Improving the Building Envelope
Addressing Thermal Bridging

Aerogel Building Insulation Blanket
Agenda

• Insulation technology needs
• Aerogel technology
• Thermal properties
• Material properties
• Application details and thermal modeling
Energy Efficiency Codes & Regulations

- IECC
- ASHRAE 90.1
- ASHRAE 189.1
- LEED v4.0
- Living Building Challenge
- Net Zero Buildings
- 2030 Challenge

![Energy Efficiency Codes & Regulations](image)

The 2030 Challenge

- Fossil Fuel Energy Reduction
- Fossil Fuel Energy Consumption

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![Logos](image)
Aerogel Technology

- Invented in the 1930s
- Synthetically produced amorphous silica gel
- Nanoporous structures that minimize thermal transport – low thermal conductivity
- Aerogel is composed of 95-99% air, making it one of the lightest existing materials
- Aerogel started its applications in aerospace and expanded into many fields
- Manufactured and sold in a blanket form
Thermal Properties
Superior thermal performance

Comparative R-value Per Inch[^2]

<table>
<thead>
<tr>
<th>Material</th>
<th>R-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building Insulation Blanket</td>
<td>9.6[^1]</td>
</tr>
<tr>
<td>Polyisocyanurate</td>
<td>6</td>
</tr>
<tr>
<td>Extruded Polystyrene (XPS)</td>
<td>5</td>
</tr>
<tr>
<td>Mineral Wool</td>
<td>4.2</td>
</tr>
<tr>
<td>Expanded Polystyrene (EPS)</td>
<td>3.8</td>
</tr>
<tr>
<td>Fiberglass Batts</td>
<td>3.5</td>
</tr>
</tbody>
</table>

[^1]Average R-values per ASTM C518 at 100°F and 2 psi compression, shown in hr-ft²-F/BTU; USI-values shown in W/m²K.

[^2]Thermal conductivity varies by specific grade of insulation for any given material family. Values shown represent typical values and are only provided for general comparison of families.
Thin-Profile, Flexible Insulating Blanket
A simple solution for thermal bridging

- Significantly increase thermal resistance in space-limited situations
- Enables new design possibilities
- Easy to install in difficult profiles such as curves and corners
- Fast installation with simple tools
- Fire resistant
- Hydrophobic
- Does not settle over time
- ASTM C1728 Standard Specification for Flexible Aerogel Insulation
Thermal Bridging

“...the heat flow through a poor-performing detail, like an exposed concrete slab edge, could account for over 40% of the heat flow through the building envelope. In comparison, a thermally efficient detail, such as insulated slab edge, could contribute less than 10%...”

An Evaluation of Thermal Performance of Various Details

1. Curtainwall to at-grade detail with the insulation blanket applied to the neck of the curtainwall to the below-grade rigid insulation

2. Curtainwall jamb at the exterior and interior insulated steel stud assembly with the insulation blanket applied around the adjacent steel stud and at the wall-to-curtainwall transition

3. Rehabilitated window-wall system with the insulation blanket at the slab edge and around glazing vertical and horizontal mullions

4. Curtainwall-to-roof parapet transition

5. Curtainwall spandrel vertical mullion wrap
1. Curtainwall to At-Grade Slab Transition

Perimeter heat loss for curtainwall at-grade by varying U-values

<table>
<thead>
<tr>
<th>Depth of Insulation</th>
<th>Below-Grade Insulation (hr·ft²·°F/BTU)</th>
<th>Slab Perimeter Heat Loss (BTU/hr·ft·°F)</th>
<th>% Reduction in Heat Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Without Insulation Blanket</td>
<td>10 mm Insulation Blanket</td>
</tr>
<tr>
<td>24”</td>
<td>R-10</td>
<td>0.495</td>
<td>0.370</td>
</tr>
</tbody>
</table>

Aerogel insulation blanket was placed to cover the neck of the curtainwall to the below-grade insulation.

Without insulation blanket.
2. Curtainwall to Exterior/Interior Insulated Steel-Stud Wall Transition

Insulation blanket was added in two locations:
1. Around the interior steel studs adjacent to the curtain mullion
2. Bridging between the curtainwall neck to the exterior sheathing

Without aerogel insulation blanket

Linear transmittance calculations for steel-stud wall transition

<table>
<thead>
<tr>
<th>Transmittance Description</th>
<th>Linear Transmittance (BTU/hr·ft·°F)</th>
<th>% Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curtinwall jamb to an interior and exterior insulated steel stud assembly</td>
<td>Without Insulation Blanket</td>
<td>10 mm Insulation Blanket</td>
</tr>
<tr>
<td></td>
<td>0.069</td>
<td>0.019</td>
</tr>
</tbody>
</table>
3. Window-Wall at Floor Slab

Linear transmittance calculations for a window-wall spandrel section slab face

<table>
<thead>
<tr>
<th>Transmittance Description</th>
<th>Linear Transmittance (BTU/hr·ft·°F)</th>
<th>% Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Without Insulation Blanket</td>
<td>10 mm Insulation Blanket</td>
</tr>
<tr>
<td>Window-wall spandrel section</td>
<td>0.556</td>
<td>0.264</td>
</tr>
</tbody>
</table>

Aerogel insulation blanket was modeled over the slab face and both the horizontal and vertical mullions.
4. Curtainwall-to-Roof Parapet Transition

Linear transmittance calculations for parapet detail

<table>
<thead>
<tr>
<th>Transmittance Description</th>
<th>Linear Transmittance, BTU/hr·ft·°F</th>
<th>% Reduction in Heat Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curtinwall parapet</td>
<td>Without Insulation Blanket: 0.614</td>
<td>With 10 mm Insulation Blanket: 0.513</td>
</tr>
</tbody>
</table>
5. Curtainwall Spandrel Vertical Mullion Wrap

U-value results for curtainwall spandrel section

<table>
<thead>
<tr>
<th>Spandrel Height, ft</th>
<th>Curtainwall Backpan Insulation, hr·ft²·°F/FTU</th>
<th>Spandrel U-Value, BTU/hr·ft²·°F</th>
<th>% Reduction in Heat Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Without Insulation Blanket</td>
<td>With 10 mm Insulation Blanket</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>R 16.8</td>
<td>0.169</td>
<td>0.153</td>
</tr>
</tbody>
</table>
Thermal Models
Show a 10 to 75% reduction of heat loss by reducing thermal bridging

<table>
<thead>
<tr>
<th>Detail</th>
<th>Transmittance Description</th>
<th>Linear Transmittance (BTU/hr·ft·°F)</th>
<th>% Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Without Insulation Blanket</td>
<td>10 mm Insulation Blanket</td>
</tr>
<tr>
<td>1</td>
<td>Curtainwall at grade</td>
<td>0.495</td>
<td>0.370</td>
</tr>
<tr>
<td>2</td>
<td>Curtainwall jamb to an interior and exterior insulated steel stud assembly</td>
<td>0.069</td>
<td>0.019</td>
</tr>
<tr>
<td>3</td>
<td>Window-wall at floor slab</td>
<td>0.556</td>
<td>0.264</td>
</tr>
<tr>
<td>4</td>
<td>Curtainwall to roof parapet</td>
<td>0.614</td>
<td>0.513</td>
</tr>
<tr>
<td>5</td>
<td>Curtainwall spandrel vertical mullion wrap</td>
<td>0.169</td>
<td>0.153</td>
</tr>
</tbody>
</table>
Whole-Building Energy Models
Show 3 to 7% energy savings by reducing thermal bridging

**Annual heating energy savings for Chicago climate**

<table>
<thead>
<tr>
<th>Building Scenario</th>
<th>Assembly Performance</th>
<th>Annual Heating Energy Use, MMBtu (GJ)</th>
<th>Savings Due to Aerogel Details</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>With Insulation Blanket</td>
<td>Without Insulation Blanket</td>
</tr>
<tr>
<td>Scenario 1: Façade with glazing system covering 100% of the façade area</td>
<td>Conventional assemblies</td>
<td>5,905 (6,230)</td>
<td>6,123 (6,460)</td>
</tr>
<tr>
<td></td>
<td>Higher-performance assemblies</td>
<td>4,275 (4,511)</td>
<td>4,421 (4,665)</td>
</tr>
<tr>
<td>Scenario 2: Façade with curtainwall glazing and a steel stud wall assembly</td>
<td>Conventional assemblies</td>
<td>4,279 (4,515)</td>
<td>4,545 (4,796)</td>
</tr>
<tr>
<td></td>
<td>Higher-performance assemblies</td>
<td>3,114 (3,285)</td>
<td>3,340 (3,524)</td>
</tr>
</tbody>
</table>
SELECTED APPLICATIONS/INSTALLATIONS
Space-Constrained Locations
Easy-to-use, thin material that offers freedom of design and improved energy efficiency
Thermal Separator
Oregon
Space-Constrained Transitions
Ontario
Project Information

Large Project in Asia
Height: 280 m
Façade: Unitized Curtainwall System
Typical Mullion Detail at Spandrel

Condensation may occur at the marked area

\[ U_{ij} = 10.3 \text{ W/m}^2\text{K} \]

Min. Temperature: 8.1°C
Optimized Curtainwall Detail

Insulation blanket, 10 mm thick
Typical Mullion Detail at Spandrel

Traditional Solution

Optimized High-Performance Solution

$U_{tj} = 10.3 \text{ W/m}^2\text{K}$
Min. Temperature: 8.1°C

$\theta_s = 10.20 \degree \text{C}$

$\theta_{si} \text{ min} = 8.047 \degree \text{C}$
$f_{R} = 0.590$
$\psi_{s(50\%)} = 100\%$
$\psi_{100\%} = 41\%$
$\psi_{50\%} = 32\%$

$\theta_c = 16.50 \degree \text{C}$

$U_{tj} = 4.61 \text{ W/m}^2\text{K} \quad (\downarrow 55\%)$
Min. Temperature: 15.4°C

$\theta_{si} \text{ min} = 15.448 \degree \text{C}$
$f_{R} = 0.807$
$\psi_{s(50\%)} = 75\%$
$\psi_{100\%} = 66\%$
$\psi_{50\%} = 53\%$
Performance Mockup Testing
Performance Mockup Testing
Performance Mockup Testing

<table>
<thead>
<tr>
<th>Channel</th>
<th>Exterior Surface Temperature</th>
<th>Interior Surface Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH01</td>
<td>24.149°F</td>
<td>-9.2°F</td>
</tr>
<tr>
<td>CH02</td>
<td>-9.4°F</td>
<td>-9.7°F</td>
</tr>
<tr>
<td>CH03</td>
<td>-7.3°F</td>
<td>-5.1°F</td>
</tr>
<tr>
<td>CH04</td>
<td>-8.0°F</td>
<td>14.5°F</td>
</tr>
<tr>
<td>CH05</td>
<td>12.4°F</td>
<td>-2.7°F</td>
</tr>
<tr>
<td>CH06</td>
<td>10.6°F</td>
<td>-10.2°F</td>
</tr>
<tr>
<td>CH07</td>
<td>10.6°F</td>
<td>-13.0°F</td>
</tr>
<tr>
<td>CH08</td>
<td>18.4°F</td>
<td>18.4°F</td>
</tr>
<tr>
<td>CH09</td>
<td>18.8°F</td>
<td>16.7°F</td>
</tr>
<tr>
<td>CH10</td>
<td>16.7°F</td>
<td>13.7°F</td>
</tr>
<tr>
<td>CH11</td>
<td>11.8°F</td>
<td>10.8°F</td>
</tr>
<tr>
<td>CH12</td>
<td>18.8°F</td>
<td>10.8°F</td>
</tr>
<tr>
<td>CH13</td>
<td>11.8°F</td>
<td>10.8°F</td>
</tr>
<tr>
<td>CH14</td>
<td>10.8°F</td>
<td>10.8°F</td>
</tr>
<tr>
<td>CH15</td>
<td>10.8°F</td>
<td>10.8°F</td>
</tr>
<tr>
<td>CH16</td>
<td>10.8°F</td>
<td>10.8°F</td>
</tr>
<tr>
<td>CH17</td>
<td>10.8°F</td>
<td>10.8°F</td>
</tr>
</tbody>
</table>

- **Exterior air temperature**
- **Exterior surface temperature of the aluminum panel at spandrel**
- **Exterior surface temperature of the glass at vision**
- **Interior surface temperature of the glass at vision**
- **Exterior surface temperature of the mullion at spandrel**
- **Interior surface temperature of the mullion at vision**
Performance Mockup Testing

The consultant inspected the facade after 8 hours of testing, and no condensation was found at the spandrel area …
Insulation Blanket Installation Procedure (cont.)
Installing Aerogel Insulation Blanket
Clarification: OSHA Requirements for Silica Dust

- Applies to **crystalline silica**
- Aerogels are **amorphous silica**
  - Amorphous silica is exempt from the OSHA regulation
- This was confirmed through federal (EPA) ruling
  - Refer to EPA 40 CFR Part 180

**ENVIRONMENTAL PROTECTION AGENCY**

40 CFR Part 180

Silica, Amorphous, Fumed (Crystalline Free); Exemption from the Requirement of a Tolerance

**AGENCY:** Environmental Protection Agency (EPA).

**ACTION:** Final rule.
Material Handling

• Recommended PPE
  – Gloves
  – Safety glasses
  – Dust mask
  – Well-ventilated area

• Cutting
  – Straight-edge box cutter
  – Fabric cutter
Installation

• Attachments vary based on the needed green strength and the backing support
  – Common construction materials – Apply 3/16" ribbon of an approved sealant and press the insulation flat against the ribbon to adhere
  – Plastics and air barriers – Apply 3/16" ribbons of a compatible air barrier sealant and press the insulation flat against the ribbons to adhere
  – Mechanical fasteners can be used to attach the blanket or to support it while the adhesives cure
  – Higher-green-strength spray adhesives and/or contact cements work well when it is necessary to make sharp curves and bends in the material
Installation (cont.)

• Surface prep (building and insulation blanket)
  – Dry
  – Sound
  – Free of dirt, foreign objects and protrusions >1/8"

• Ambient conditions
  – Do NOT install in the rain or in wind conditions that could affect the quality of the installation or cure of the adhesives selected

• Exposure
  – If installed correctly, the blanket may be exposed to weather prior to installing the cladding, with minimal impact on performance
  – Should be protected if subject to mechanical abrasion and/or traffic

• Visible surfaces
  – If permanently exposed, a coat of a tinted silicone elastomeric coating may be applied for aesthetics
Compatibility

• Compatible
  – Sealants
  – Air barrier materials
  – Other water-based adhesives

• Limitations
  – Medical or pharmaceutical uses
  – Not tested or recommended in residential applications
  – Long-term exposure to, or submersion in, water or other fluid mediums
  – Air-handling vents or HVAC
  – Applications subject to
    • Repeated striking
    • Mechanical abrasion
    • Contact with oils and solvents
Aerogel Compression

Tested for compression per ASTM C165

10% strain @ 10 psi

Aerogel insulation has high compression resistance but will still contour to wall surface, which will eliminate the potential for air pockets.
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