Onondaga County (NY) Correctional Facility Re-roof Project: Lessons Learned and Implications for Roof Design

CRRC Membership Meeting

June, 2013 Reno NV

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Director Codes & Regulatory Affairs
Project Background

- Onondaga County Infrastructure
  - Storm-water Runoff and Sewer Capacity
  - County-Owned Buildings
  - Penitentiary Project Opportunity

- Penitentiary Reroof
  - Cool Roofing
  - Vegetative Roofing
  - High R-Value Roof Assemblies

- CDH Engineering
  - Hugh Henderson
Bigger Picture Issues

• Project Location
  – Climate Zone 5, South of Syracuse NY

• Storm-water and Sanitary Capacity Issues

• Energy Efficiency
  – Cooling vs. Heating

• Building Performance Issues
  – Durability
  – Moisture Management
  – Maintenance Costs
Project Details

- Location
  - Climate
  - Elevation
- Building Size
- Building Occupancy
  - Human Factors
- Maintenance
Project Details

• Side-by-Side Comparison of Roofing Systems
  – UNIT 1: EPDM w/ 4” of Foam Insulation
  – UNIT 2: TPO w/ 4” of Foam Insulation
  – UNIT 3: Vegetative Roof w/ 4” of Foam Insulation
  – UNIT 4: TPO w/ 8” of Foam Insulation

• Measured Performance Impacts
  – Thermal Transfer / Energy Cost Impacts
  – Water Retention Performance
# Roof Assemblies

<table>
<thead>
<tr>
<th>Location</th>
<th>Insulation</th>
<th>Surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit 1</td>
<td>4 inches Poly Iso(^1) foam board (R22)</td>
<td>EPDM rubber(^2)</td>
</tr>
<tr>
<td>Unit 2</td>
<td>4 inches Poly Iso(^1) foam board (R22)</td>
<td>TPO White(^3)</td>
</tr>
<tr>
<td>Unit 3</td>
<td>4 inches Poly Iso(^1) foam board (R22 + vegetative layer)</td>
<td>EPDM w/ Vegetative Assembly on top</td>
</tr>
<tr>
<td>Unit 4</td>
<td>8 inches Poly Iso(^1) foam board (R45)</td>
<td>TPO White(^3)</td>
</tr>
</tbody>
</table>

Notes:
1. Polyisocyanurate foam board applied in 2-inch layers
2. Black EPDM (Ethylene Propylene Diene Monomer) single-ply rubber roof membrane
3. White TPO (Thermoplastic Polyolefin) roof membrane
Approach

• **Install dataloggers to continuously monitor performance**
  – Two independent locations on each roof
  – Collect data continuously at 15-minute intervals
  – Directly measure temperature differences through roof assembly
  – **Direct measurement of HVAC energy use was not practical**

• **Presentation and Analysis**
  – Present data on internet (password protected)
  – Others can use data for independent data analysis
Roof Sensor Location/Station

- Thermocouple TRO
- Thermocouple TRI
- Thermocouple TAI
A & B Stations on Each Unit
Sensors Installed During Construction

- Insulation Board
- Thermocouple Probe
Thermocouple on Top of Insulation (station 1B)
Indoor Thermocouple
Vegetative Roof

Shallow Assembly
Earn LEED points with green roof technology and increase thermal efficiency

1. Growth Media
2. Moisture Retention Mat
3. Drainage Board
4. Protection Fabric
5. EPDM or Sure-Weld TPO Membrane (Adhered)
6. 1/2" Dens-Deck Prime
7. Approved Insulation
8. Substrate
# Instrumentation

<table>
<thead>
<tr>
<th>Point</th>
<th>Description</th>
<th>Instrument</th>
<th>Eng Units</th>
<th>Locations</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRO</td>
<td>Roof Temperature (on top of insulation, under roof brd)</td>
<td>Type-T Thermocouple</td>
<td>°F</td>
<td>At each station</td>
</tr>
<tr>
<td>TRI</td>
<td>Roof Temperature (under roof insulation, above deck)</td>
<td>Type-T Thermocouple</td>
<td>°F</td>
<td>At each station</td>
</tr>
<tr>
<td>TAI</td>
<td>Indoor Temperature (just below the roof)</td>
<td>Type-T Thermocouple</td>
<td>°F</td>
<td>At each station</td>
</tr>
<tr>
<td>TAO</td>
<td>Outdoor Temperature</td>
<td>Type-T Thermocouple</td>
<td>°F</td>
<td>Station 2A</td>
</tr>
<tr>
<td>ISH</td>
<td>Solar Insulation (horizontal)</td>
<td>Licor LI200x</td>
<td>W/m²</td>
<td>Station 2A</td>
</tr>
<tr>
<td>TGR</td>
<td>Green Roof Temperature (in middle of soil layer)</td>
<td>Type-T Thermocouple</td>
<td>°F</td>
<td>Station 3A</td>
</tr>
<tr>
<td>MGR</td>
<td>Green Roof Moisture Content (in middle of soil layer)</td>
<td>Campbell Scientific CS616</td>
<td>0-1</td>
<td>Station 3A</td>
</tr>
<tr>
<td>RAIN</td>
<td>Rainfall</td>
<td>Texas Electronics 525</td>
<td>Inches</td>
<td>Station 2A</td>
</tr>
<tr>
<td>WF</td>
<td>Water Flow from Green Roof Mockup</td>
<td>Hydrolynx 5050</td>
<td>Gal/h</td>
<td>Station 2A</td>
</tr>
</tbody>
</table>
Heat Transfer Analysis

Where:

- \( R_{\text{insulation}} \) - R-value for Insulation layer (°F-h-ft\(^2\)/Btu)
- \( q \) - Heat flux through the roof assembly (Btu/h-ft\(^2\))

\[ q = \frac{(TRI - TRO)}{R_{\text{insulation}}} \]
Daily Heat Loss

Outdoor Temperature (F)

Heat Loss (Btu/ft²-day)

Unit 1: 4 in, EPDM
Unit 2: 4 in, TPO
Unit 3: 4 in, Veg
Unit 4: 8 in, TPO

Impact of Snow Cover

Heat Loss
Heat Gain
Monthly Heat Loss

Heat Loss (Btu/ft^2)

Unit 1: 4 in EPDM
Unit 2: 4 in TPO
Unit 3: 4 in Veg
Unit 4: 8 in TPO
# Heating Vs. Cooling Expense

## Heating

<table>
<thead>
<tr>
<th></th>
<th>Unit 1 4 in EPDM</th>
<th>Unit 2 4 in TPO</th>
<th>Unit 3 4 in Veg</th>
<th>Unit 4 8 in TPO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Heat Load (MMBtu per 1000 sq ft)</td>
<td>4.9</td>
<td>6.4</td>
<td>6.0</td>
<td>4.4</td>
</tr>
<tr>
<td>Annual Gas Use (therms per 1000 sq ft)</td>
<td>61.1</td>
<td>79.5</td>
<td>75.4</td>
<td>54.6</td>
</tr>
<tr>
<td>Annual Cost per 1000 sq ft</td>
<td>$ 61</td>
<td>$ 80</td>
<td>$ 75</td>
<td>$ 55</td>
</tr>
<tr>
<td>Savings per 1000 sq ft</td>
<td>$ (18)</td>
<td>$ (14)</td>
<td>$ 6</td>
<td></td>
</tr>
</tbody>
</table>

## Cooling

<table>
<thead>
<tr>
<th></th>
<th>Unit 1 4 in EPDM</th>
<th>Unit 2 4 in TPO</th>
<th>Unit 3 4 in Veg</th>
<th>Unit 4 8 in TPO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced Cooling (ton-hrs/yr per 1000 sq ft)</td>
<td>152.6</td>
<td>194.2</td>
<td>157.2</td>
<td></td>
</tr>
<tr>
<td>Reduced Cooling Power (kWh/yr per 1000 sq ft)</td>
<td>137.3</td>
<td>174.7</td>
<td>141.5</td>
<td></td>
</tr>
<tr>
<td>Savings per 1000 sq ft</td>
<td>$ 16</td>
<td>$ 21</td>
<td>$ 17</td>
<td></td>
</tr>
</tbody>
</table>

## Combined

<table>
<thead>
<tr>
<th></th>
<th>Unit 1 4 in EPDM</th>
<th>Unit 2 4 in TPO</th>
<th>Unit 3 4 in Veg</th>
<th>Unit 4 8 in TPO</th>
</tr>
</thead>
<tbody>
<tr>
<td>NET Savings per 1000 sq ft</td>
<td>$ (2)</td>
<td>$ 7</td>
<td>$ 23</td>
<td></td>
</tr>
</tbody>
</table>
Water Retention Testing

Rainfall Plot

Rainfall (inch): 0.2
Drainage (inch): 0.2

- RAIN
- Drainage
Vegetative Roof Provides Evaporative Cooling

July 27, 2010
Stormwater Management

- Vegetative Roof Provided Manageable Stormwater Flow
- Evaporative Cooling Effect
- Some Thermal Effects
- Maintenance Issues TBD
Impact of Snow & Rain

Unit 2: 4 in, TPO  Unit 3: 4 in, Veg  Unit 4: 8 in, TPO
OC Conclusions From Jamesville

- Reflective Roofing is Energy Neutral
- Vegetative Roof Retains 75-80% of Stormwater
  - Additional Cooling Season Benefits
- Insulation Saves Heating Energy
- Additional Study Needed:
  - Reflectance/Durability/Maintenance
  - Vegetative Roof Maintenance Costs
  - Building Performance
  - Snow and Ice Effects
The Cool Roofing Debate

• Energy Efficiency
  – Heating vs. Cooling
  – Expanded Reflectance Requirements in Code

• Heat Island Mitigation

• Roof Assembly Performance and Durability
  – Condensation
  – Wetting/Drying Cycles
Next Steps

• Project Will Continue For Total of Six Years
• Reflectance Measurements Will be Collected
• Additional Consideration for Solar Effects and Accumulation of Snow and Ice
Questions?

Thanks to Hugh Henderson
CDH Engineering
Cazenovia, NY