Thermal Performance of Exterior Insulated Wall Assemblies: Why this is the new norm

RCI SEMINAR: WALLS AND ROOFS
JUNE 9, 2014
PRESENTED BY BRITTANY HANAM  P.ENG.
Outline

→ Effective R-values & Thermal Bridging
→ Alternate High R-value Wall Assemblies
→ Evolution of Cladding Attachment Systems
→ Alternate Cladding Attachment Systems
→ Other Thermal Bridging Considerations
→ Energy codes outline minimum thermal performance criteria based on climate zone
  → BCBC, VBBL
  → ASHRAE 90.1-2010, 2011 NECB
→ Energy codes in BC are some of most stringent in North America
→ Wall & Roof (R-value/U-values) very important part of compliance
→ Effective R-values must be considered
### ASHRAE 90.1-2010 & NECB 2011 R-Values

#### NECB 2011

<table>
<thead>
<tr>
<th>Climate Zone</th>
<th>Wall: Min. R-value</th>
<th>Roof - Sloped or Flat: Min. R-value</th>
<th>Window: Max. U-value</th>
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</thead>
<tbody>
<tr>
<td>8</td>
<td>31.0</td>
<td>40.0</td>
<td>0.28</td>
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<tr>
<td>7A/7B</td>
<td>27.0</td>
<td>35.0</td>
<td>0.39</td>
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<tr>
<td>6</td>
<td>23.0</td>
<td>31.0</td>
<td>0.39</td>
</tr>
<tr>
<td>5</td>
<td>20.4</td>
<td>31.0</td>
<td>0.39</td>
</tr>
<tr>
<td>4</td>
<td><strong>18.6</strong></td>
<td>25.0</td>
<td>0.42</td>
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</tbody>
</table>

#### ASHRAE 90.1-2010

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>8</td>
<td>27.8</td>
<td>47.6, 20.8</td>
<td>0.45, 0.35</td>
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<tr>
<td>7A/7B</td>
<td>19.6</td>
<td>37.0, 20.8</td>
<td>0.45, 0.35</td>
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<tr>
<td>6</td>
<td>19.6</td>
<td>37.0, 20.8</td>
<td>0.55, 0.35</td>
</tr>
<tr>
<td>5</td>
<td><strong>19.6 Res</strong></td>
<td>37.0, 20.8</td>
<td>0.55, 0.35</td>
</tr>
</tbody>
</table>

*7A/7B combined in ASHRAE 90.1
No Zone 4 in ASHRAE 90.1

All Units IP
Effective R-values

- ASHRAE 90.1 & NECB consider effective R-values (vs insulation nominal R-values)
- **Nominal R-values** = Rated R-values of insulation which do not include impacts of how they are installed
  - For example R-20 batt insulation or R-10 rigid insulation
- **Effective R-values** include impacts of insulation installation and all thermal bridges
  - For example nominal R-20 batts within steel studs becoming ~R-9 effective, or in wood studs ~R-15 effective
Thermal bridging occurs when a more conductive material (e.g. metal, concrete, wood etc.) bypasses a less conductive material (insulation)

“Short Circuit”

3.5” Fibreglass batt insulation
R-12 to R-14

Steel stud wall assembly with concrete slab
R 3 – 4 effective
Minimizing thermal bridging is key to energy code compliance and an energy efficient building.

- Exterior continuous insulation with thermally improved cladding attachments
- Minimize thermal bridges

Energy codes have historically focused on *insulation R-values*, however more attention is now being placed on *assembly R-values*.
In BC, minimum energy code R-value targets are in the range of:
- R-15 to R-25 effective for walls
- R-25 to R-50 effective for roofs
- R-2 to R-4 for windows

More energy efficient building programs such as Passive House or Net Zero have R-value targets in the range of:
- R-30 to R-50+ effective for walls
- R-40 to R-60+ effective for roofs
- R-6+ for windows
What Is Passive Design?

→ Reduce the demand for heating, cooling and ventilation energy through passive design strategies

→ Well-insulated building enclosure: walls, roof, windows
→ Passive solar – use the windows for heat
→ Airtight construction
→ Heat recovery ventilation

→ Highly insulated walls are an important part of passive design
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

New vs Retrofit Considerations
Double or Deep Stud Insulated Walls

- Double 2x4/2x6 stud, single deep 2x10, 2x12, I-Joist etc.
- Common wood-frame wall assembly in many passive houses (and prefabricated highly insulated walls)
- Inherently at a higher risk for damage if sheathing gets wet (rainwater, air leakage, vapor diffusion) – due to more interior insulation
Rigid exterior foam insulations (XPS, EPS, Polyiso, closed cell SPF) are vapor impermeable (in thicknesses of 2”+)

- Is the vapor barrier on the wrong side?
- Does the wall have two vapor barriers, can it dry?
- How much insulation should be put outside of the sheathing?
  - More is always better, but is there room? Budget?

Semi-rigid/rigid mineral wool insulation is vapor permeable and address these moisture concerns
But Why?

Vapor diffusion drying allowed through mineral wool insulation

Vapor diffusion drying restricted by foam plastic insulation on outside
Split Insulation and Moisture Risk Assessment

2x6 R-16 vs. R-40 Split Insulated Walls - Rain Water Leak over 2 years

Moisture Content of Sheathing (%)

Jan | Mar | May | Jul | Sep | Nov | Jan | Mar | May | Jul | Sep | Nov

2x6 Wall R-16

6" Mineral Wool Split over 2x6

6" Foam Split over 2x6
Side by Side Drying Test – Vapour Open vs Closed

Plywood Behind XPS – wet for 8 weeks

Plywood Behind Mineral Wool – dried within 8 weeks
Higher R-value Walls – Non-Combustible

- Insulation outboard of structure and control layers (air/vapor/water)
- Thermal mass at interior
- Cladding attachment biggest source of thermal loss/bridging
- Excellent performance in all climate zones
Cladding Attachment through Exterior Insulation
Cladding Attachment & Exterior Insulation

→ Exterior insulation is only as good as the cladding attachment strategy
→ How to achieve true continuous insulation (ci) performance?
→ What attachment system works best?
Background – Exterior Insulation Drivers
Background – Exterior Insulation Drivers

Pre-Rehabilitation – Stud Insulated, Lots of Thermal Bridging

Post-Rehabilitation – Exterior Membrane & Fully Exterior Insulated
Evolution of Exterior Girt Cladding Attachments
Trial Thermally Improved Cladding Attachments
Thermally Improved Performance

Continuous metal Z-girts

Fiberglass Clips & Hat-Tracks
Evolution of Exterior Insulation Approaches
Evolution of Exterior Insulation Approaches
Cladding Attachment: Screws through Insulation
→ 5-storey structure with steel, timber, concrete
→ Living Building Challenge
→ R-value design target up to R-25 effective for steel framed wall assembly (Minimum code R-18.2)
→ Within a 6” steel stud frame wall structure
→ Tasked with coming up with innovative cladding attachment to meet ambitious target
Expectation to be cost effective, buildable and minimize wall thickness

Available various Z-Girt & Metal Clip options evaluated with thermal modeling

None could achieve R-25 target, closest was to use expensive stainless steel clips

Modeling identified opportunity to improve performance with non-conductive fiberglass clip
Bullitt Center – Exterior Wall Assembly

- Metal panel cladding
- 1” horizontal metal hat tracks
- 3 ½” semi-rigid mineral fiber (R-14.7) between 3 ½” fiberglass clips (16” x 48” spacing)
- Fluid applied vapor permeable WRB/air barrier on gypsum sheathing
- 6” mineral fiber batts (R-19) between 6” steel studs (outboard of slab edge)
- Gypsum drywall

→ Effective R-value R-26.6
Bullitt Center – Exterior Wall Construction
Recent retrofit in Vancouver – 20% measured energy savings through exterior insulated walls, triple glazed fibreglass frame windows, air sealing
→ Over clad and exterior insulate walls (R-16 effective)
→ Also new windows and air sealing
→ Total 20% measured energy savings at the building
Exterior Insulation, Stucco & Metal Panel Overcladding
Choosing a Cladding Attachment System
Exterior Insulation & Cladding Attachment Considerations

- Cladding weight & gravity loads
- Wind loads
- Seismic loads
- Back-up wall construction (wood, concrete, steel)
  - Attachment from clip/girt back into structure (studs, sheathing, or slab edge)
- Exterior insulation thickness
- Rigid vs semi-rigid insulation
- R-value target
- Ease of attachment of cladding – returns, corners
- Combustibility requirements
Many Alternate Attachment Options
Cladding Attachment: Continuous Wood Framing
Cladding Attachment: Vertical Z-Girts
Cladding Attachment: Horizontal Z-Girts
Cladding Attachment: Diagonal Z-Girts & Clips
Cladding Attachment: Clip & Rail, Metal
Cladding Attachment: Clip & Rail, Metal
Cladding Attachment: Clip & Rail, Metal
Cladding Attachment: Metal Panel Clips
Cladding Attachment: Clip & Rail, Improved
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→ Reduce the metal, improve the performance
Cladding Attachment: Clip & Rail, Low Conductivity
Cladding Attachment: Screws through Insulation

- Longer cladding fasteners directly through rigid insulation (up to 2” for light claddings)
- Long screws through vertical strapping and rigid insulation creates truss – short cladding fasteners into vertical strapping
- Rigid shear block type connection through insulation, short cladding fasteners into vertical strapping
Cladding Attachment: Screws through Insulation
Screws through Insulation - Corners
Screws through Insulation - Corners
New Roxul Comfortboard IS & CIS Guides out soon
Exterior Insulation Finish System (EIFS)
Cladding Attachment: Masonry Ties & Shelf Angles

Continuous shelf angle – 40-55% reduction in overall wall R-value

Brick ties – small 5-15% (stainless steel) reduction in overall wall R-value

Shelf angle on stand-offs, reduction only 10-20% overall
Cladding Attachment: Masonry on CLT

- Ronald McDonald House
- 4 Buildings with residential and common areas
- 3 storey tilt-up Cross Laminated Timber (CLT) structure

*Michael Green Architecture (MGA)*
Building Enclosure Assemblies - Walls

R-32
Cladding Attachment: Masonry
Thermal Comparison of Options
## Cladding Attachment Recommendations

<table>
<thead>
<tr>
<th>Substrate / Cladding Type</th>
<th>Wood Backup (OSB/Plywood)</th>
<th>Steel Stud Backup</th>
<th>Concrete or Concrete Block Backup</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Light weight</strong></td>
<td>Clip &amp; Rail good</td>
<td>Clip &amp; Rail good</td>
<td>Clip &amp; Rail good</td>
</tr>
<tr>
<td><em>(up to fiber cement panels, &lt;10psf)</em></td>
<td>Screws good</td>
<td>Screws okay, but difficult to hit stud</td>
<td>Screws can be difficult to install</td>
</tr>
<tr>
<td><strong>Medium weight</strong></td>
<td>Clip &amp; Rail good</td>
<td>Clip &amp; Rail good</td>
<td>Clip &amp; Rail good</td>
</tr>
<tr>
<td><em>(stucco, cultured stone, 10-30 psf)</em></td>
<td>Screws with shear block or engineered</td>
<td>Screws with shear block or engineered</td>
<td>Screws can be difficult to install</td>
</tr>
<tr>
<td><strong>Heavy weight</strong></td>
<td>Gravity supports, anchors &amp; engineered connections only</td>
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</tr>
</tbody>
</table>
Other Thermal Bridging Considerations

Windows, spandrel panels, balconies, slab edges
Windows have a significant impact on overall R-value as the weakest link in the enclosure. Little benefit to improving wall R-values when heat loss through the windows dominates.
Where is Heat Loss Occurring?

Yellow/red/white = hot = high heat flow/high U-value  Blue = Cold = low heat flow/low U-value
Window Impacts in Highly Insulated Walls

Best window in an R-38 wall gives R-20 overall
Spandrel Panels

→ Low overall R-values due to thermal bridging
→ Considered an opaque wall, which makes it very difficult to comply with prescriptive building code requirements
Spandrel Panel Effective R-values

- Insulation within back-pans or to exterior of slab edge is bridged by aluminum frames
- Insulation reduction of 50% and greater with depreciating returns is typical
- **R-3 to R-5** effective R-value for any amount of insulation is a general rule of thumb
Spandrel Panel Effective R-Values

verticals
Added insulation provides minimal overall thermal improvement considering thermal bridging (R-4 max even for >R-20 of SPF)

+ Adding insulation to backside of back pans introduces condensation risk on back-pans and reduces exposed frame temperatures – leading to greater condensation potential at windows
Overall R-values are limited even with back-pan insulation and interior insulation.

With interior spray foam:
Max R-9

Without interior spray foam:
Max R-5

Source: ASHRAE Research Project 1365
Balconies & Slab Edge Projections
Thermal Bridging at Balconies
What Thermal Impact Can Balconies Possibly Have?

- Exposed slab edges, balconies, eyebrows have an R-value of ~R-1
- Individual balconies occupy 1 to 2% of gross wall area in typical high-rise
- Continuous exposed concrete slab edges or eyebrows occupy ~8% of gross wall area
- How can something small matter that much? Can’t I just ignore it?
### Impact of Slabs & Balconies – Exterior Insulated

#### R-values for 8’8” High Wall - No Balcony or Eyebrow (Center of Wall)

<table>
<thead>
<tr>
<th>Insulation Strategy</th>
<th>Effective R-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>3” EPS (R-12), Exterior Insulation</td>
<td><strong>R-13.9</strong></td>
</tr>
<tr>
<td>4” EPS (R-16), Exterior Insulation</td>
<td><strong>R-18.0</strong></td>
</tr>
<tr>
<td>6” EPS (R-24), Exterior Insulation</td>
<td><strong>R-25.8</strong></td>
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#### R-values for 8’8” High Wall with Balcony or Eyebrow (Overall)

<table>
<thead>
<tr>
<th>Insulation Strategy</th>
<th>Effective R-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>3” EPS (R-12), Exterior Insulation</td>
<td><strong>R-7.4 (-47%)</strong></td>
</tr>
<tr>
<td>4” EPS (R-16), Exterior Insulation</td>
<td><strong>R-8.6 (-52%)</strong></td>
</tr>
<tr>
<td>6” EPS (R-24), Exterior Insulation</td>
<td><strong>R-10.6 (-59%)</strong></td>
</tr>
</tbody>
</table>

Exterior insulation over concrete wall
### Impact of Slabs & Balconies – Interior Insulated

**R-values for 8’8” High Wall - No Balcony or Eyebrow (Center of Wall)**

<table>
<thead>
<tr>
<th>Insulation Strategy</th>
<th>Effective R-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1” XPS (R-5) + R-12 batts/steel studs</td>
<td>R-14.3</td>
</tr>
<tr>
<td>2” XPS (R-10) + R-12 batts/steel studs</td>
<td>R-19.7</td>
</tr>
<tr>
<td>3” XPS (R-15) + R-12 batts/steel studs</td>
<td><strong>R-24.7</strong></td>
</tr>
</tbody>
</table>

**R-values for 8’8” High Wall with Balcony or Eyebrow (Overall)**

<table>
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<th>Insulation Strategy</th>
<th>Effective R-value</th>
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</thead>
<tbody>
<tr>
<td>1” XPS (R-5) + R-12 batts/steel studs</td>
<td>R-7.5 (-48%)</td>
</tr>
<tr>
<td>2” XPS (R-10) + R-12 batts/steel studs</td>
<td>R-8.9 (-55%)</td>
</tr>
<tr>
<td>3” XPS (R-15) + R-12 batts/steel studs</td>
<td><strong>R-10.0 (-60%)</strong></td>
</tr>
</tbody>
</table>

XPS/batt insulation to interior of exposed concrete wall.
Thermal Comfort and Moisture Issues

Increased heat loss at slab results in colder indoor floor and ceiling temperatures – increasing risk for mould/condensation.
Ceiling and Flooring Moisture Issues
Balconies – Solutions?

→ Wrap with insulation
→ Use off-set point supports and hang the balcony precast units with threaded rods tied back to the columns of the structural frame
→ Offset point supports rather than cantilevering the slab
→ Stand-alone support structure
Cast-in Place Concrete Balcony Slab Thermal Breaks

- Thermally decouples the concrete slab connection from inside to outside – most efficient location to locate insulation
- Expanded polystyrene insulation
- Stainless steel reinforcing (better performance than standard rebar)
- Polymer concrete compression blocks
- Gypsum/concrete fire plates
## R-value Improvement from Balcony Thermal Breaks

### R-values for 8’8” High Wall with 6’ Balcony

<table>
<thead>
<tr>
<th>Wall Insulation Strategy</th>
<th>Effective R-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1” XPS (R-5) + R-12 batt/studs (R-14.3)</td>
<td>R-7.5</td>
</tr>
<tr>
<td>2” XPS (R-10) + R-12 batt/studs (R-19.7)</td>
<td>R-8.9</td>
</tr>
<tr>
<td>3” XPS (R-15) + R-12 batt/studs (R-24.7)</td>
<td>R-10.0</td>
</tr>
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</table>

### R-values for 8’8” High Wall with 6’ Balcony & Thermal Break

<table>
<thead>
<tr>
<th>Wall Insulation Strategy &amp; Thermal Break R-value</th>
<th>Effective R-values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R-2.5 thermal break</td>
</tr>
<tr>
<td>1” XPS (R-5) + R-12 batt/studs (R-14.3)</td>
<td>R-11.0</td>
</tr>
<tr>
<td>2” XPS (R-10) + R-12 batt/studs (R-19.7)</td>
<td>R-14.4</td>
</tr>
<tr>
<td>3” XPS (R-15) + R-12 batt/studs (R-24.7)</td>
<td>R-17.0</td>
</tr>
</tbody>
</table>
Wall insulation requirements are increasing, both for codes and for low energy buildings.

Wall assembly thermal performance is only as good as the cladding attachment.

- Many different cladding attachment systems, some are better than others!

Other thermal bridges have a big impact on building enclosure thermal performance.

- Spandrel panels, windows, balconies, eyebrows, exposed slab edges
Discussion + Questions

FOR FURTHER INFORMATION PLEASE VISIT

→ rdhbe.com
SLIDES NOT USED
Design Guides & Other Resources
→ 1999/2001 *Wood Frame Envelopes in the Coastal Climate of British Columbia* - Best Practice Guide (CMHC)
   - Emphasis on moisture control in Pacific Northwest

   - Emphasis on best practices, moisture and new energy codes
   - Will be updated later this year
Cross Laminated Timber Handbooks

- Canadian & USA versions published by FPInnovations
- Provides design guidance for Cross Laminated Timber (CLT) buildings in all climate zones
- Building enclosure chapter focuses on durability and energy efficiency
Further Guidance on Highly Insulated Walls & Details

→ Highly Insulated Wood-Frame Design Guide for Marine and Cold Climates (tall building/multi-family building focus)
Highly Insulated Wood-frame Guide

→ 2013 Guide for Designing Energy-Efficient Wood-Frame Building Enclosures (FP Innovations)
  → Focus on highly insulated wood-frame assemblies to meet current and upcoming energy codes
  → Strategies, assemblies & many building enclosure details provided for passive design and “green” buildings
  → Sequential detailing for windows and other complicated details
2014 Tall Wood Buildings Guide (FPInnovations) – highrise wood and hybrid wood buildings

Building enclosure chapter #6 focuses on design fundamentals for durable and energy efficient high-rise mass timber buildings

- Moisture management & control
- Heat flow & thermal bridging
- Condensation control
- Air flow control & air barrier systems
- Noise & Fire control
- Assemblies & Details
- Claddings, Roofing
- Wood Durability
Misc. Slides Not Used
Modeled Annual Energy Savings

→ Pre-retrofit
  → 225 kWh/m²/yr
→ Building enclosure EEMs (insulation, windows, airtightness)
  → 20% savings overall
  → 87% electric baseboard heating savings
→ Modeled Post-Retrofit
  → 177 kWh/m²
→ Effective R-values of building enclosure assemblies & details can be determined by:

→ Hand methods – simple wood frame walls, not suitable for many assemblies/details

→ Laboratory (Guarded hot-box testing) – good for confirmation, expensive and not efficient for design/analysis purposes

→ Two-dimensional finite element thermal modeling – not accurate for modeling discrete or intermittent elements such as clips, ties, or fasteners

→ Three-dimensional finite element thermal modeling – most accurate and cost effective. Calibrated with laboratory testing to improve accuracy.
Key Considerations - Exterior Insulation Assemblies

- Key Considerations:
  - Cladding attachment
  - Wall thickness
- Heat Control: Exterior insulation (any type)
- Air Control: Membrane on exterior of structure
- Vapor Control: Membrane on exterior of structure
- Water Control: Rainscreen cladding, membrane on exterior of structure, surface of insulation
Key Considerations - Split Insulation Assemblies

- Key Considerations:
  - Exterior insulation type
  - Cladding attachment
  - Sequencing & detailing

- **Heat Control**: Exterior and stud space
  - Insulation (designed)

- **Air Control**: House-wrap adhered/
  - sheet/liquid membrane on sheathing,
  - sealants/tapes etc. Often vapor
  - permeable

- **Vapor Control**: Poly or VB paint at
  - interior, plywood/OSB sheathing

- **Water Control**: Rainscreen cladding,
  - WRB membrane, surface of insulation
Key Considerations – Double Stud/Deep Stud

→ Key Considerations:
  → Air-sealing
  → Rainwater management/detailing
→ Heat Control: Double stud cavity fill insulation(s) – dense-pack cellulose, fiberglass, sprayfoam
→ Air Control: House-wrap/membrane on sheathing, poly, airtight drywall on interior, OSB/plywood at interior, tapes, sealants, sprayfoam. *Airtightness on both sides good*
→ Vapor Control: Poly, smart vapour retarder, VB paint or OSB/plywood at interior
→ Water Control: Rainscreen cladding, WRB at house-wrap/membrane, flashings etc.
Deep/Double Stud and Moisture Risk Assessment

2x6 R-16 vs. R-40 Deep Stud Wall - Rain Water Leak over 2 years

Moisture Content of Sheathing (%)

- 2x6 Wall R-16
- Deep/Double Stud R-40
Trial Exterior Insulation Rehab - Late 1990s
Trial Exterior Insulation Rehab – Late 1990s
Trial Split Insulated Assembly
Trial Split Insulated Assembly
Lessons Learned About Indoor Humidity & Drying
Trial Thermally Improved Cladding Attachments
Cladding Attachment: Clip & Rail, Non-Conductive
Cladding Attachment: Clip & Rail, Non-Conductive
Cladding Attachment: Screws through Insulation

Figure 9: Short term deflection testing results (4” thick insulation)
Cladding Attachment: Screws through Insulation
Screws through Insulation: Shear Blocks

- With heavier weight claddings – may consider shear blocks to limit deflection and creep.
  - Not necessary with light-weight claddings.

- Shear block material:
  - Continuous or intermitted wood blocks, metal clips etc.
Other Considerations - Flashings
Thermal Comparison of Options
CLT Construction
Cladding Attachment: Masonry
Assemblies and Cladding Attachment – Slides Not Used
Insulation Placement & Wall Design Considerations

- Interior Insulation
- Exterior Insulation
- Split Insulation
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
Exterior Insulated Walls

- Insulation outboard of structure and control layers (air/vapor/water)
- Thermal mass at interior where useful
- Excellent performance in all climate zones

- Cladding attachment: biggest source of thermal loss/

- Not a bad idea, can build it up

Steel Stud Timber (CLT)  Concrete  Heavy
Key Considerations:
- Cladding Attachment
- Wall Thickness

Heat Control: Exterior Insulation

Air Control: Membrane on exterior of structure

Vapor Control: Membrane on exterior of structure

Water Control: Membrane on exterior of structure (possibly surface of insulation)
Many Possible Strategies – Wide Range of Performance
Minimizing Thermal Bridging through Exterior Insulation

Longer cladding fasteners directly through rigid insulation (up to 2” for light claddings)

Long screws through vertical strapping and rigid insulation creates truss (8”+) – short cladding fasteners into vertical strapping

Rigid shear block type connection through insulation, cladding to
Key Considerations - Split Insulation Assemblies

→ Key Considerations:
  → Exterior insulation type
  → Cladding attachment
  → Sequencing & detailing

→ **Heat Control:** Exterior and stud space Insulation

→ **Air Control:** House-wrap adhered/sheet/liquid membrane on sheathing, sealants/tapes etc. Often vapor permeable

→ **Vapor Control:** Poly or VB paint at interior, plywood/OSB sheathing

→ **Water Control:** Rainscreen cladding, WRB membrane, surface of insulation
Foam insulations (XPS, EPS, Polyiso, ccSPF) are vapor impermeable
  - Is the vapor barrier on the wrong side?
  - Does your wall have two vapor barriers?
  - How much insulation should be put outside of the sheathing? – More the better, but room?

Rigid Mineral or Glass Fiber Insulation are vapor permeable and can address these concerns

Vapor permeance properties of WRB and air-barrier also important

Insulation selection suitable for wet exposure – moisture tolerant, non absorptive, hydrophobic, draining
Several other alternate strategies to build highly insulated walls including Larsen Trusses and other exterior trussed assemblies filled with low-density fibrous fill or sprayfoam insulation.
→ Double 2x4/2x6 stud, Single Deep 2x10, 2x10, I-Joist etc…

→ Common wood-frame wall assembly in many passive houses

→ Lends itself well to pre-fabricated wall/roof assemblies

→ Interior service wall – greater control over interior airtightness

→ Higher risk for damage if sheathing gets wet (rainwater, air leakage, vapor diffusion)
Key Considerations: Double Stud/Deep Stud

- Key Considerations:
  - Air-sealing
  - Rainwater management/detailing

- **Heat Control**: Double stud cavity fill insulation(s)

- **Air Control**: House-wrap/membrane on sheathing, poly, airtight drywall on interior, OSB/plywood at interior, tapes, sealants, sprayfoam. Airtightness on both sides of cavity recommended

- **Vapor Control**: Poly, VB paint or OSB/plywood at interior

- **Water Control**: Rainscreen cladding, WRB at house-wrap/membrane, flashings etc.
No ASHRAE Tables for These Cladding Attachments
Context – What R-values are Required?

- BC Building Code – Part 10
  - Prescriptive Tables for Part 9 buildings (houses)
  - Reference to ASHRAE 90.1 Table 5 (Effective R-values)

- City of Vancouver
  - Prescriptive Tables for Part 9 buildings (houses)
  - Reference to ASHRAE 90.1 Table 5 (Effective R-values)

  and National Energy Code for Buildings 2011 (NECB)
## Climate Zone 5 – Residential Buildings

<table>
<thead>
<tr>
<th>Building Enclosure Component</th>
<th>Minimum Assembly R-value ft² °F h/Btu</th>
<th>Minimum Insulation R-value ft² °F h/Btu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof – Insulation Above Deck</td>
<td>R-20.8</td>
<td>R-20 c.i.</td>
</tr>
<tr>
<td>Roof – Attic</td>
<td>R-37.0</td>
<td>R-38</td>
</tr>
<tr>
<td>Above Grade Wall – Wood-Frame</td>
<td>R-19.6</td>
<td>R-13 + 7.5 c.i.</td>
</tr>
<tr>
<td>Above Grade Wall – Steel Frame</td>
<td>R-15.6</td>
<td>R-13 + 7.5 c.i.</td>
</tr>
<tr>
<td>Above Grade Wall – Mass</td>
<td>R-12.5</td>
<td>R-13.3 c.i.</td>
</tr>
<tr>
<td>Below Grade Wall – Concrete</td>
<td>R-8.4</td>
<td>R-7.5 c.i.</td>
</tr>
<tr>
<td>Windows</td>
<td></td>
<td><strong>Maximum Window U-value Btu/h ft² °F</strong></td>
</tr>
<tr>
<td>› Non Metal Frame (Vinyl, Fibreglass and Wood)</td>
<td></td>
<td>U-0.35</td>
</tr>
<tr>
<td>› Metal Framed Windows (Aluminum)</td>
<td></td>
<td>U-0.55</td>
</tr>
<tr>
<td>› Metal frames (Curtainwall &amp; Storefront)</td>
<td></td>
<td>U-0.45</td>
</tr>
</tbody>
</table>
Context: R-Values

- Down Jacket: R 3-5
- Acoustic Ceiling Tile: R-2
- Fiberglass Batt Insulation: ~R-12, 3 ½”
  ~R-20, 5 ½”
Seeing Heat Loss – Infrared Thermography

Yellow/red/white = hot = high heat flow/high U-value  Blue = Cold = low heat flow/low U-value
Wood Framed Walls
## Current Thermal Performance – Effective R-values

<table>
<thead>
<tr>
<th>Wall Assembly / Insulation Rated R-value</th>
<th>Effective Wall R-value *</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Studs at 16”, 25% F.F.</td>
</tr>
<tr>
<td>2x4 w/ R-12 batts/SPF</td>
<td>10.7</td>
</tr>
<tr>
<td>2x4 w/ R-14 batts</td>
<td>11.5</td>
</tr>
<tr>
<td>2x4 w/ sprayfoam (R-5/in)</td>
<td>12.6</td>
</tr>
<tr>
<td>2x6 w/ R-19 batts</td>
<td>15.5</td>
</tr>
<tr>
<td>2x6 w/ R-22 batts</td>
<td>16.6</td>
</tr>
<tr>
<td>2x6 w/ sprayfoam (R-5/in)</td>
<td>18.3</td>
</tr>
<tr>
<td>2x6 w/ sprayfoam (R-6/in)</td>
<td>18.6</td>
</tr>
</tbody>
</table>

* Studs at 16” o.c.=25% total framing factor and Studs at 24” o.c. =22% total framing factor. This includes typical framing arrangements of studs, sill and top plates, window headers, corners, built-up studs etc..
## ASHRAE 90.1 Effective R-value Tables – Wood Framing (Studs @16” 25% Framing Factor)

<table>
<thead>
<tr>
<th>Wood Framing Depth</th>
<th>Nominal Insulation R-value (RSI)</th>
<th>Effective R-value for Base Wall Assembly</th>
<th>Effective R-value of Base Wall Plus Continuous Insulation (Includes bringing effect of strapping/fasteners/ clips)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>R-5 c.i.</td>
<td>R-8 c.i.</td>
</tr>
<tr>
<td>31/2” (89 mm)</td>
<td>None</td>
<td>R-3.4 (0.6)</td>
<td>R-8.6 (1.5)</td>
</tr>
<tr>
<td></td>
<td>R-11 (1.9)</td>
<td>R-10.4 (1.8)</td>
<td>R-15.9 (2.8)</td>
</tr>
<tr>
<td></td>
<td>R-13 (2.3)</td>
<td>R-11.2 (2.0)</td>
<td>R-16.9 (3.0)</td>
</tr>
<tr>
<td></td>
<td>R-15 (2.6)</td>
<td>R-12.0 (2.1)</td>
<td>R-17.9 (3.1)</td>
</tr>
<tr>
<td>51/2” (140 mm)</td>
<td>R-19 (3.3)</td>
<td>R-14.9 (2.6)</td>
<td>R-20.8 (3.7)</td>
</tr>
<tr>
<td></td>
<td>R-21 (3.7)</td>
<td>R-15.9 (2.8)</td>
<td>R-22.2 (3.9)</td>
</tr>
</tbody>
</table>
5 and 6 Storey Wood Framing

→ Framing factors >>25%, cannot use ASHRAE tables
Tables within ASHRAE 90.1 provide some exterior/split insulated R-values.

Wood-frame Best Practice Guide provides further guidance.

Thermal simulation needed.

Energy codes do not provide guidance on durability and moisture control!
Higher R-value Wood Frame Walls – Best Practices
Foam insulation (XPS, EPS, Polyiso, SPF) are vapour impermeable
- Is the vapour barrier on the wrong side?
- Does your wall have two vapour barriers?
- How much insulation should be put outside of the sheathing?

Rigid Mineral or Glass Fiber Insulation (Roxul, Fibrex etc.) are vapour permeable and address these concerns

Foam sheathing is at a higher risk of moisture entrapment than baseline 2x6 wall or mineral fiber (rain, air, initially wet)

Vapour permeance properties of WRB and air-barrier
Split Insulation Walls

- **Key Considerations:**
  - Exterior Insulation Type
  - Cladding Attachment
  - Sequencing & Detailing

- **Heat Control:** Exterior and Stud Space Insulation

- **Air Control:** Breathable House-wrap/membrane on sheathing, sealants/tapes etc. (air barrier in middle)

- **Vapour Control:** Poly or VB paint at interior, sheathing

- **Water Control:** Rainscreen cladding, WRB at surface of insulation & house-wrap/membrane
XPS/Foam as Exterior Insulation
Rigid Mineral/Glass Fiber as Exterior Insulation
Attaching Cladding Through Exterior Insulation

→ Strategies to minimize thermal bridging (+ wall thickness)
  → Intermittent Clips (i.e. low-conductivity spacers, stainless steel clips)
  → Screws directly through strapping and insulation
  → Brick Ties
  → Truss Frame Assemblies
→ Medium Density Mineral Fiber (i.e. Roxul Rockboard)
Split Insulation
Split Insulation
<table>
<thead>
<tr>
<th>Exterior Insulation R-value added to exterior of sheathing</th>
<th>Effective Wall R-value Accounting for Thermal Bridging &amp; Fasteners</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2x4 stud wall @ 16” o.c. with R-14 batts</td>
</tr>
<tr>
<td></td>
<td>2x6 stud wall @ 16” o.c. with R-22 batts</td>
</tr>
<tr>
<td>1” Mineral Wool (R-4)</td>
<td>-</td>
</tr>
<tr>
<td>1” XPS (R-5)</td>
<td>-</td>
</tr>
<tr>
<td>1.5” Mineral Wool (R-6)</td>
<td>-</td>
</tr>
<tr>
<td>1.5” XPS (R-7.5)</td>
<td>-</td>
</tr>
<tr>
<td>2” Mineral Wool (R-8)</td>
<td>19.6</td>
</tr>
<tr>
<td>2” XPS (R-10)</td>
<td>21.4*</td>
</tr>
<tr>
<td>2.5” Mineral Wool (R-10)</td>
<td>21.5</td>
</tr>
<tr>
<td>3” Mineral Wool (R-12)</td>
<td>23.2</td>
</tr>
<tr>
<td>2.5” XPS (R-12.5)</td>
<td>* Potential Elevated Moisture risk 23.7*</td>
</tr>
</tbody>
</table>

* Potential Elevated Moisture risk
# Split Insulation R-values above R-20: Brick Ties

<table>
<thead>
<tr>
<th>Exterior Insulation R-value added to exterior of sheathing</th>
<th>Effective Wall R-value Accounting for Thermal Bridging &amp; Fasteners</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2x4 stud wall @ 16” o.c. with R-14 batts</td>
</tr>
<tr>
<td>1” Mineral Wool (R-4.2)</td>
<td>-</td>
</tr>
<tr>
<td>1” XPS (R-5)</td>
<td>-</td>
</tr>
<tr>
<td>1.5” Mineral Wool (R-6.3)</td>
<td>-</td>
</tr>
<tr>
<td>1.5” XPS (R-7.5)</td>
<td>-</td>
</tr>
<tr>
<td>2” Mineral Wool (R-8.4)</td>
<td>20.2</td>
</tr>
<tr>
<td>2” XPS (R-10)</td>
<td>21.4*</td>
</tr>
<tr>
<td>2.5” Mineral Wool (R-10.5)</td>
<td>21.9</td>
</tr>
<tr>
<td>3” Mineral Wool (R-12.6)</td>
<td>*</td>
</tr>
</tbody>
</table>
| 2.5” XPS (R-12.5)                                         | 23.3*                                          | Potential Elevated Moisture risk

* Potential Elevated Moisture risk
Key Considerations:
- Insulation Type
- Air-sealing
- Rainscreen detailing

Heat Control: Double stud cavity fill in
Air Control: breathable House-wrap/membrane on sheathing, poly on interior, tapes, sealants, air-barriers (in and out) recommended

Vapour Control: Poly at interior
Water Control: Rainscreen cladding, membrane, flashings etc.
Double Stud Walls
### Double Stud and 2x8/2x10 Framing R-values

<table>
<thead>
<tr>
<th>Wall Assembly / Insulation Rated R-value</th>
<th>Effective Wall R-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2x8 w/ R-26 fibrous insulation (R 3.4/inch)</td>
<td>21.1</td>
</tr>
<tr>
<td>2x8 w/ R-30 fibrous insulation (R 4/inch)</td>
<td>22.8</td>
</tr>
<tr>
<td>2x8 w/ R-38 sprayfoam insulation (R 5/inch)</td>
<td>25.4</td>
</tr>
<tr>
<td>2x10 w/ R-31 fibrous insulation (R 3.4/inch)</td>
<td>25.4</td>
</tr>
<tr>
<td>2x10 w/ R-37 fibrous insulation (R 4/inch)</td>
<td>27.5</td>
</tr>
<tr>
<td>2x10 w/ R-46 sprayfoam insulation (R 5/inch)</td>
<td>30.6</td>
</tr>
<tr>
<td>Double Stud 2x4 no gap w/ R-28 fibrous insulation (R 4/inch)</td>
<td>21.4</td>
</tr>
<tr>
<td>Double Stud 2x4 no gap w/ R-35 sprayfoam insulation (R 5/inch)</td>
<td>23.8</td>
</tr>
<tr>
<td>Double Stud 2x4 1” gap w/ R-27 fibrous insulation (R 3.4/inch)</td>
<td>23.6</td>
</tr>
<tr>
<td>Double Stud 2x4 1” gap w/ R-32 fibrous insulation (R 4/inch)</td>
<td>26.1</td>
</tr>
</tbody>
</table>

*Studs at 24” o.c., 22% total framing factor includes: studs, sill and top plates, window headers, corners, built-up studs etc.
Steel Framed Walls

R-12 or R-14 batt insulation

R 3 – 4 effective

→ Steel stud wall assembly with concrete slab
Assumes steel stud spacing at 16" o.c. and accounts for top and sill track.

### Effective R-values: Steel Stud Framed Walls (ASHRAE 90.1 Table)

<table>
<thead>
<tr>
<th>Wood Framing Depth</th>
<th>Nominal Insulation R-value</th>
<th>Effective R-value for Base Wall Assembly</th>
<th>Effective R-value of Base Wall Plus Continuous Insulation (Includes bringing effect of fasteners/clips)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>R-2.8</td>
<td>R-7.8</td>
</tr>
<tr>
<td>3 ½”</td>
<td>None</td>
<td>R-7.6</td>
<td>R-12.5</td>
</tr>
<tr>
<td></td>
<td>R-11</td>
<td>R-8.1</td>
<td>R-13.0</td>
</tr>
<tr>
<td></td>
<td>R-13</td>
<td>R-8.5</td>
<td>R-13.5</td>
</tr>
<tr>
<td></td>
<td>R-15</td>
<td>R-9.2</td>
<td>R-14.1</td>
</tr>
<tr>
<td>5 ½”</td>
<td>R-19</td>
<td>R-9.4</td>
<td>R-14.5</td>
</tr>
</tbody>
</table>
Problem Spots: Structural Steel Framing
Continuous Insulation – c.i.

*continuous insulation (ci):* insulation that is continuous across all structural members without thermal bridges other than fasteners and service openings. It is installed on the interior, exterior, or is integral to any opaque surface of the building envelope.
Continuous Insulation Examples
Non-Continuous Insulation – Examples
### Middle of Wall (away from slab edge):
*Could use ASHRAE 90.1 Tables*

<table>
<thead>
<tr>
<th>Configuration</th>
<th>R-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 5/8” Steel Studs, Empty Cavity</td>
<td>R-3.2</td>
</tr>
<tr>
<td>3 5/8” Steel Studs with R-12 Batts</td>
<td>R-7.9</td>
</tr>
<tr>
<td>6” Steel Studs with R-20 Batts</td>
<td>R-9.6</td>
</tr>
</tbody>
</table>

### Overall Effective – Including Slab Edges
*3D Thermal Modeling*

<table>
<thead>
<tr>
<th>Configuration</th>
<th>R-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 5/8” Steel Studs, Empty Cavity</td>
<td>R-2.9</td>
</tr>
<tr>
<td>3 5/8” Steel Studs with R-12 Batts</td>
<td>R-5.5</td>
</tr>
<tr>
<td>6” Steel Studs with R-20 Batts</td>
<td>R-6.4</td>
</tr>
</tbody>
</table>
Exterior insulation and self-adhered membrane properties affect safe insulation ratios.

### Exterior Vertical Girt Assemblies

**Overall Effective – Including Slab Edges**

**Backup:** 3 5/8” Steel Studs, Empty Cavity

- 2” Mineral Wool (R-8.4) - R-5.9
- 3” Mineral Wool (R-12.6) - R-6.7
- 4” Mineral Wool (R-16.8) - R-7.3
- 5” Mineral Wool (R-21.0) - R-7.9

---

**Exterior insulation and membrane properties affect safe insulation ratios.**

---
### Exterior Vertical Girt Assemblies – Sprayfoam?

#### Overall Effective – Including Slab Edges

**Backup: 3 5/8” Steel Studs, Empty Cavity**

- **2” Mineral Wool (R-8.4)** | R-5.9
- **3” Mineral Wool (R-12.6)** | R-6.7
- **4” Mineral Wool (R-16.8)** | R-7.3
- **5” Mineral Wool (R-21.0)** | R-7.9

#### Overall Effective – Including Slab Edges

**Backup: 3 5/8” Steel Studs, Empty Cavity**

- **2” Sprayfoam (R-12)** | R-6.5
- **3” Sprayfoam (R-18)** | R-7.2
- **4” Sprayfoam (R-24)** | R-7.8
- **5” Sprayfoam (R-30)** | R-8.4
Sprayfoam and Steel Z-Girts – Other Considerations
Horizontal Girts

Overall Effective – Including Slab Edges

Backup: 3 5/8” Steel Studs, Empty Cavity

<table>
<thead>
<tr>
<th>Material</th>
<th>R-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2” Mineral Wool (R-8.4)</td>
<td>8.2</td>
</tr>
<tr>
<td>3” Mineral Wool (R-12.6)</td>
<td>9.5</td>
</tr>
<tr>
<td>4” Mineral Wool (R-16.8)</td>
<td>10.7</td>
</tr>
<tr>
<td>5” Mineral Wool (R-21.0)</td>
<td>11.6</td>
</tr>
</tbody>
</table>
Exposed Cast-In-Place Concrete

**Center of Wall – Away from Slab Edge**

*Backup: 2 ½” Steel Studs  R-8 Batts*

<table>
<thead>
<tr>
<th>Material</th>
<th>R-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>+1” XPS (R-5) at concrete</td>
<td>R-6.7</td>
</tr>
<tr>
<td>+2” XPS (R-10) at concrete</td>
<td>R-8.1</td>
</tr>
<tr>
<td>+3” XPS (R-15) at concrete</td>
<td>R-9.3</td>
</tr>
</tbody>
</table>
Shelf Angle Supported Brick Masonry

- Center of Wall – Away from Slab Edge
- Backup: 3 5/8" Steel Studs, Empty
- +2" Mineral Wool Exterior (R-8.4)
- R-12.1
- +3" Mineral Wool Exterior (R-12.6)
- R-15.8
- +4" Mineral Wool Exterior (R-16.8)
- R-19.5

Overall Effective – Including Slab Edges
- Backup: 3 5/8" Steel Studs, Empty
- +2" Mineral Wool Exterior (R-8.4)
- R-8.6
- +3" Mineral Wool Exterior (R-12.6)
- R-10.1
- +4" Mineral Wool Exterior (R-16.8)
- R-11.5
### Brick Masonry – With Stand-off Shelf Angles

#### Without Stand-off Plates:
- **Overall Effective – Including Slab Edges**
- **Backup:** 3 5/8” Steel Studs, Empty

<table>
<thead>
<tr>
<th>Material</th>
<th>R-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>+2” Mineral Wool Exterior</td>
<td>R-8.6</td>
</tr>
<tr>
<td>+3” Mineral Wool Exterior</td>
<td>R-10.1</td>
</tr>
<tr>
<td>+4” Mineral Wool Exterior</td>
<td>R-11.5</td>
</tr>
</tbody>
</table>

#### WITH Stand-off Plates:
- **Overall Effective – Including Slab Edges**
- **Backup:** 3 5/8” Steel Studs, Empty

<table>
<thead>
<tr>
<th>Material</th>
<th>R-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>+2” Mineral Wool Exterior</td>
<td>R-11.3</td>
</tr>
<tr>
<td>+3” Mineral Wool Exterior</td>
<td>R-14.5</td>
</tr>
<tr>
<td>+4” Mineral Wool Exterior</td>
<td>R-17.7</td>
</tr>
</tbody>
</table>
Impact of Cladding Attachment – R-15 of Insulation

Current Practice
R-7.4

Better
R-10.3

Even Better
R-11.6 to 14.4

galvanized vs stainless

Most Efficient
R-15.8
Screws only
Intermittent cladding supports are significantly more thermally efficient than continuous girts.

- Insulation R-value reductions of $<15-30\%$ with clips.
- Are necessary in retrofit situations to achieve high R-values.
Intermittent Cladding Supports
### Intermittent Clip Cladding Supports

<table>
<thead>
<tr>
<th>6” Long Galvanized Z-Bar Clips @ 24 “ o.c. Overall Effective – Including Slab Edges</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Backup: 3 5/8” Steel Studs, Empty</td>
<td></td>
</tr>
<tr>
<td>+2” Mineral Wool Exterior (R-8.4)</td>
<td>R-8.2</td>
</tr>
<tr>
<td>+3” Mineral Wool Exterior (R-12.6)</td>
<td>R-10.0</td>
</tr>
<tr>
<td>+4” Mineral Wool Exterior (R-16.8)</td>
<td>R-11.6</td>
</tr>
<tr>
<td>+5” Mineral Wool Exterior (R-21.0)</td>
<td>R-13.1</td>
</tr>
</tbody>
</table>

### Intermittent Clip Cladding Supports

<table>
<thead>
<tr>
<th>6” Long Galvanized Z-Bar Clips @ 24 “ o.c. Overall Effective – Including Slab Edges</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Backup: 3 5/8” Steel Studs, <strong>Filled with R-12</strong></td>
<td></td>
</tr>
<tr>
<td>+2” Mineral Wool Exterior (R-8.4)</td>
<td>R-11.3</td>
</tr>
<tr>
<td>+3” Mineral Wool Exterior (R-12.6)</td>
<td>R-13.0</td>
</tr>
<tr>
<td>+4” Mineral Wool Exterior (R-16.8)</td>
<td>R-14.6</td>
</tr>
<tr>
<td>+5” Mineral Wool Exterior (R-21.0)</td>
<td>R-16.0</td>
</tr>
</tbody>
</table>
Non Conductive Spacer

Non-Conductive Spacer

Overall Effective – Including Slab Edges

<table>
<thead>
<tr>
<th>Configuration</th>
<th>R-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>4” Mineral Wool Exterior (R-16.8) over Empty 3-5/8” Steel Stud Backup wall</td>
<td>R-15.7</td>
</tr>
<tr>
<td>4” Mineral Wool Exterior (R-16.8) over R-12 in Steel Stud Backup wall</td>
<td>R-19.5</td>
</tr>
<tr>
<td>6” Mineral Wool Exterior (R-25.2) over Empty 3-5/8” Steel Stud Backup wall</td>
<td>R-21.4</td>
</tr>
<tr>
<td>6” Mineral Wool Exterior (R-25.2) over R-12 in Steel Stud Backup wall</td>
<td>R-25.2</td>
</tr>
</tbody>
</table>
Intermittent Cladding Supports
Concrete Slab Edges, Balconies & Eyebrows