr>
</tbody>
</table>
Check Shear Wall Under Seismic
- Controlling Load Combination: \( D + 0.7E \) (ASCE 7-05)
- Plot \((P, M) = (13,300 \text{ lbs}; 41,000 \text{ lbs-in})\)
Drift Calculations

- Top Story Drift
  \[ \Delta = 0.023'' \leq \Delta_{\text{limit}} = 0.01 h_{SX} = 0.7'' \rightarrow \text{OK} \]

- First Story Drift
  \[ \Delta = 0.00025'' \leq 0.7'' \rightarrow \text{OK} \]

Structural Depth – Shear Wall Design
Shear Strength Check

\[ F = \frac{M}{V_d} \]

Where \( M/V_d \leq 80 \)

As = \( \frac{V_d}{(\sqrt{f' \cdot m})} \)

MSJC 2008

If Shear reinforcement is provided:

\[ F_v = \sqrt{f' \cdot m} \leq 35 \text{ psi} \]

Where \( M/V_d \geq 1 \):

\[ F_v = \sqrt{f' \cdot m} \leq 35 \text{ psi} \]

If shear reinforcement is provided:

\[ As = \frac{V}{(F \cdot d)} \]

No shear reinforcement is needed

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Structural Depth – Shear Wall Design

- Shear Strength Check
- MSJC 2008
- Where \( M/V_d < 1 \):
  - \( F_v = \left( \frac{1}{3} \right) \left[ 1 - \left( \frac{M}{V_d} \right) \right] \sqrt{f' \cdot m} \leq 80 - 45 \left( \frac{M}{V_d} \right) \)
- Where \( M/V_d \geq 1 \):
  - \( F_v = \sqrt{f' \cdot m} \leq 35 \text{ psi} \)

If shear reinforcement is provided:

\[ As = \frac{V}{(F \cdot d)} \]
Architectural Breadth

- Floor plans
  - Ceiling height = 10 ft
  - Long corridor
  - More study rooms
  - 124 additional rooms
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Architectural Breadth

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Architectural Breadth

- Codes
  - Corridor width = 6’ min
  - Minimum number of Exists = 3 (392 <500)
  - Dead-Ends
  - Travel distance < 250 ft

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Building Illustration

Legend:
- Red: Main entrance
- Yellow: Accessible entry
- Purple: Men’s toilet
- Green: Women’s toilet
- Brown: Fire exit
- White: Travel distance
- Blue: Corridor
- Pink: Dead-Ends

Architectural Breadth
Conclusion

- Goals
  - Structural implementation feasible
  - Longer construction time frame
  - Additional cost

- Recommendations:
  - Foundation would need to be checked and resized
Questions/Comments

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- Murray Associates Architects, P.C
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- Penn State AE Faculties
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