Presentation Outline

- Building Introduction
- Existing Conditions
- Structural Depth – Structural Redesign
- Breadth One – Sustainability
- Breadth Two – Mechanical
- Conclusion
- Comments
Building Introduction

- Hershey, PA
- Research Facility
- 80,000 square feet
- Three Stories, 50 feet tall
- Construction started in April 2006
- Opened in May 2007
- $10.7 Million

Project Team

- Owner: Wexford Technology, LLC
- Engineers: Brinjac Engineering
- Construction Managers: Whiting – Turner Construction
Existing Structural System

- Steel Moment Frame
- Composite Metal Deck
  - Vulcraft 3VLI18
  - Piers with Concrete Caps
Existing Structural System

- Steel Moment Frame
- Composite Metal Deck
  - Vulcraft 3VL18
  - Piers with Concrete Caps

Deck Cross Section
Structural Depth

- System Redesign
  - Steel to Concrete
  - One Way Slab with Beams
- Lateral Design
  - Concrete Moment Frame
- Goals
  - Design an adequate system
  - Cost effective and easy to construct

Thesis Breadths

- Breadth One – Sustainability
- Breadth Two – Mechanical
- Goals
  - LEED Certification through the addition of green roof
  - More energy efficient
Redesign Details

- Controlling Load Combination
  - 1.2D + 1.6L
- Live Load = 100 psf
- Superimposed Dead Load = 25 psf
- Total Load = 190 psf
- Table 9.5(a) of ACI used to help determine beam depths
- \( As = \frac{Mu}{4d} \)

Slab Design

- Span Length
  - 10.67 ft
- Slab Thickness
  - 5.5 in
- Slab Weight
  - 68.75 psf
- Reinforcement
  - Flexural - # 4 bars @ 12 in OC
  - Transverse - # 4 bars @ 18 in OC
Redesign Details

- Controlling Load Combination
  - 1.2D + 1.6L
- Live Load = 100 psf
- Superimposed Dead Load = 25 psf
- Total Load = 190 psf
- Table 9.5(a) of ACI used to help determine beam depths
- \( As = \frac{Mu}{4d} \)

Beam B1 Design

- Span Length
  - 32.5 ft
- Beam Section
  - 16" x 28"
- Mu = 237 k-ft < \( \Phi \)Mn = 264 k-ft
- Vu = 39 k < \( \Phi \)Vn = 78 k
- Reinforcement
  - Exterior Spans – (3) # 7 bars
  - Interior Spans – (4) # 7 bars
  - # 4 Stirrups
Beams B2 Design

- Span Length: 32.5 ft
- Beam Section: 16" x 28"
- Mu = 237 k-ft < ΦMn = 264 k-ft
- Vu = 39 k < ΦVn = 78 k
- Reinforcement:
  - Exterior Spans – (3) # 7 bars
  - Interior Spans – (4) # 7 bars
  - # 4 Stirrups

Beams B1 Design

- Span Length: 32.5 ft
- Beam Section: 20" x 28"
- Mu = 247 k-ft < ΦMn = 267 k-ft
- Vu = 41 k < ΦVn = 88 k
- Reinforcement:
  - Exterior Spans – (3) # 7 bars
  - Interior Spans – (4) # 7 bars
  - # 4 Stirrups
Beam B2 Design

- Span Length
  - 32.5 ft
- Beam Section
  - 20" x 28"
- $\mu = 247 \text{ k-ft} < \Phi M_n = 267 \text{ k-ft}$
- $V_u = 41 \text{ k} < \Phi V_n = 88 \text{ k}$
- Reinforcement
  - Exterior Spans – (3) # 7 bars
  - Interior Spans – (4) # 7 bars
  - # 4 Stirrups

Girder Design

- Span Length
  - 32 ft
- Beam Section
  - 20" x 28"
- $\mu = 302 \text{ k-ft} < \Phi M_n = 333 \text{ k-ft}$
- $V_u = 47 \text{ k} < \Phi V_n = 117 \text{ k}$
- Reinforcement
  - Exterior Spans – (3) # 7 bars
  - Interior Spans – (5) # 7 bars
  - # 4 Stirrups
Column Design

- Column Layout Unchanged
- Simplified Design for Columns
- Alsamsam and Kamara
- Design Aids based of ACI
- Column Section
  - 20" x 20"
- Reinforcement
  - (12) # 10 bars
- Max Load
  - $Pu = 564 \text{kips} < \Phi Pn = 1050 \text{kips}$

Girder Design

- Span Length
  - 32 ft
- Beam Section
  - 20" x 28"
- Mu = 302 k-ft < $\Phi Mn = 333$ k-ft
- Vu = 47 k < $\Phi Vn = 117$ k
- Reinforcement
  - Exterior Spans – (3) # 7 bars
  - Interior Spans – (5) # 7 bars
  - # 4 Stirrups

Typical Bay
Lateral Redesign

- Concrete Moment Frame
- No addition lateral resisting needed
- Analysis done using RAM Structural System

Controlling Load Cases
- Wind – 1.2 D + 1.0 L + 1.0 W
- Seismic – 1.2 D + 1.0 L + 1.0 E
Wind Loads

- ASCE 7 – 10
- Load Combination
  - 1.2 D + 1.0 L + 1.0 W
  - Wind Case One
  - Max Story Drift
  - H/400

Serviceability

<table>
<thead>
<tr>
<th>Floor</th>
<th>X Deflection (m)</th>
<th>Y Deflection (m)</th>
<th>X Drift (m)</th>
<th>Y Drift (m)</th>
<th>Allowable Drift (m)</th>
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RAM Structural Model
Seismic Loads

- ASCE 7 – 10
- Load Combination
  - 1.2 D + 1.0 L + 1.0 E
- Max Story Drift
  - 0.015 x H
- Design Variables
  - Seismic Design Category = “D”
  - R = 3.0
  - I = 1.25

Serviceability

<table>
<thead>
<tr>
<th>Floor</th>
<th>X Deflection (in)</th>
<th>Y Deflection (in)</th>
<th>X Drift (in)</th>
<th>Y Drift (in)</th>
<th>Allowable Drift (in)</th>
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<td>Total</td>
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<td>0.0112</td>
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Sustainability Breadth

• Main goal is to achieve LEED certification through the addition of a green roof
• Owners Future Plans – LEED Certification for all buildings
• Two different green roofs were compared
  • LiveRoof
  • TectaGreen
• Roof Structure
  • Extra 35 psf on Roof
Sustainability Breadth

- Both designs have similar advantages and disadvantages
- The LiveRoof system was chosen as the better choice
- Standard Module
- Possible of obtaining over 20 LEED credits
- Optimized Energy Performance – Mechanical Breadth

<table>
<thead>
<tr>
<th>LiveRoof System</th>
<th>LEED Category</th>
<th>Credit Abbreviation</th>
<th>Credits Possible</th>
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<tbody>
<tr>
<td></td>
<td>Protect or Restore Habitat and Maximum Open Space</td>
<td>SS 5.1/5.2</td>
<td>1 each (2 total)</td>
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<td>Storm Water Design</td>
<td>SS 6.1/6.2</td>
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<td></td>
<td>Heat Island Effect</td>
<td>SS 7.1/7.2</td>
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<td></td>
<td>Water Efficient Landscape</td>
<td>WE 1.1/1.2</td>
<td>2/4 (6 total)</td>
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<td></td>
<td>Optimized Energy Performance</td>
<td>EA 1.1-1.19</td>
<td>1 each (19 total)</td>
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<tr>
<td></td>
<td>Construction Waste Management</td>
<td>MR 2</td>
<td>1 to 2</td>
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<tr>
<td></td>
<td>Recycled Content</td>
<td>MR 4.1/4.2</td>
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<td></td>
<td>Regional Materials</td>
<td>MR 5.1/5.2</td>
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<td>Rapidly Renewable Materials</td>
<td>MR 6</td>
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</table>
Both designs have similar advantages and disadvantages.

The LiveRoof system was chosen as the better choice.

Standard Module

Possible of obtaining over 20 LEED credits

Optimized Energy Performance – Mechanical Breadth
Structural Effects

- **Roof Loads**
  - Roof Live Load – 30 psf
  - Superimposed Dead Load – 25 psf
  - Green Roof – 35 psf
  - Snow Load – 30 psf

- **Controlling Load Case**
  - 1.2 D + 1.6 Lr

- **Total Load** – 120 psf

### Roof Slab Design Details
- **Slab Thickness**: 5.5"
- **Flexural Reinforcement (Top and Bottom)**: # 4 Bars @ 12"
- **Transverse Reinforcement**: # 4 Bars @ 18"
- **System Weight**: 68.75 psf

### Roof Beam Design Details
- **Beam Section**: 12"x22"
- **Flexural Reinforcement (Exterior Spans)**: (3) #7 Bars
- **Flexural Reinforcement (Interior Spans)**: (2) #10 Bars
- **Beam Weight**: 206 plf

### Roof Girder Design Details
- **Beam Section**: 18"x22"
- **Flexural Reinforcement (Midspan)**: (3) #7 Bars
- **Flexural Reinforcement (Supports)**: (5) #7 Bars
- **Beam Weight**: 310 plf
Breadth Conclusion

- The addition of a green roof would be helpful
- LEED credits can help for LEED certification
  - Certified: 40 – 49 points
  - Silver: 50 – 59 points
  - Gold: 60 – 79 points
  - Platinum: 80 or more
Conclusions

• The existing steel frame is the more feasible structural system for the building
  • Higher floor thickness
  • Longer construction time
• The addition of a green roof would be helpful
  • Possible addition of over 20 LEED Credits
  • LEED Certification
  • Lower energy cost
Comments
Or
Questions?

Acknowledgements

Wexford Science and Technology, LLC
Brinjac Engineering
Ayers/Saint/Gross Inc.
AE Staff
Advisor: Dr. Linda Hanagan
Mechanical Breadth

- Main goal was to find the energy saving ability of the green roof
- The more energy the green saves, the better
- More LEED Credits
  - Optimized Energy Performance – Mechanical Breadth
  - Up to 19 Credits Possible
Mechanical Breadth

- Main goal was to find the energy saving ability of the green roof
- The more energy the green saves, the better
- More LEED Credits
  - Optimized Energy Performance – Mechanical Breadth
  - Up to 19 Credits Possible

### Roof Assembly R-Values

<table>
<thead>
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<th>Material</th>
<th>R – Value</th>
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<tr>
<td>Insulation</td>
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<tr>
<td>Roof Board</td>
<td>1.09</td>
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<tr>
<td>Water Proofing Membrane</td>
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<tr>
<td>LiveRoof Standard Green Roof System</td>
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</tr>
</tbody>
</table>
Mechanical Breadth

- Energy Saving of 77,375,928 BTU per year
- Additional financial benefits from tax credits
  - Federal – 30% of total cost
- LEED points
  - One Credit from energy reduction

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