Keys to High Performance Buildings Through Structural Thermal Breaks

Chamonix Larsen, AIA, LEED AP
Morrison Hershfield – Salt Lake City
LEARNING OBJECTIVES

✓ Learn how the building envelope plays a role in resilient buildings and energy performance

✓ Understand how thermal bridging impacts energy performance

✓ Understand how thermal bridging analysis can be applied to decision making and value engineering efforts to maintain the best value at the least cost
WHAT WE ARE TALKING ABOUT…

Why Building Envelope?

What is Thermal Bridging?

Why Thermal Bridging is the Achilles Heel to Performance?

A Case Study: Applied Strategies for Thermal Bridging
WHY BUILDING ENVELOPE?
WHERE IS ENERGY BEING USED?

![Energy Use by Sector](chart)

Source: U.S. Energy Information Administration, *Monthly Energy Review – Table 2.1*
HOW IS BUILDING ENERGY USED?

Heating and cooling account for 1/3 of the energy demand.

Figure 5. Space heating demanded the most overall energy use in commercial buildings in 2012, followed by other uses.
PATH TO HIGH PERFORMANCE

Net Zero
Demand Reductions
Efficiency Enhancements
Renewables
BUILDING PERFORMANCE METRICS

- LEED
- BOMA BEST
- Green Globe
- Built Green
- Etc.

- NECD/ASHRAE90.1
- Passive House
- Net Zero Energy
- Net Zero Ready
- Living Building Challenge
- CaGBC ZCB Standard
- Net Zero Carbon
- Floating Target ($ or GJ)
- Hard Target (energy or carbon)

- LEED
- BOMA BEST
- Green Globe
- Built Green
- Etc.
What is Whole Building Energy Simulation?

- weather
- envelope
- Internal gain
- HVAC
- cost

operations → engine → Results

load, system, plant, cost

Simulation parameters

Performance Path in Action

Screenshot of Morrison Hershfield’s Energy Optimization Tool
THE BUILDING ENVELOPE

Building Envelope = Environmental Separation
What is expected of this building?
BUILDING ENVELOPE DESIGN FACTORS

- DURABLE
  - Resist imposed loads
  - Control rain penetration
  - Control air flow
  - Accommodate movement
  - Control heat flow
  - Control vapor diffusion

- AESTHETICALLY PLEASING
- PROVIDE SECURITY
- PROVIDE SOUND CONTROL
- EASY TO BUILD
- ECONOMICAL
- PROTECT FROM FIRE
- CONTROL RADIATION
Battle for the thermostat: Gender and the effect of temperature on cognitive performance

Tom Y. Chang, Agne Kajackaite

Published: May 22, 2019 • https://doi.org/10.1371/journal.pone.0216362

Abstract

This paper studies differences in the effect of temperature on cognitive performance by gender in a large controlled lab experiment (N = 543). We study performance in math, verbal and cognitive reflection tasks and find that the effects of temperature vary significantly across men and women. At higher temperatures, women perform better on a math and verbal task while the reverse effect is observed for men. The increase in female performance in response to higher temperature is significantly larger and more precisely estimated than the corresponding decrease in male performance. In contrast to math and verbal tasks, temperature has no impact on a measure of cognitive reflection for either gender. Our findings suggest that gender mixed workplaces may be able to increase productivity by setting the thermostat higher than current standards.
CHANGING FOCUS ON BUILDING ENVELOPE

Durability/Resiliency
• Controlling Water
• Design Reviews
• Field Review & Testing

Efficiency
• Air & Thermal Barrier Design
• Whole Building Energy Modeling
• Whole Building Commissioning
... WHAT ELSE IS CHANGING?
CONSEQUENCES OF POOR ENVELOPE DESIGN

Spray foam insulation for continuity of air / vapor barrier and thermal insulation

Parapet– Lack of Continuity of Air Barrier
CONSEQUENCES OF POOR ENVELOPE INSTALLATION

Window Interface – Lack of Continuity of Air Barrier
WHY GET THE BUILDING ENVELOPE RIGHT?
WHAT IS THERMAL BRIDGING?
**U-factor** is a rate to quantify the energy moving through an area of a material or an assembly. The higher the U-factor the faster energy is moving through the material.

**SI:** $\text{W/m}^2\cdot\text{deg K}$  
**IM:** $\text{BTU/HR}\cdot\text{FT}^2\cdot\text{deg F}$
R-Value is the resistance to energy moving through a material in the form of heat. It is the inverse if the U-factor.

\[
U = \frac{1}{R} \\
R = \frac{1}{U}
\]
Common Thickness and R-Value of Cladding Materials

<table>
<thead>
<tr>
<th>Material</th>
<th>R Value</th>
<th>Thickness (Inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vinyl</td>
<td>0.02</td>
<td>0.00</td>
</tr>
<tr>
<td>Stucco</td>
<td>0.08</td>
<td>0.00</td>
</tr>
<tr>
<td>Brick Veneer</td>
<td>0.80</td>
<td>0.75</td>
</tr>
<tr>
<td>Cementious</td>
<td>0.15</td>
<td>0.31</td>
</tr>
<tr>
<td>Wood Bevel (thin)</td>
<td>0.80</td>
<td>0.50</td>
</tr>
<tr>
<td>Wood Bevel (standard)</td>
<td>1.05</td>
<td>0.6875</td>
</tr>
<tr>
<td>Wood Bevel (thick)</td>
<td>1.10</td>
<td>1.00</td>
</tr>
<tr>
<td>Aluminum Siding</td>
<td>0.00</td>
<td>0.02</td>
</tr>
<tr>
<td>Corrugated Metal Siding</td>
<td>0.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

- R Value: Thermal resistance measure.
- Thickness (Inches): Physical thickness of the cladding material.
RIGID INSULATION

Photo Credit: Green Building Advisor, Choosing Rigid Foam
R/inch of Common Types of Insulation

- EPS
- Rigid Mineral Board
- XPS
- Polyiso (Sprayfoam)
SOLVING THERMAL BRIDGING PROBLEMS
Types of Transmittances

- **Clear Field**
  \[ U_0 \]

- **Linear**
  \[ \Psi \text{ psi} \]

- **Point**
  \[ \chi \text{ chi} \]
- Steel is 400 times more conductive than wood
- Steel studs are usually around 40 times thinner
- On average, steel studs are roughly 10 or more times more conductive
Baseline
2x6 w/ R-22 batts = R-16 effective

Exterior Insulation: R-20 to R-40+ effective
- Constraints: cladding attachment, wall thickness
- Good for wood/steel/concrete

Deep/Double Stud: R-20 to R-40+ effective
- Constraints wall thickness
- Good for wood, wasted for steel

Split Insulation: R-20 to R-40+ effective
- Constraints: cladding attachment
- Good for wood, palatable for steel
## ESTIMATING THERMAL EFFECTIVENESS

<table>
<thead>
<tr>
<th>Framing Type and Spacing Width (Actual Depth)</th>
<th>Cavity Insulation R-Value: Rated (Effective Installed [see Table A9.2B])</th>
<th>Overall U-Factor for Entire Base Wall Assembly</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R-1.00</td>
<td>R-2.00</td>
<td>R-3.00</td>
</tr>
<tr>
<td>Steel Framing at 16 in. on center</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None (0.0)</td>
<td>0.352</td>
<td>0.260</td>
<td>0.207</td>
</tr>
<tr>
<td>3.5 in. depth</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R-11 (5.5)</td>
<td>0.132</td>
<td>0.117</td>
<td>0.105</td>
</tr>
<tr>
<td>R-13 (6.0)</td>
<td>0.124</td>
<td>0.111</td>
<td>0.100</td>
</tr>
<tr>
<td>R-15 (6.4)</td>
<td>0.118</td>
<td>0.106</td>
<td>0.096</td>
</tr>
<tr>
<td>R-8.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.0 in.</td>
<td>0.109</td>
<td>0.099</td>
<td>0.090</td>
</tr>
</tbody>
</table>
CONTINUOUS INSULATION

Per ASHRAE 90.1: Continuous Insulation - Insulation that is continuous across all structural members without thermal bridges other than fasteners and service openings

- If there are elements other than nails or screws through the insulation, it is not continuous
- If there are studs, girts, clips, even brick ties they need to be accounted for
- This can be done by calculating the effective U (or R) values of these assemblies
REALISTIC ENVELOPE PERFORMANCE
EFFECT OF THERMAL BRIDGING IN 3D

ASHRAE 90.1 2010
R-VALUE NEEDED FOR DESIRED PERFORMANCE

Project Goal
### Parallel Path Method

<table>
<thead>
<tr>
<th>Wall Assembly</th>
<th>R-Value</th>
<th>Thickness [Inch]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Exterior Air Films Coefficient</td>
<td>0.17</td>
<td>-</td>
</tr>
<tr>
<td>2 Cladding</td>
<td>0.15</td>
<td>0.31</td>
</tr>
<tr>
<td>3 Vented Airspace</td>
<td>0.25</td>
<td>0.75</td>
</tr>
<tr>
<td>4 Exterior Insulation (Continuous)</td>
<td>0.40</td>
<td>2.00</td>
</tr>
<tr>
<td>5 Sheathing</td>
<td>0.63</td>
<td>0.50</td>
</tr>
<tr>
<td>6 Interior Insulation</td>
<td>3.50</td>
<td>5.50</td>
</tr>
<tr>
<td>7 Wood Studs</td>
<td>6.98</td>
<td>5.50</td>
</tr>
<tr>
<td>8 Interior drywall</td>
<td>0.45</td>
<td>0.50</td>
</tr>
<tr>
<td>9 Interior Air Films Coefficient</td>
<td>0.67</td>
<td>-</td>
</tr>
<tr>
<td><strong>Assembly Total</strong></td>
<td><strong>R - 32.7</strong></td>
<td><strong>9.6 In</strong></td>
</tr>
</tbody>
</table>

**Assembly U-Value**

0.031
THE WHOLE IS GREATER THAN THE SUM OF THE PARTS

R20 Wall?

Parallel Path

\[ R \approx 11.5 \]

With Lateral Heat Flow

\[ R \approx 9.8 \]
DETAILING WINDOW TO WALL INTERFACE
Parapets

Detail 5.5.12

Exterior and Interior Insulated 3 5/8" x 1 5/8" Steel Stud (16" o.c.)
Wall Assembly with Intermittent Vertical Z Girts (16" o.c.)
Supporting Metal Cladding – Concrete Roof Deck at Isokorb AXT1
Thermally Broken Concrete Parapet

Thermally Broken Parapet Detail
(Isokorb AXT1)

Figure 3.11: A thermally broken parapet where the roof insulation is carried to the exterior insulation at the same level via a manufactured thermal break. The parapet is cold (blue), indicating less heat flow and a more efficient system.

Figure 3.12: A parapet with the insulation wrapped around the parapet structure. The parapet is warm (green), indicating more heat flow and a less efficient system.
EXAMPLES OF THERMAL BREAKS – CONDENSATION RESISTANCE
WHY THERMAL BRIDGING IS THE ACHILLES HEEL FOR PERFORMANCE?
WHICH HAS A BIGGER EFFECT?

- More Insulation
- Thermal Break
Climate Zones

All of Alaska in Zone 7 except for the following Boroughs in Zone 8:
- Bethel, Dillingham, Fairbanks, N. Star, Nome North Slope, Northwest Arctic, Southeast Fairbanks, Wade Hampton, and Yukon-Koyukuk

Zone 1 includes: Hawaii, Guam, Puerto Rico, and the Virgin Islands
### Climate Zones

<table>
<thead>
<tr>
<th>Climate Zone</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4 Exception Marine</th>
<th>5 and Marine 4</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rooftops</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insulation entirely above roof deck</td>
<td>R-2.5ci</td>
<td>R-2.5ci</td>
<td>R-2.5ci</td>
<td>R-2.5ci</td>
<td>R-3.0ci</td>
<td>R-3.0ci</td>
<td>R-3.0ci</td>
<td>R-3.0ci</td>
</tr>
<tr>
<td><strong>Gable End walls</strong></td>
<td>R-19</td>
<td>R-19</td>
<td>R-19</td>
<td>R-19</td>
<td>R-19</td>
<td>R-19</td>
<td>R-25</td>
<td>R-30</td>
</tr>
<tr>
<td><strong>Side walls</strong></td>
<td>R-35</td>
<td>R-35</td>
<td>R-35</td>
<td>R-35</td>
<td>R-35</td>
<td>R-35</td>
<td>R-35</td>
<td>R-35</td>
</tr>
<tr>
<td><strong>Walls, below grade</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Below grade walls</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td><strong>Floors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Masonry floor</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td><strong>Slab-on-grade floors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concrete slab</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td><strong>Other Slabs</strong></td>
<td>R-10 24&quot;</td>
<td>R-10 24&quot;</td>
<td>R-10 24&quot;</td>
<td>R-10 24&quot;</td>
<td>R-15 24&quot;</td>
<td>R-15 24&quot;</td>
<td>R-15 24&quot;</td>
<td>R-15 24&quot;</td>
</tr>
<tr>
<td><strong>Ceilings</strong></td>
<td>R-4.75</td>
<td>R-4.75</td>
<td>R-4.75</td>
<td>R-4.75</td>
<td>R-4.75</td>
<td>R-4.75</td>
<td>R-4.75</td>
<td>R-4.75</td>
</tr>
</tbody>
</table>

**Table C402.4.5**

Opaque Thermal Envelope Insulation Component Minimum Requirements, Value Method®

| **Walls, above grade** |   |   |   |                   |                |   |   |   |
| Masonry | R-5.7ci | R-5.7ci | R-5.7ci | R-5.7ci | R-5.7ci | R-5.7ci | R-5.7ci | R-5.7ci |
| Metal building | R-12 | R-12 | R-12 | R-12 | R-12 | R-12 | R-12 | R-12 |
| Steel frames | R-15 | R-15 | R-15 | R-15 | R-15 | R-15 | R-15 | R-15 |
| **Walls, below grade** |   |   |   |                   |                |   |   |   |
| Below grade walls | NR | NR | NR | NR | NR | NR | NR | NR |
| **Floors** |   |   |   |                   |                |   |   |   |
| Masonry floor | NR | NR | NR | NR | NR | NR | NR | NR |
| **Slab-on-grade floors** |   |   |   |                   |                |   |   |   |
| Concrete slab | NR | NR | NR | NR | NR | NR | NR | NR |
| **Other Slabs** | R-10 24" | R-10 24" | R-10 24" | R-10 24" | R-15 24" | R-15 24" | R-15 24" | R-15 24" |
| **Ceilings** | R-4.75 | R-4.75 | R-4.75 | R-4.75 | R-4.75 | R-4.75 | R-4.75 | R-4.75 |
## Incentives for building envelope new construction/major renovation

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Category</th>
<th>Minimum Efficiency Requirement</th>
<th>Incentive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cool Roof</td>
<td>--</td>
<td>ENERGY STAR® qualified</td>
<td>$0.05/square foot</td>
</tr>
<tr>
<td>Roof/Attic Insulation</td>
<td>--</td>
<td>Minimum increment of R-5 insulation above code (See note 5)</td>
<td>$0.05/square foot</td>
</tr>
<tr>
<td>Wall Insulation</td>
<td>--</td>
<td>Minimum increment of R-3.7 continuous insulation above code (See note 5)</td>
<td>$0.07/square foot</td>
</tr>
<tr>
<td>Windows (See note 3, 4)</td>
<td>Site-built</td>
<td>U-factor ≤ 0.30 and SHGC ≤ 0.33 (glazing only rating)</td>
<td>$0.35/square foot</td>
</tr>
<tr>
<td></td>
<td>Assembly</td>
<td>U-factor ≤ 0.30 and SHGC ≤ 0.33 (entire window assembly rating)</td>
<td>$0.35/square foot</td>
</tr>
</tbody>
</table>
WHAT HAVE WE NOT BEEN SEEING?
PARAMETRIC ANALYSIS
ESTIMATION OF THERMAL PERFORMANCE

Interior Air Film: 0.70
Interior GWB: 0.50
Air Space: 0.90
Exterior Sheathing: 0.56
Insulation: 12.60
Air Space: 0.40
Brick Veneer: 0.75
Exterior Air Film: 0.20
Assembly R-Value: 16.6
Assembly U-Factor: 0.060
TYPICAL DETAILS

Assembly R-Value: R-16.6

- Masonry Anchors: R-13.6 (-21.7%)
- Typical Shelf Angle: R-11.5 (-30.7%)
- Parapet: R-10.0 (-40%)
- Window Perimeters: R-7.7 (-54%)
IMPROVED DETAILS

Assembly R-Value: R-16.6

- Masonry Anchors: R-15.9 (-4.2%)
- Typical Shelf Angle: R-14.0 (-16%)
- Parapet: R-13.1 (-21%)
- Window Perimeters: R-12.1 (-27%)
Typical Details: Assembly R-7.7

<table>
<thead>
<tr>
<th>Add/Remove Detail</th>
<th>Transmittance Type</th>
<th>Include</th>
<th>Transmittance Description</th>
<th>Area, Length or Amount Takeoff</th>
<th>Units</th>
<th>Transmittance Value</th>
<th>Units</th>
<th>Source Reference</th>
<th>Heat Flow (BTU/hr°F)</th>
<th>%Total Heat Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Add Clear Field</td>
<td>Clear Field</td>
<td>Opaque Wall</td>
<td>1104.00 ft²</td>
<td>ft²</td>
<td>0.074</td>
<td>BTU/hr ft²°F</td>
<td></td>
<td>Inner Source Here</td>
<td>81.1</td>
<td>57%</td>
</tr>
<tr>
<td>Add Linear Interface Detail</td>
<td>Linear Interface Detail</td>
<td>Shelf Angle</td>
<td>50.00 ft</td>
<td>ft</td>
<td>0.314</td>
<td>BTU/hr ft °F</td>
<td>Inner Source Here</td>
<td>15.7</td>
<td>11%</td>
<td></td>
</tr>
<tr>
<td>Remove Linear Interface Detail</td>
<td>Linear Interface Detail</td>
<td>Parapet</td>
<td>50.00 ft</td>
<td>ft</td>
<td>0.263</td>
<td>BTU/hr ft °F</td>
<td>Inner Source Here</td>
<td>13.2</td>
<td>9%</td>
<td></td>
</tr>
<tr>
<td>Remove Linear Interface Detail</td>
<td>Linear Interface Detail</td>
<td>Window Perimeter</td>
<td>80.00 ft</td>
<td>ft</td>
<td>0.410</td>
<td>BTU/hr ft °F</td>
<td>Inner Source Here</td>
<td>32.8</td>
<td>23%</td>
<td></td>
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</tbody>
</table>

Improved Details: Assembly R-12.1

<table>
<thead>
<tr>
<th>Add/Remove Detail</th>
<th>Transmittance Type</th>
<th>Include</th>
<th>Transmittance Description</th>
<th>Area, Length or Amount Takeoff</th>
<th>Units</th>
<th>Transmittance Value</th>
<th>Units</th>
<th>Source Reference</th>
<th>Heat Flow (BTU/hr°F)</th>
<th>%Total Heat Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Add Clear Field</td>
<td>Clear Field</td>
<td>Opaque Wall</td>
<td>1104.00 ft²</td>
<td>ft²</td>
<td>0.063</td>
<td>BTU/hr ft²°F</td>
<td></td>
<td>Inner Source Here</td>
<td>69.6</td>
<td>76%</td>
</tr>
<tr>
<td>Add Linear Interface Detail</td>
<td>Linear Interface Detail</td>
<td>Shelf Angle</td>
<td>50.00 ft</td>
<td>ft</td>
<td>0.189</td>
<td>BTU/hr ft °F</td>
<td>Inner Source Here</td>
<td>9.5</td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td>Remove Linear Interface Detail</td>
<td>Linear Interface Detail</td>
<td>Parapet</td>
<td>50.00 ft</td>
<td>ft</td>
<td>0.100</td>
<td>BTU/hr ft °F</td>
<td>Inner Source Here</td>
<td>5.0</td>
<td>5%</td>
<td></td>
</tr>
<tr>
<td>Remove Linear Interface Detail</td>
<td>Linear Interface Detail</td>
<td>Window Perimeter</td>
<td>80.00 ft</td>
<td>ft</td>
<td>0.090</td>
<td>BTU/hr ft °F</td>
<td>Inner Source Here</td>
<td>7.2</td>
<td>8%</td>
<td></td>
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## Masonry Wall Performance

<table>
<thead>
<tr>
<th>Insulation</th>
<th>Nominal</th>
<th>Effective</th>
<th>Decrease</th>
</tr>
</thead>
<tbody>
<tr>
<td>4&quot;</td>
<td>R-20.8</td>
<td>R-9.6</td>
<td>54%</td>
</tr>
<tr>
<td>3&quot;</td>
<td>R-16.6</td>
<td>R-8.6</td>
<td>48%</td>
</tr>
<tr>
<td>2&quot;</td>
<td>R-12.4</td>
<td>R-7.3</td>
<td>41%</td>
</tr>
<tr>
<td>1&quot;</td>
<td>R-8.2</td>
<td>R-5.6</td>
<td>32%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Insulation</th>
<th>Nominal</th>
<th>Effective</th>
<th>Decrease</th>
</tr>
</thead>
<tbody>
<tr>
<td>4&quot;</td>
<td>R-20.8</td>
<td>R-14.8</td>
<td>29%</td>
</tr>
<tr>
<td>3&quot;</td>
<td>R-16.6</td>
<td>R-12.6</td>
<td>24%</td>
</tr>
<tr>
<td>2&quot;</td>
<td>R-12.4</td>
<td>R-9.9</td>
<td>20%</td>
</tr>
<tr>
<td>1&quot;</td>
<td>R-8.2</td>
<td>R-7.1</td>
<td>13%</td>
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</table>
## METAL PANEL WALL PERFORMANCE

<table>
<thead>
<tr>
<th>Insulation</th>
<th>Nominal</th>
<th>Effective</th>
<th>Decrease</th>
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<tr>
<td>4&quot;</td>
<td>R-23.2</td>
<td>R-13.1</td>
<td>44%</td>
</tr>
<tr>
<td>3&quot;</td>
<td>R-18.2</td>
<td>R-11.3</td>
<td>38%</td>
</tr>
<tr>
<td>2&quot;</td>
<td>R-13.2</td>
<td>R-9.4</td>
<td>28%</td>
</tr>
<tr>
<td>1&quot;</td>
<td>R-8.2</td>
<td>R-6.8</td>
<td>17%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Insulation</th>
<th>Nominal</th>
<th>Effective</th>
<th>Decrease</th>
</tr>
</thead>
<tbody>
<tr>
<td>4&quot;</td>
<td>R-20</td>
<td>R-17.2</td>
<td>14%</td>
</tr>
<tr>
<td>3&quot;</td>
<td>R-17.9</td>
<td>R-15.7</td>
<td>12%</td>
</tr>
<tr>
<td>2&quot;</td>
<td>R-15.8</td>
<td>R-14.1</td>
<td>11%</td>
</tr>
<tr>
<td>1&quot;</td>
<td>R-11.6</td>
<td>R-10.8</td>
<td>7%</td>
</tr>
</tbody>
</table>
CLADDING ORIENTATION

Effective R-Value (Vertical Z Girt) = 11.9
Effective R-Value (Horizontal Z Girt) = 14.5
The vertical girt loses energy 20% faster than the horizontal girt detail.
CLADDING ATTACHMENT AND EFFECTIVE R-VALUE GOAL
EFFECTIVENESS OF CI FROM CLADDING ATTACHMENT CHOICES

ASHRAE 90.1 2010
IMPROVEMENTS TO ACTUAL CI PERFORMANCE
IMPROVED SYSTEMS
CHALLENGES IN THE FIELD
## MARKET TRANSFORMATION

### SPANDREL PANEL

<table>
<thead>
<tr>
<th>Description</th>
<th>U-Value</th>
<th>R-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>U-0.17, R-5.8</td>
<td></td>
</tr>
<tr>
<td>+ more insulation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ large thermal break</td>
<td>U-0.09, R-11.3</td>
<td></td>
</tr>
<tr>
<td>+ Intermittent clips</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ deflection header</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ more insulation</td>
<td>U-0.06, R-17.6</td>
<td></td>
</tr>
<tr>
<td>+ large thermal break</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ Intermittent clips</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ deflection header</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ R-18 SPF</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
With Spray Foam

No Spray Foam

![Graph showing the comparison of Spandrel Section Effective R-value with and without spray foam. The graph indicates that the Effective R-value increases with the Nominal Insulation R-value, and the presence of spray foam results in a higher R-value compared to air in the stud cavity.](image)
SLAB PROJECTIONS

Detail 5.2.13

Exterior and Interior Insulated 3 5/8” x 1 5/8” Steel Stud (16” o.c.) Wall Assembly with Horizontal Z-girts (24” o.c.) Supporting Metal Cladding – Isokorb CM20 Thermally Broken Slab Projection with Uninsulated Curb

Thermally Broken Slab Detail (Isokorb CM20)
Building energy use - mid-rise MURB in Edmonton
SUMMARY OF IMPACT

Figure 3.3: Comparison of Relative Contribution of Heat Flow (W/K) to the Effective Thermal Resistance (°F ft² hr/ BTU) for Various Construction Types
Whole Building Energy Simulation

- Replaces complying with prescriptive requirements of energy codes (envelope, lighting, HVAC, swh, power)
- Assess overall building’s annual energy use through energy modeling
- Design energy use must be equal to or lower than energy use from building meeting prescriptive requirements
## Linear Transmittance Effects

### Floor Slab Linear Transmittance

<table>
<thead>
<tr>
<th>Description of Detail (Thermal Anomaly)</th>
<th>Construction Type</th>
<th>Wall Assembly Description</th>
<th>Detailed Description</th>
<th>Reference</th>
<th>Linear Transmittance (W/m K)</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shelf Angle</td>
<td>Steel Framed</td>
<td>Interior and exterior Insulated Steel Stud with Brick Veneer</td>
<td>Standard Shelf Angle with Metal Flashing at Concrete Floor Slab with Exterior and interior Insulated Steel Stud with Brick Veneer</td>
<td>5.2.9</td>
<td>0.216 0.217 0.316</td>
<td>Poor</td>
</tr>
<tr>
<td>Shelf Angle</td>
<td>Steel Framed</td>
<td>Interior and exterior Insulated Steel Stud with Brick Veneer</td>
<td>Stand-off Shelf Angle with Metal Flashing at Concrete Floor Slab with Exterior and interior Insulated Steel Stud with Brick Veneer</td>
<td>5.2.10</td>
<td>0.217 0.216 0.316</td>
<td>Regular</td>
</tr>
<tr>
<td>Shelf Angle</td>
<td>Concrete</td>
<td>Exterior Insulated Concrete Block with brick veneer</td>
<td>Shelf Angle with Metal Flashing at Concrete Floor with Exterior Insulated Concrete Block Wall Assembly with Masonry Veneer</td>
<td>6.2.14</td>
<td>0.217 0.216 0.447</td>
<td>Regular</td>
</tr>
<tr>
<td>Shelf Angle</td>
<td>Concrete</td>
<td>Exterior Insulated Concrete Block with brick veneer</td>
<td>Stand-off Shelf Angle with Metal Flashing at Concrete Floor with Exterior Insulated Concrete Block Wall Assembly with Masonry Veneer</td>
<td>6.2.15</td>
<td>0.186 0.186 0.322</td>
<td>Improved</td>
</tr>
</tbody>
</table>
The blue arrows show how the difference in energy-use between any envelope scenario is determined.

Figure 2.1: Annual Electrical Energy for a 40% Glazed High-Rise MURB in Vancouver, Heated with Electric Baseboards.
Figure 3.7: Comparison of Annual Energy Use and Simple Payback for High-Rise MURB with 40% Glazing in Vancouver
### Building Specifications

<table>
<thead>
<tr>
<th>Gross Floor Area (sq ft)</th>
<th>240,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Floors</td>
<td>6</td>
</tr>
<tr>
<td>Window to Wall Ratio</td>
<td>50%</td>
</tr>
</tbody>
</table>

### Scenario 1: Steel Construction

<table>
<thead>
<tr>
<th>Case</th>
<th>U-value (W/m²K)</th>
<th>Reduction</th>
<th>Absolute</th>
<th>Incremental</th>
<th>Percent Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Case 1: Standard Assemblies + Details</td>
<td>0.95</td>
<td>-</td>
<td>$3,354,838</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Case 1A: More Insulation for Stud Wall (R-20 e.i., R-12)</td>
<td>0.93</td>
<td>3%</td>
<td>$3,449,038</td>
<td>$94,200</td>
<td>3%</td>
</tr>
<tr>
<td>Case 1B: More Insulation at Spandrel (Continuous Spray Foam)</td>
<td>0.89</td>
<td>7%</td>
<td>$3,392,468</td>
<td>$37,630</td>
<td>1%</td>
</tr>
<tr>
<td>Case 1C: Double Glazing with AIM (conventional CW)</td>
<td>0.89</td>
<td>7%</td>
<td>$3,403,202</td>
<td>$48,364</td>
<td>1%</td>
</tr>
<tr>
<td>Case 1D: More Insulation at Spandrel &amp; Steel Studs</td>
<td>0.81</td>
<td>15%</td>
<td>$3,486,668</td>
<td>$131,830</td>
<td>4%</td>
</tr>
<tr>
<td>Case 1E: Exterior Insulated Steel Stud at All Opaque Areas</td>
<td>0.72</td>
<td>24%</td>
<td>$3,185,000</td>
<td>($169,778)</td>
<td>-5%</td>
</tr>
<tr>
<td>Case 1F: Improved Details (Exterior Insulation)</td>
<td>0.74</td>
<td>22%</td>
<td>$3,251,614</td>
<td>($103,224)</td>
<td>-3%</td>
</tr>
<tr>
<td>Case 1G: Improved Details + More Insulation</td>
<td>0.60</td>
<td>37%</td>
<td>$3,308,084</td>
<td>($46,754)</td>
<td>-1%</td>
</tr>
</tbody>
</table>
Thermal Bridging:


CASE STUDY: GETTING VALUE FROM BETTER DETAILING
Project Case Study

Credit: Architecture and graphic provided by Architectural Nexus
Opaque Walls

Opaque Wall Thermal Resistance Target: R-11

Credit: Energy model and graphic provided by Total Building Commissioning (TBC)
EFFECTIVE THERMAL PERFORMANCE

![Bar chart showing effective thermal performance]

- Percieved R-Value with 3" of Insulation: 20
- Accounting for Thermal Bridging with 3" of Insulation: 11
- Accounting for Thermal Bridging with 2" of Insulation: 11

Legend:
- R-Value
- Goal for Energy Model Target
Clear Field Transmittance

Base Design Accounting for thermal bridging: R-7.3
Improved Clear Field: R-10.1 (< R-11 Goal)
LINEAR TRANSMITTANCE

Base: Accounting for thermal bridging: R-7.3
Improved Linear Transmittances: R-11.3 (> R-11 Goal)
EFFECTIVE R-VALUE AND DECISIONS MAKING

Comparing Transmittance Types

- Clear Field Transmittance: 605.5 (Base), 464.4 (Improved)
- Linear Transmittance: 795 (Base), 432 (Improved)
- Combined: 1400.5 (Base), 896.4 (Improved)

Legend: Base, Improved
COMPARING OPPORTUNITIES FOR IMPROVEMENT
IMPROVED LINEAR TRANSMITTANCES

Base: Accounting for thermal bridging: R-7.3
Improved Linear Transmittances: R-11.3
Best practices when specifying thermal resistance systems:

- Code Compliant, minimum
- Performs as intended (energy goal)
- Accounts for location of air/water barriers to limit potential for mold, condensation and material degradation
- Accounts for thermal bridging from all assembly components (clips, ties, girts).
WHERE DOES THIS LEAD US?

- Thermal bridging can reduce the value of an investment in more insulation.
- Thermal breaks can help owners find the least expensive path to performance goals.
- Changes to the building envelope, once constructed, are expensive and rarely done.
- Building envelope improvements make the most sense during initial construction or during a major renovation, however some problems cannot wait (leaks, condensation).
THANK YOU

Chamonix Larsen, AIA
Morrison Hershfield
clarsen@morrisonhershfield.com

Rick Ziegler, PE, RRC
Morrison Hershfield
rziegler@morrisonhershfield.com
801-707-0382
1. Use the Building Envelope Thermal Bridging Guide Enhanced Calculator (betbg-enhanced-spreadsheet-excel), and the data found in the thermal bridging guide, compare the overall opaque wall thermal performance values of a building with the following considerations:

- 1500 sf of exterior walls are metal stud and brick veneer
- 1500 sf of exterior walls are metal stud and metal panel
- 1000 sf of exterior walls are curtainwall glazing systems
- The building is in climate zone 5.
- The owner want to achieve a code compliant design with no insulation in the stud cavity.
ASSEMBLY-SPECIFIC TEMPERATURE INDEX

\[ T_i = \frac{T_{\text{surface}} - T_{\text{outside}}}{T_{\text{inside}} - T_{\text{outside}}} \]
Detail 5.1.43

Exterior Insulated 3 5/8" x 1 5/8" Steel Stud (16" o.c.) Wall Assembly with Hohmann & Barnard Masonry Carbon Steel HB-213 2X Anchor Supporting Brick Veneer – Clear Wall

View of Exterior
View of Anchoring Tie

Thermal Performance Indicators
- Assembly ID (Nominal) R-Value
- R-6.3 (0.76 RSI) = exterior insulation
- Transmittance / Resistance U, Uo
- "Clear wall" U and R-value
- Surface Temperature Index
  - T0 = exterior temperature
  - T1 = interior temperature

Note: Assumptions and limitations for surface temperatures identified in ASHRAE 1300-07

Nominal (1D) vs. Assembly Performance Indicators

<table>
<thead>
<tr>
<th>Exterior Insulation</th>
<th>1D R-Value (R8)</th>
<th>Uo</th>
<th>9&quot; Vertical Clip Spacing</th>
<th>12&quot; Vertical Clip Spacing</th>
<th>18&quot; Vertical Clip Spacing</th>
<th>24&quot; Vertical Clip Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-4.2 (3.74)</td>
<td>0.136 (0.770)</td>
<td>0.127 (0.722)</td>
<td>R-7.4 (1.30)</td>
<td>0.162 (0.580)</td>
<td>R-7.9 (1.39)</td>
<td>0.127 (0.722)</td>
</tr>
<tr>
<td>R-8.4 (1.48)</td>
<td>0.162 (0.580)</td>
<td>0.110 (0.848)</td>
<td>R-8.8 (1.72)</td>
<td>0.162 (0.580)</td>
<td>R-11.0 (1.84)</td>
<td>0.191 (0.515)</td>
</tr>
<tr>
<td>R-12.6 (2.22)</td>
<td>0.085 (0.480)</td>
<td>0.085 (0.480)</td>
<td>R-11.8 (2.56)</td>
<td>0.085 (0.480)</td>
<td>R-13.6 (2.39)</td>
<td>0.085 (0.480)</td>
</tr>
<tr>
<td>R-16.8 (2.96)</td>
<td>0.073 (0.415)</td>
<td>0.073 (0.415)</td>
<td>R-13.7 (2.40)</td>
<td>0.073 (0.415)</td>
<td>R-16.4 (2.80)</td>
<td>0.073 (0.415)</td>
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</tbody>
</table>

Temperature Indices

<table>
<thead>
<tr>
<th>ba</th>
<th>ca</th>
<th>db</th>
<th>dc</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.59</td>
<td>0.64</td>
<td>0.69</td>
<td>0.71</td>
</tr>
<tr>
<td>0.72</td>
<td>0.76</td>
<td>0.82</td>
<td>0.84</td>
</tr>
</tbody>
</table>

Min T on sheathing behind stud at Tie Penetration
Max T on sheathing at edge of Steel Stud/Flange aligned with Tie Penetration
**Detail 5.1.43**

Exterior Insulated 3 5/8" x 1 5/8" Steel Stud (16" o.c.) Wall Assembly with Hohmann & Barnard Masonry Carbon Steel HB-213 2X Anchor Supporting Brick Veneer – Clear Wall

**Temperature Indices**

<table>
<thead>
<tr>
<th>T11</th>
<th>T12</th>
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</thead>
<tbody>
<tr>
<td>0.59</td>
<td>0.72</td>
</tr>
<tr>
<td>0.64</td>
<td>0.78</td>
</tr>
<tr>
<td>0.69</td>
<td>0.82</td>
</tr>
<tr>
<td>0.71</td>
<td>0.84</td>
</tr>
</tbody>
</table>

Min T on sheathing behind stud at Tie Penetration
Max T on sheathing at edge of Steel Stud Flange aligned with Tie Penetration
SURFACE TEMP AND CONDENSATION RISK

- What surface temperature will the interior side of the sheathing be with the following conditions?
  - Inside Temp: 70 deg F
  - Inside Relative humidity: 30%
  - Outside Temp: 20 deg F
  - Wall Assembly: Exterior Insulated 3 5/8” x 1 5/8” Steel Stud (16” o.c.) Wall Assembly with Hohmann & Barnard Masonry Carbon Steel HB-213 2X Anchor Supporting Brick Veneer – Clear Wall

- Does this create a condensation risk in the wall?

- What is the limit of interior relative humidity before a condensation risk is likely?
CALCULATING SURFACE TEMPERATURE

\[
T_i = \frac{T_{\text{surface}} - T_{\text{outside}}}{T_{\text{inside}} - T_{\text{outside}}}
\]

\[
T_{\text{surface}} = T_i(T_{\text{inside}} - T_{\text{outside}}) + T_{\text{out}}
\]
**Detail 5.1.43**

Exterior Insulated 3 5/8" x 1 5/8" Steel Stud (16" o.c.) Wall Assembly with Hohmann & Barnard Masonry Carbon Steel HB-213 2X Anchor Supporting Brick Veneer – Clear Wall

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Interior Film</td>
<td>0.125 (0.32)</td>
<td>0.256 (0.64)</td>
<td>0.76 (0.18)</td>
<td>0.94 (0.22)</td>
<td>1.04 (0.24)</td>
</tr>
<tr>
<td>2</td>
<td>Exterior Insulation 5/8&quot;</td>
<td>0.375 (0.95)</td>
<td>0.244 (0.61)</td>
<td>0.75 (0.19)</td>
<td>0.94 (0.22)</td>
<td>1.04 (0.24)</td>
</tr>
<tr>
<td>3</td>
<td>Anchor Detail</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>Steel Stud</td>
<td>3 5/8&quot;</td>
<td>0.163 (0.42)</td>
<td>0.31 (0.08)</td>
<td>0.82 (0.2)</td>
<td></td>
</tr>
</tbody>
</table>

**Thermal Performance Indicators**

<table>
<thead>
<tr>
<th>Assembly 10 (Nominal)</th>
<th>R-Value</th>
<th>R-6.2 (0.7 Rm) + exterior insulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmittance / Resistence</td>
<td>U, R</td>
<td>&quot;Clear wall&quot; U- and R-value</td>
</tr>
<tr>
<td>Surface Temperature Index</td>
<td>Y</td>
<td>0 = exterior temperature</td>
</tr>
<tr>
<td>1 = interior temperature</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Nominal (10) vs. Assembly Performance Indicators**

<table>
<thead>
<tr>
<th>Exterior Insulation</th>
<th>R-Value (R10)</th>
<th>R-8.5 (1.55)</th>
<th>R-8.5 (1.55)</th>
<th>R-7.6 (1.36)</th>
<th>R-7.6 (1.36)</th>
<th>R-7.0 (1.22)</th>
<th>R-7.0 (1.22)</th>
<th>R-6.2 (0.7 Rm) + exterior insulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>R4-2 (3.74)</td>
<td>R-7.6 (1.36)</td>
<td>0.136 (0.33)</td>
<td>0.136 (0.33)</td>
<td>0.127 (0.29)</td>
<td>0.127 (0.29)</td>
<td>0.100 (0.23)</td>
<td>0.100 (0.23)</td>
<td></td>
</tr>
<tr>
<td>R4-8 (4.44)</td>
<td>R-7.6 (1.36)</td>
<td>0.136 (0.33)</td>
<td>0.136 (0.33)</td>
<td>0.127 (0.29)</td>
<td>0.127 (0.29)</td>
<td>0.100 (0.23)</td>
<td>0.100 (0.23)</td>
<td></td>
</tr>
<tr>
<td>R4-12 (6.22)</td>
<td>R-7.6 (1.36)</td>
<td>0.136 (0.33)</td>
<td>0.136 (0.33)</td>
<td>0.127 (0.29)</td>
<td>0.127 (0.29)</td>
<td>0.100 (0.23)</td>
<td>0.100 (0.23)</td>
<td></td>
</tr>
<tr>
<td>R4-16 (8.94)</td>
<td>R-7.6 (1.36)</td>
<td>0.136 (0.33)</td>
<td>0.136 (0.33)</td>
<td>0.127 (0.29)</td>
<td>0.127 (0.29)</td>
<td>0.100 (0.23)</td>
<td>0.100 (0.23)</td>
<td></td>
</tr>
</tbody>
</table>

**Temperature Indices**

<table>
<thead>
<tr>
<th>R4-2</th>
<th>R4-6</th>
<th>R4-12</th>
<th>R4-16</th>
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</thead>
<tbody>
<tr>
<td>R1</td>
<td>0.59</td>
<td>0.64</td>
<td>0.69</td>
</tr>
<tr>
<td>R2</td>
<td>0.72</td>
<td>0.78</td>
<td>0.82</td>
</tr>
</tbody>
</table>

1. Min T on sheathing behind stud at Tie Penetration
2. Max T on sheathing at edge of Steel Stud Flange aligned with Tie Penetration