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

RCI SEMINAR: WALLS AND ROOFS
JUNE 9, 2014
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Outline

→ Effective R-values & Thermal Bridging

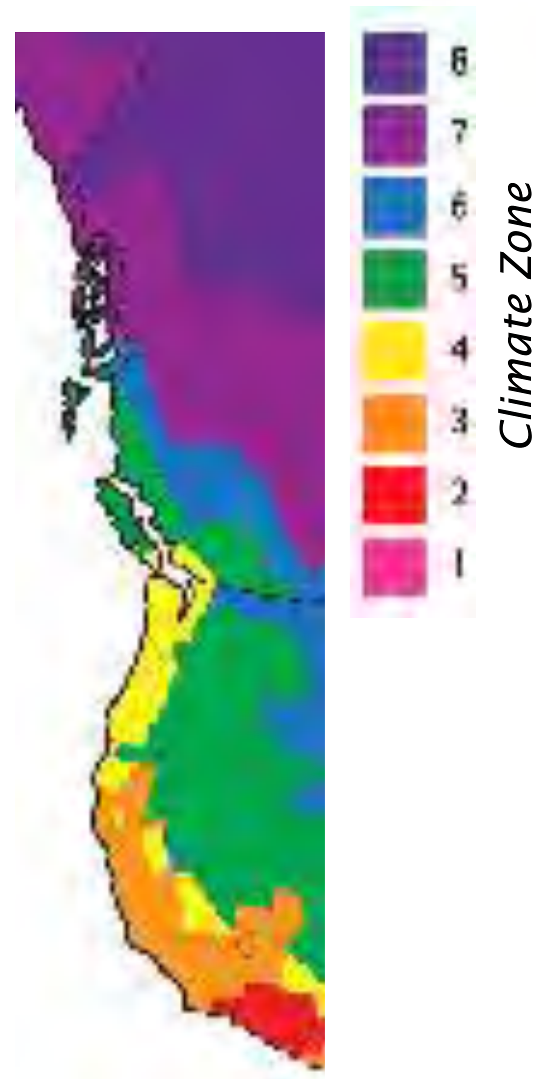
→ Alternate High R-value Wall Assemblies

→ Evolution of Cladding Attachment Systems

→ Alternate Cladding Attachment Systems

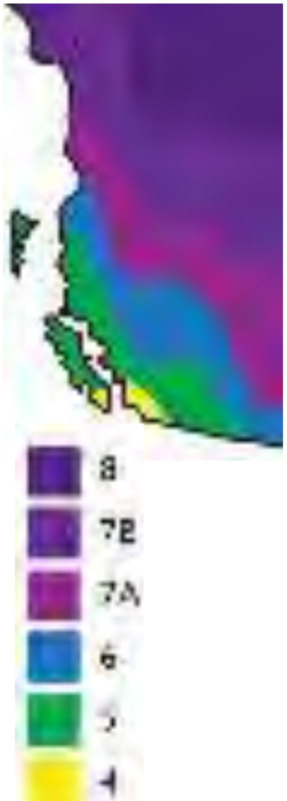
→ Other Thermal Bridging Considerations

- 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

RDH



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

All Units IP

NECB 2011

Climate Zone	Wall: Min. R-value	Roof - Sloped or Flat: Min. R-value	Window: Max. U-value
8	31.0	40.0	0.28
7A/7B	27.0	35.0	0.39
6	23.0	31.0	0.39
5	20.4	31.0	0.39
4	18.6	25.0	0.42

ASHRAE 90.1-2010

Climate Zone	Wall – Wood Res/Comm Min. R-value	Roof – Slope, Flat: Res/Comm Min. R-value	Window – Alum, PVC/FG: Res/Comm Max. U-value (IP)
8	27.8	47.6, 20.8	0.45, 0.35
7A/7B	19.6	37.0, 20.8	0.45, 0.35
6	19.6	37.0, 20.8	0.55, 0.35
5	19.6 Res *15.6 Comm*	37.0, 20.8	0.55, 0.35

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

- 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

Thermal Bridging

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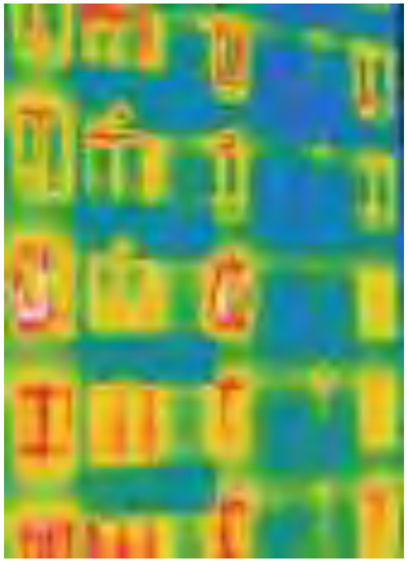
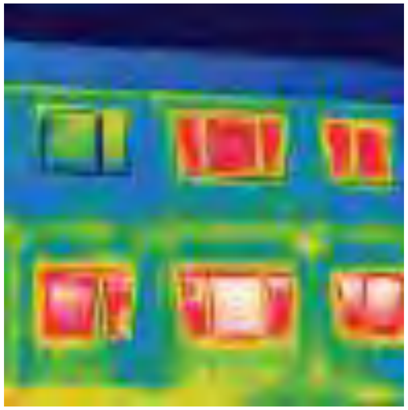
- Minimizing thermal bridging is key to energy code compliance and an energy efficient building
  - Exterior continuous insulation with thermally improved cladding attachments
  - Minimize thermal bridges
- Energy codes have historically focused on *insulation R-values*, however more attention is now being placed on *assembly R-values*





From Code Minimum to Next Generation Buildings

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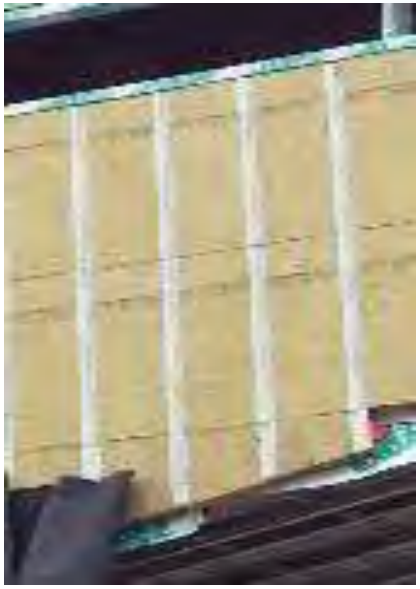

- In BC, minimum energy code R-value targets are in the range of
  - R-15 to R-25 effective for walls
  - R-25 to R-50 effective for roofs
  - R-2 to R-4 for windows
- More energy efficient building programs such as Passive House or Net Zero have R-value targets in the range of
  - R-30 to R-50+ effective for walls
  - R-40 to R-60+ effective for roofs
  - R-6+ for windows

What Is Passive Design?

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

→ Well-insulated building enclosure: walls, roof, windows

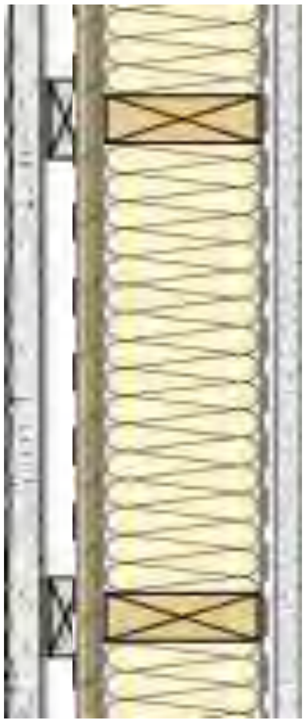
→ Passive solar – use the windows for heat

→ Airtight construction

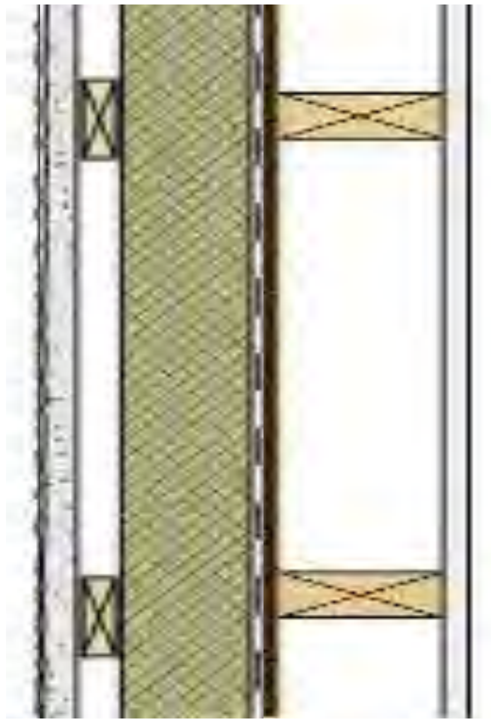
→ Heat recovery ventilation

→ Highly insulated walls are an important part of passive design

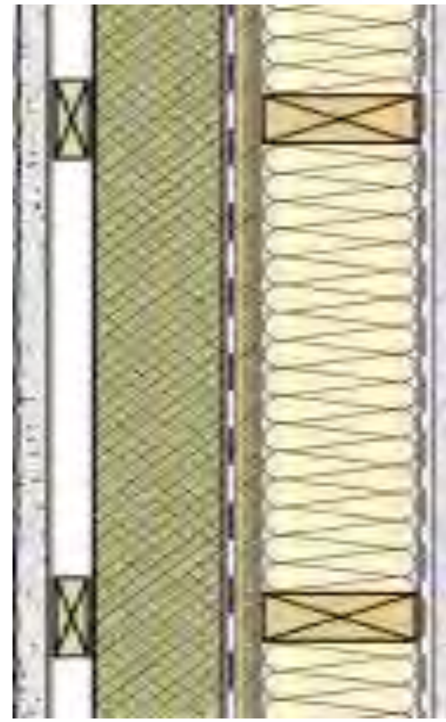
Getting to Higher R-value Walls – Wood Framing



Interior Insulation

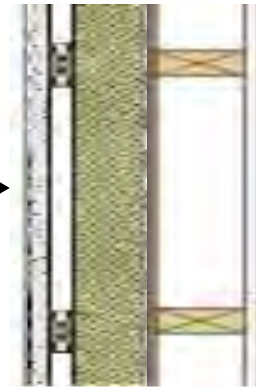


Exterior Insulation

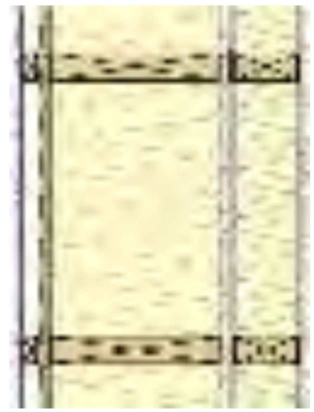


Split Insulation

<u>Baseline</u>
2x6 w/ R-22 batts = **R-16 effective**



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



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

<u>Split Insulation</u>: **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

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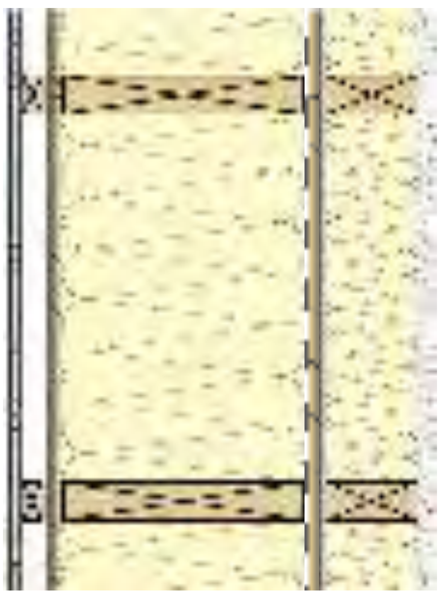
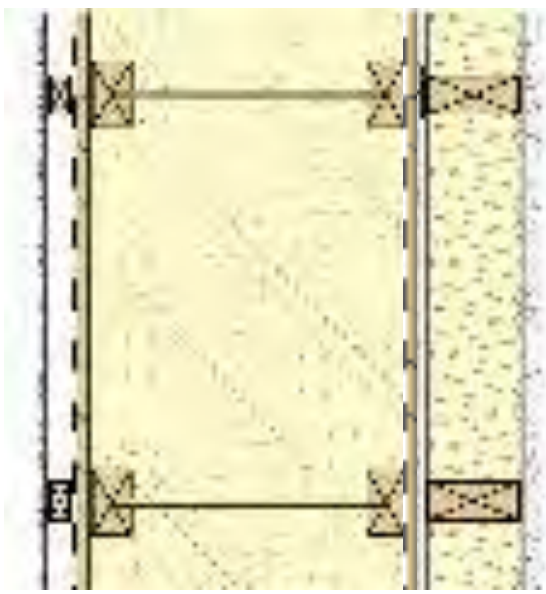
- → Double 2x4/2x6 stud, single deep 2x10, 2x12, I-Joist etc.
- → Common wood-frame wall assembly in many passive houses (and prefabricated highly insulated walls)
- → Inherently at a higher risk for damage if sheathing gets wet (rainwater, air leakage, vapor diffusion) – due to more interior insulation





Split Insulation – Exterior Insulation Choice

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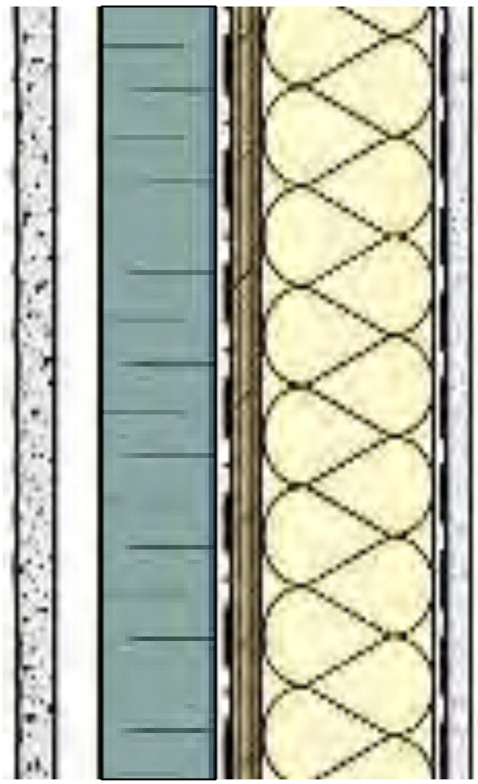
- → Rigid exterior foam insulations (XPS, EPS, Polyiso, closed cell SPF) are vapor impermeable (in thicknesses of 2”+)
  - → Is the vapor barrier on the wrong side?
  - → Does the wall have two vapor barriers, can it dry?
  - → How much insulation should be put outside of the sheathing?
    - More is always better, but is there room? Budget?
- → Semi-rigid/rigid mineral wool insulation is vapor permeable and address these moisture concerns



But Why?

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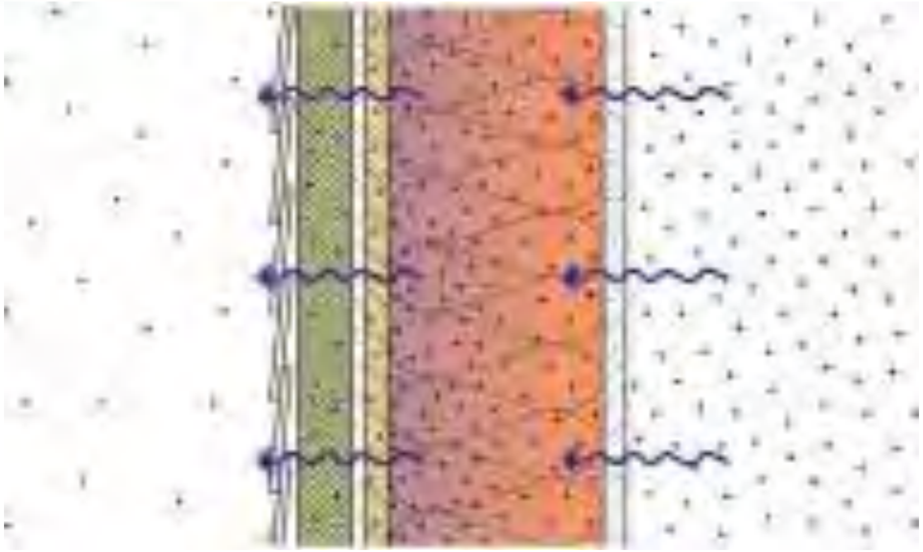
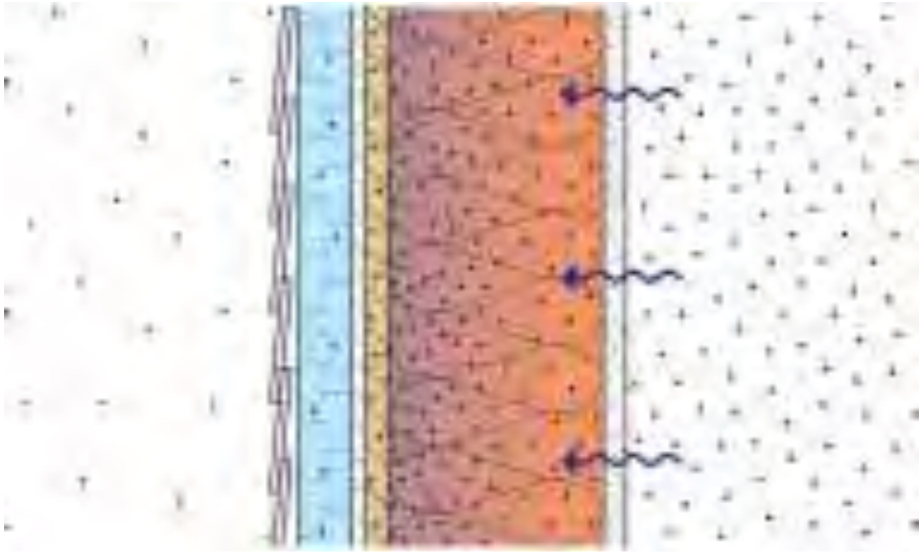
Vapor diffusion drying allowed through mineral wool insulation



Vapor diffusion drying restricted by foam plastic insulation on outside



Split Insulation and Moisture Risk Assessment

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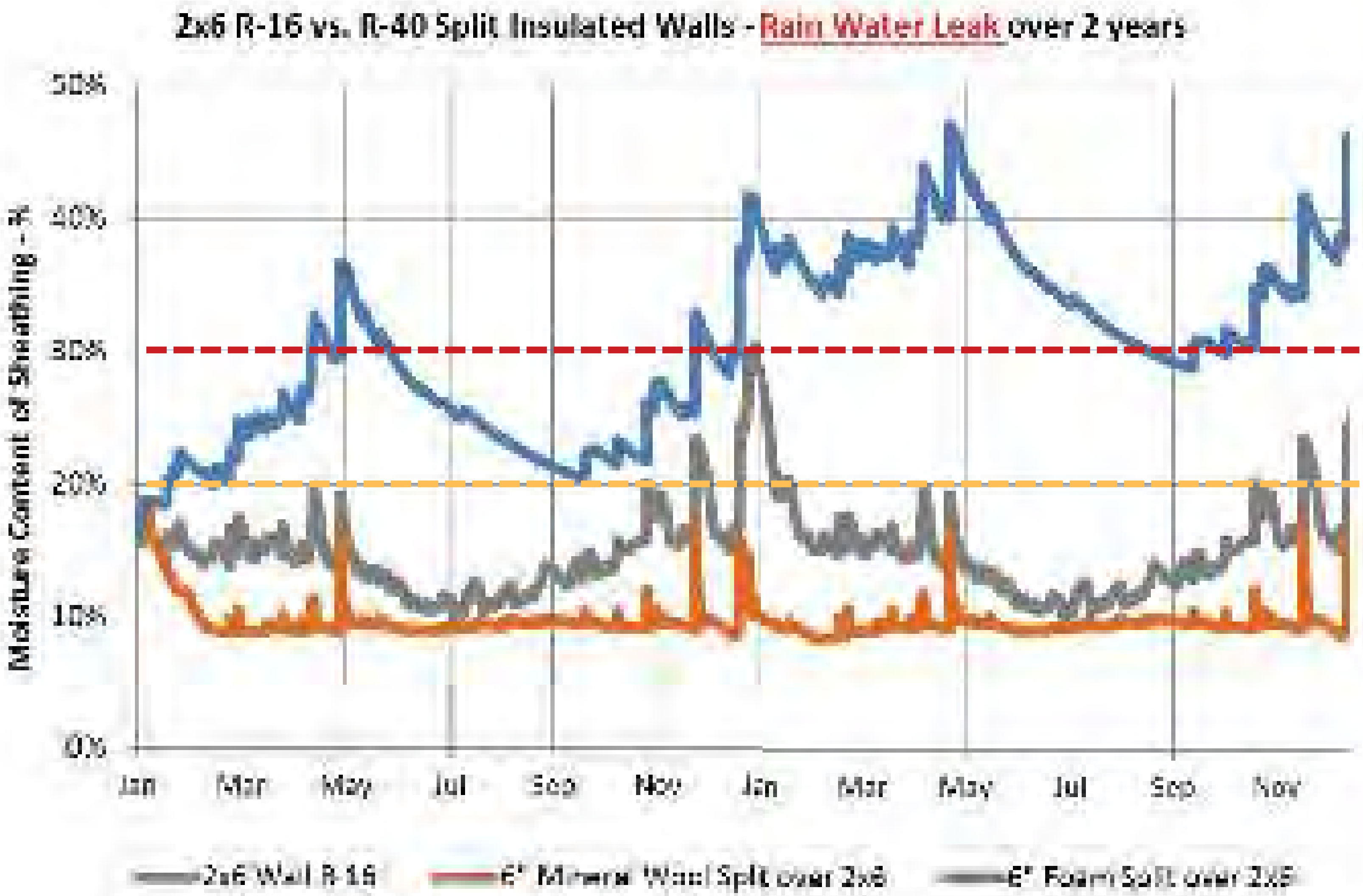

Side by Side Drying Test – Vapour Open vs Closed

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Higher R-value Walls – Non-Combustible

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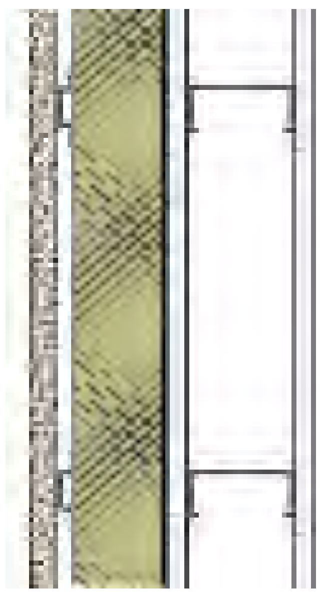
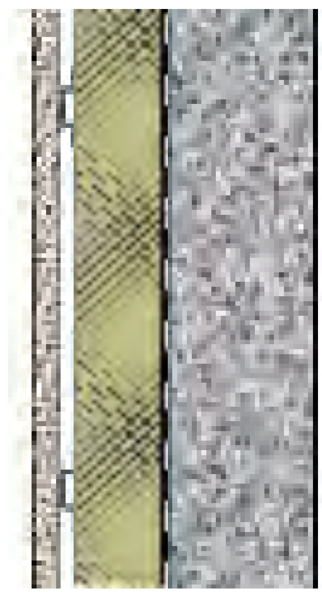
- Insulation outboard of structure and control layers (air/vapor/water)
- Thermal mass at interior
- Cladding attachment biggest source of thermal loss/bridging
- Excellent performance in all climate zones



Steel Stud



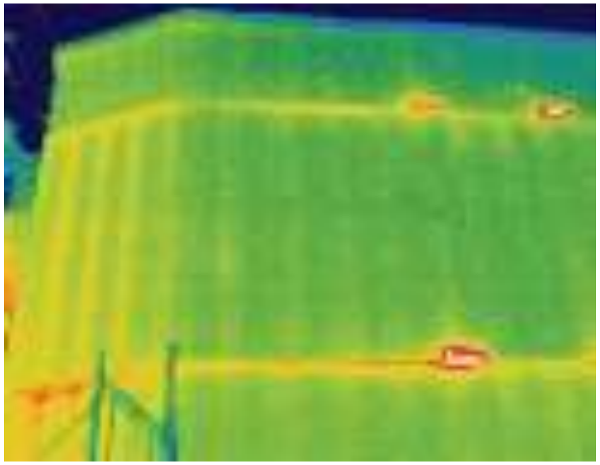
Concrete

Heavy Timber (CLT)

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

Low-Conductivity Cladding Supports

Thermally Improved Performance

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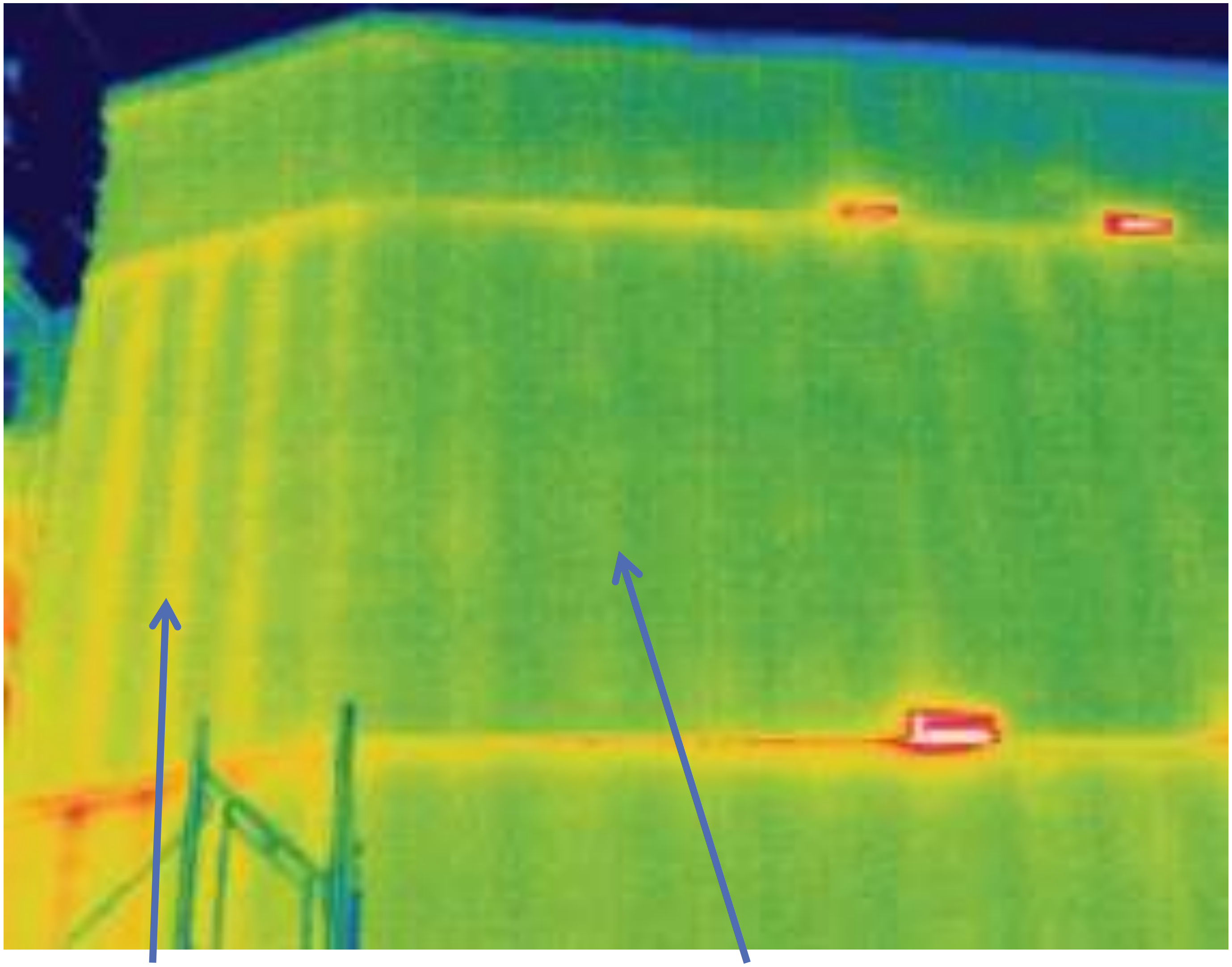

Continuous metal Z-girts

Fiberglass Clips & Hat-Tracks

Evolution of Exterior Insulation Approaches

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Cladding Attachment: Screws through Insulation

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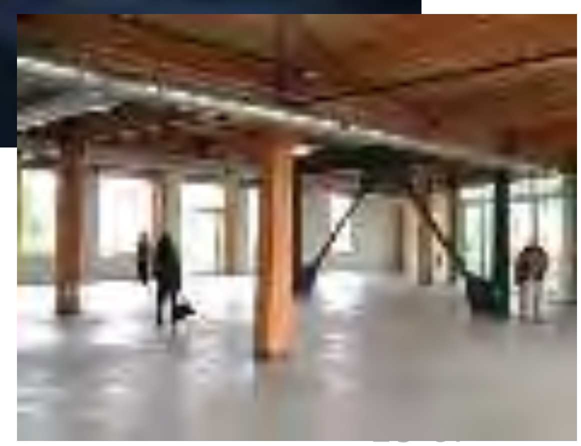
Evolution: Bullitt Center Walls

- 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



Bullitt Center – Exterior Wall Analysis

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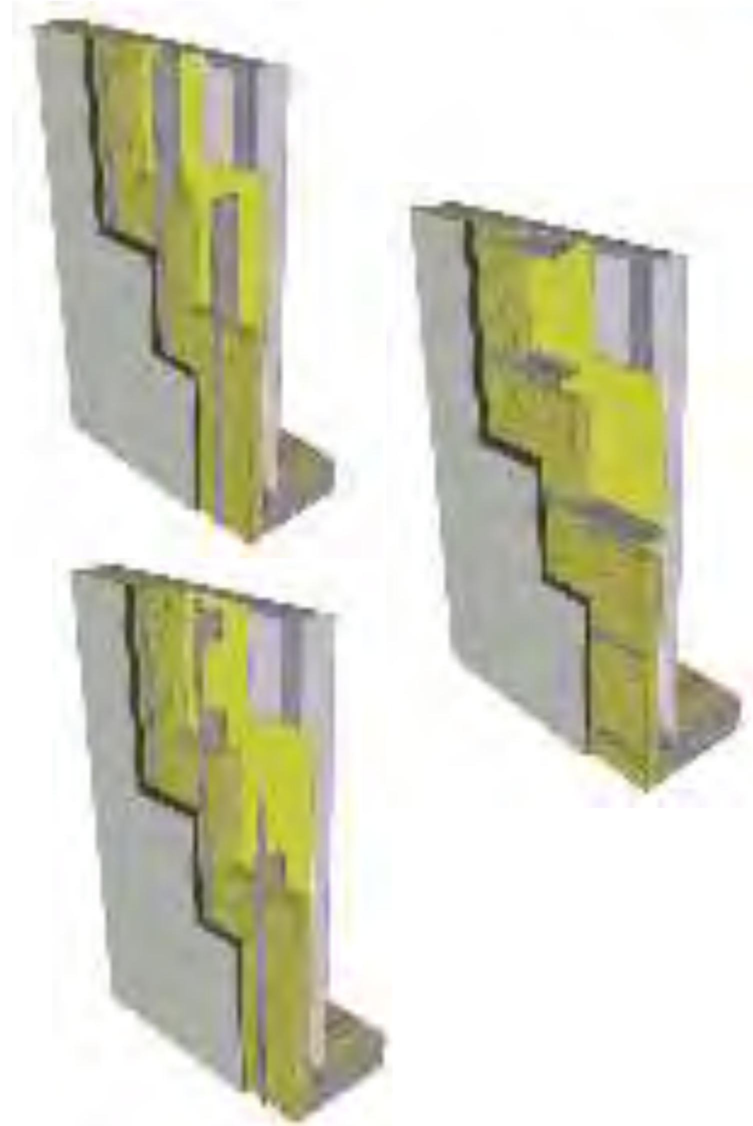
- Expectation to be cost effective, buildable and minimize wall thickness
- Available various Z-Girt & Metal Clip options evaluated with thermal modeling
  - None could achieve R-25 target, closest was to use expensive stainless steel clips
  - Modeling identified opportunity to improve performance with non-conductive fiberglass clip



Bullitt Center – Exterior Wall Assembly

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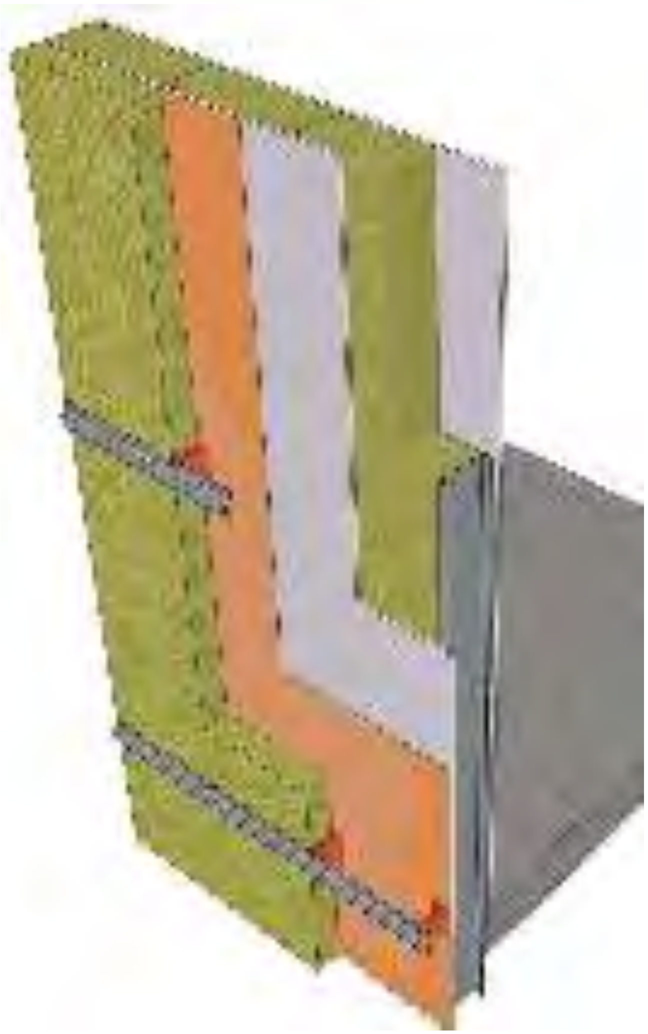

- → Metal panel cladding
- → 1" horizontal metal hat tracks
- → 3 ½" semi-rigid mineral fiber (R-14.7) between 3 ½" fiberglass clips (16" x 48" spacing)
- → Fluid applied vapor permeable WRB/ air barrier on gypsum sheathing
- → 6" mineral fiber batts (R-19) between 6" steel studs (outboard of slab edge)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

- → **Effective R-value R-26.6**

Bullitt Center – Exterior Wall Construction

Full Circle: Multifamily Exterior Insulation Retrofit

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→ Recent retrofit in Vancouver – 20% measured energy savings through exterior insulated walls, triple glazed fibreglass frame windows, air sealing

Multifamily Exterior Insulation Retrofit

- → Over clad and exterior insulate walls (R-16 effective)
- → Also new windows and air sealing
- → Total 20% measured energy savings at the building

Existing Walls Overall R-4

Upgraded Walls Overall R-16

Exterior Insulation, Stucco & Metal Panel Overcladding

Choosing a Cladding Attachment System

Exterior Insulation & Cladding Attachment Considerations

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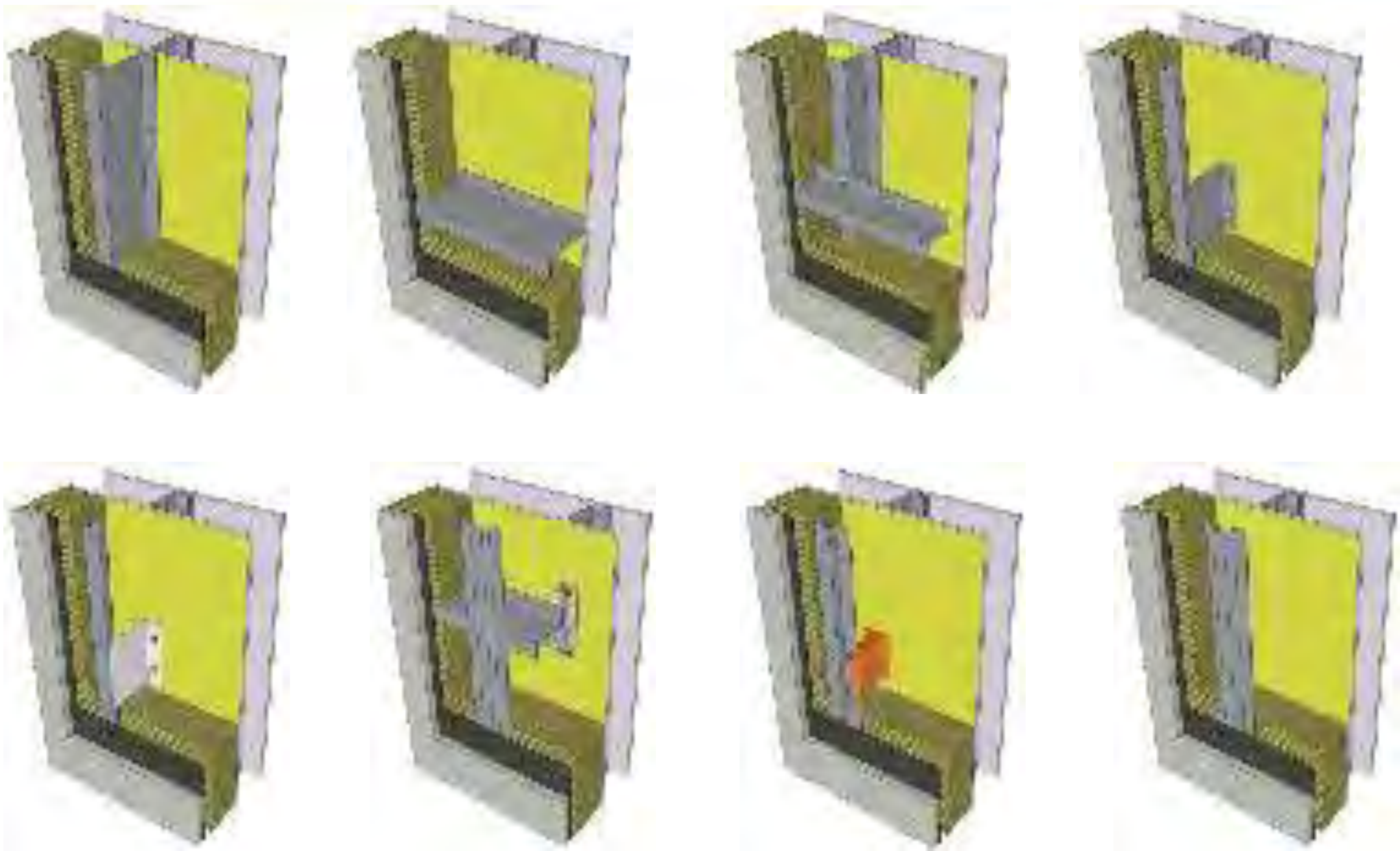
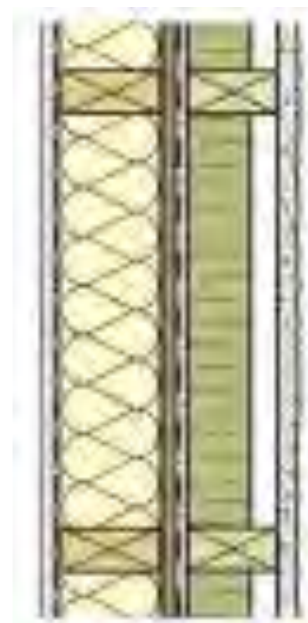
- → Cladding weight & gravity loads
- → Wind loads
- → Seismic loads
- → Back-up wall construction (wood, concrete, steel)
  - → Attachment from clip/girt back into structure (studs, sheathing, or slab edge)
- → Exterior insulation thickness
- → Rigid vs semi-rigid insulation
- → R-value target
- → Ease of attachment of cladding – returns, corners
- → Combustibility requirements

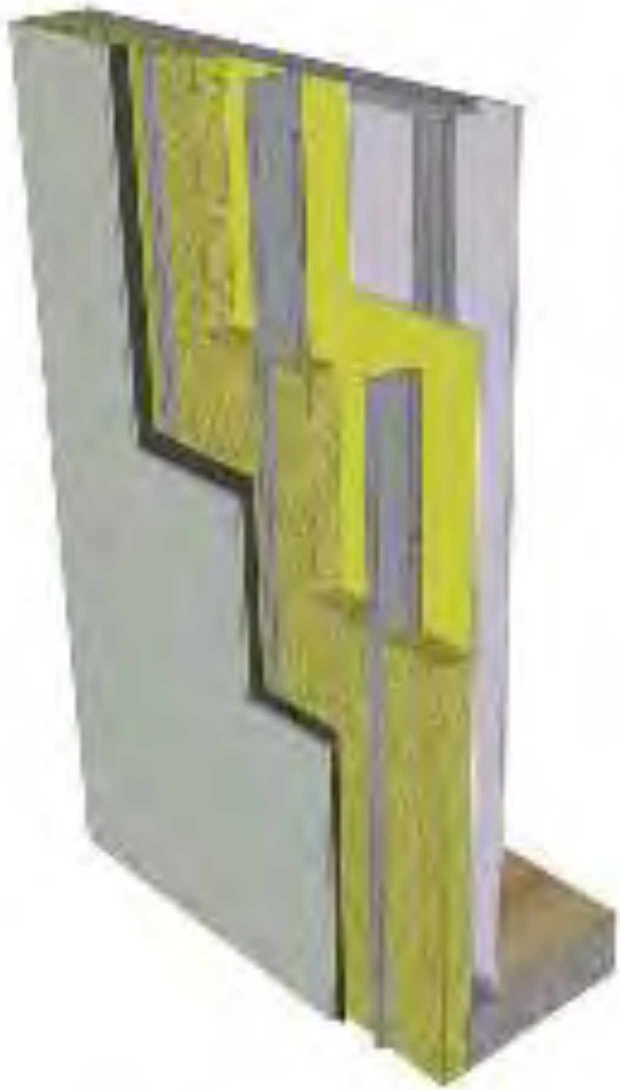
Many Alternate Attachment Options



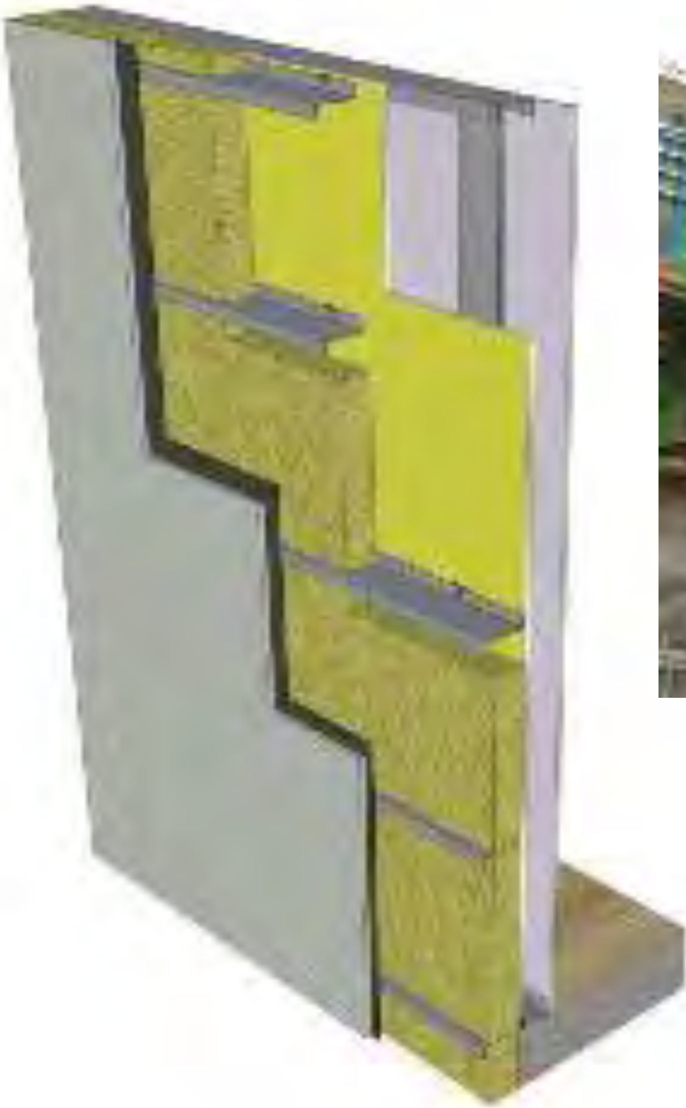
Cladding Attachment: Continuous Wood Framing



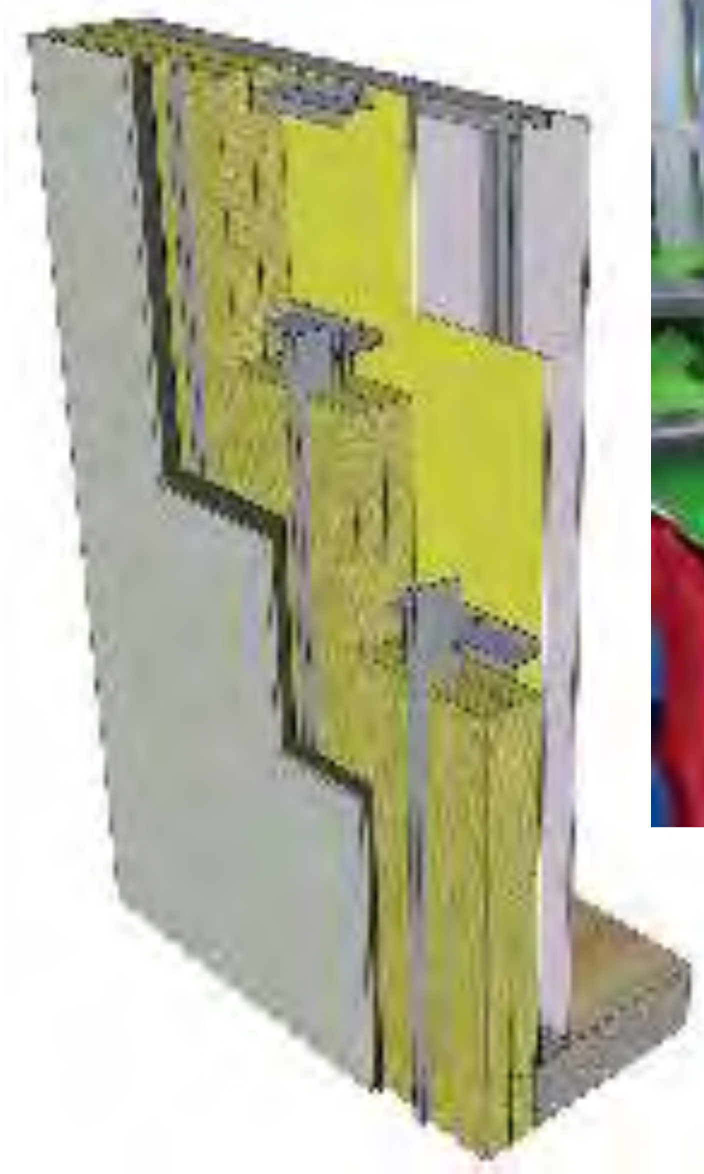
Cladding Attachment: Vertical Z-Girts



Cladding Attachment: Horizontal Z-Girts



Cladding Attachment: Crossing Z-Girts



Cladding Attachment: Diagonal Z-Girts & Clips

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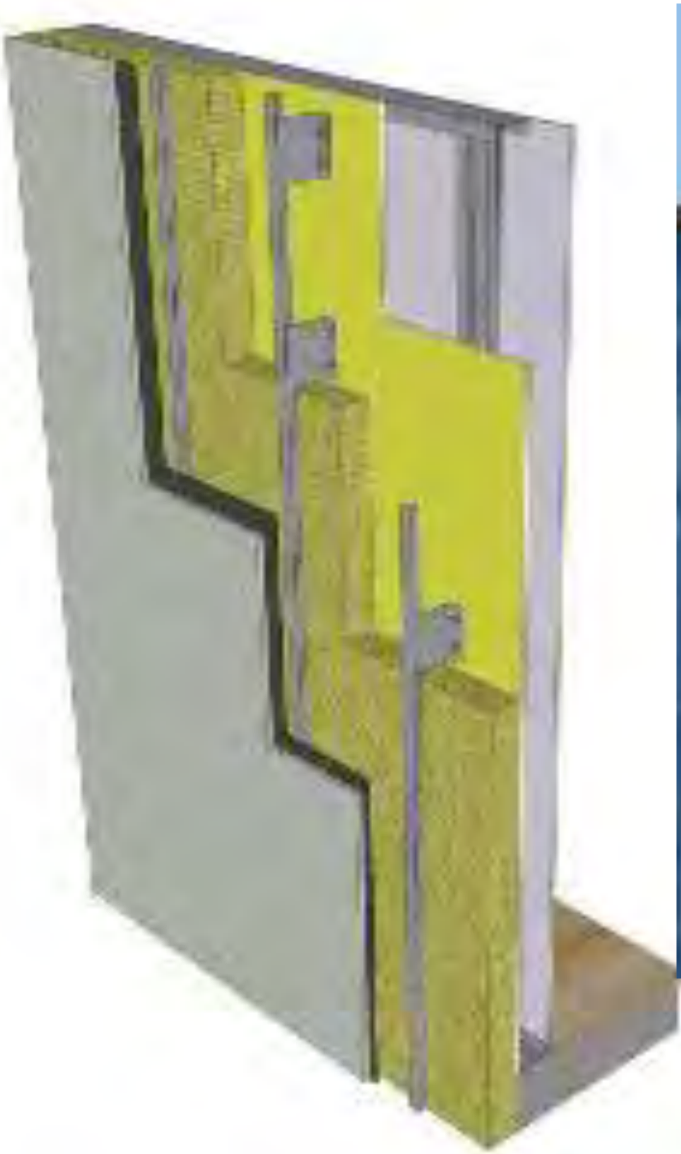
Cladding Attachment: Clip & Rail, Metal



Cladding Attachment: Clip & Rail, Metal

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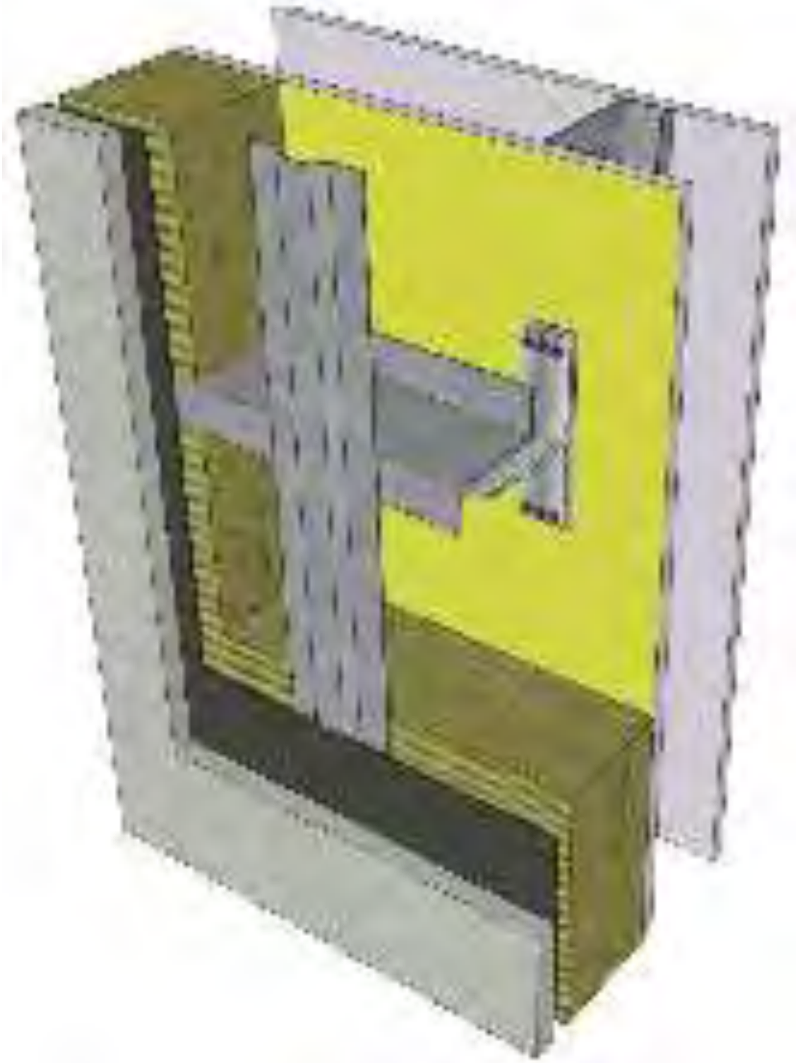
Cladding Attachment: Clip & Rail, Metal

Cladding Attachment: Metal Panel Clips

Cladding Attachment: Clip & Rail, Improved

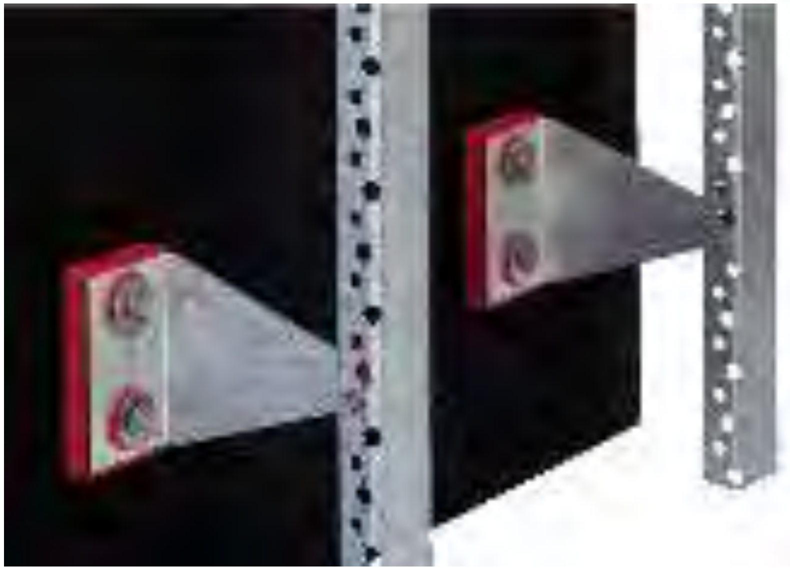
Cladding Attachment: Clip & Rail, Improved

Cladding Attachment: Clip & Rail, Improved



Cladding Attachment: Clip & Rail, Improved

→ Reduce the metal, improve the performance



Cladding Attachment: Clip & Rail, Low Conductivity

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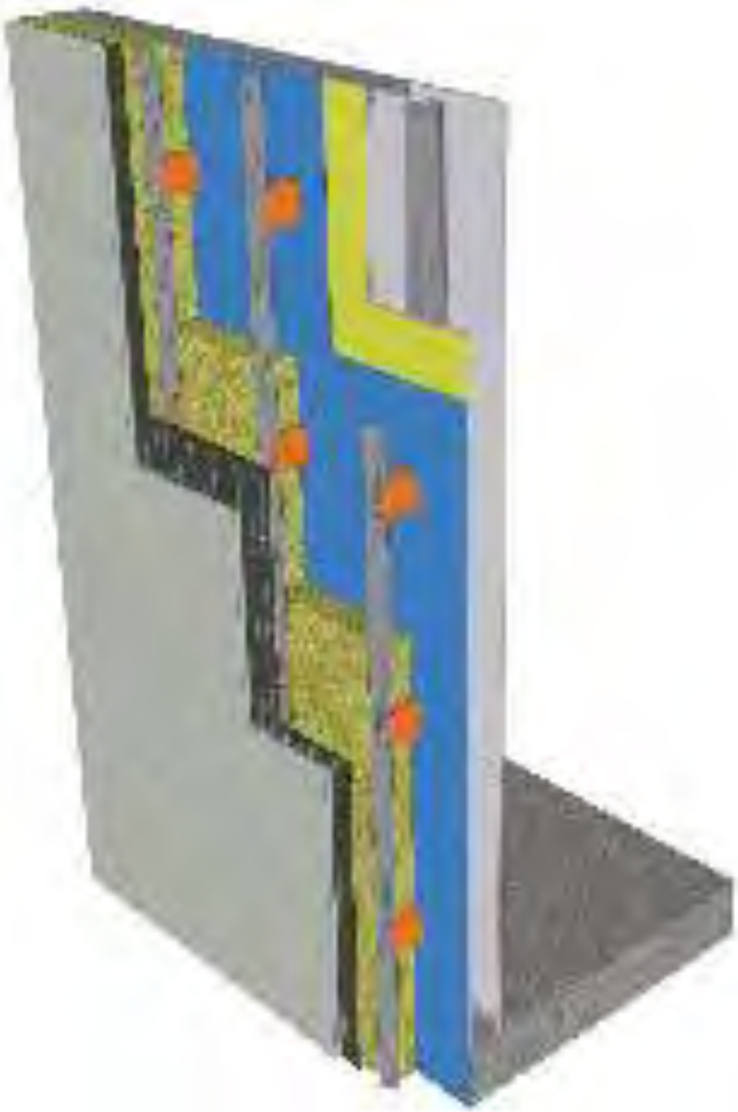

Cladding Attachment: Screws through Insulation

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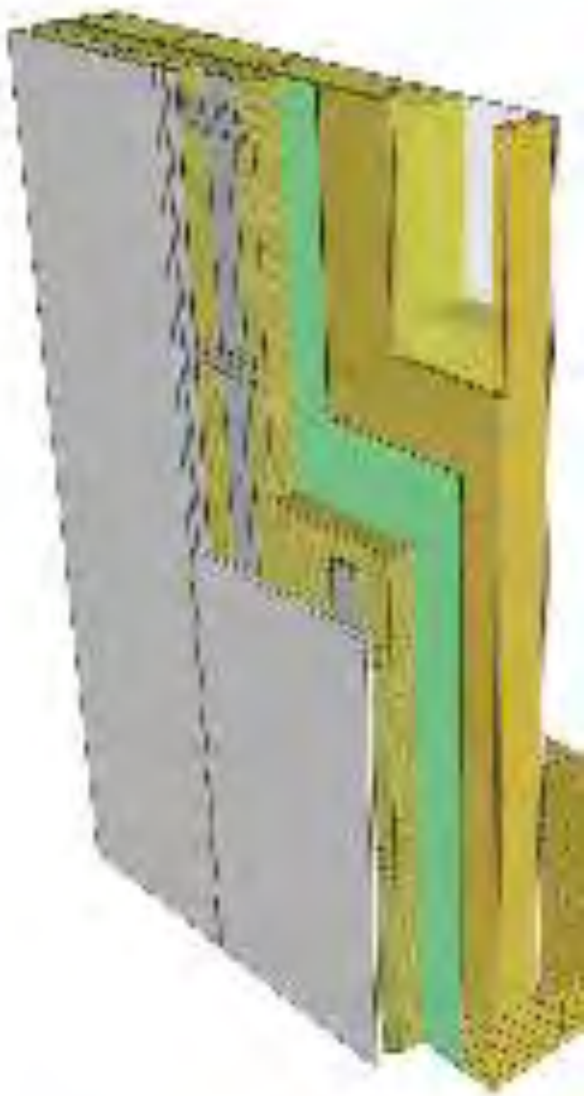
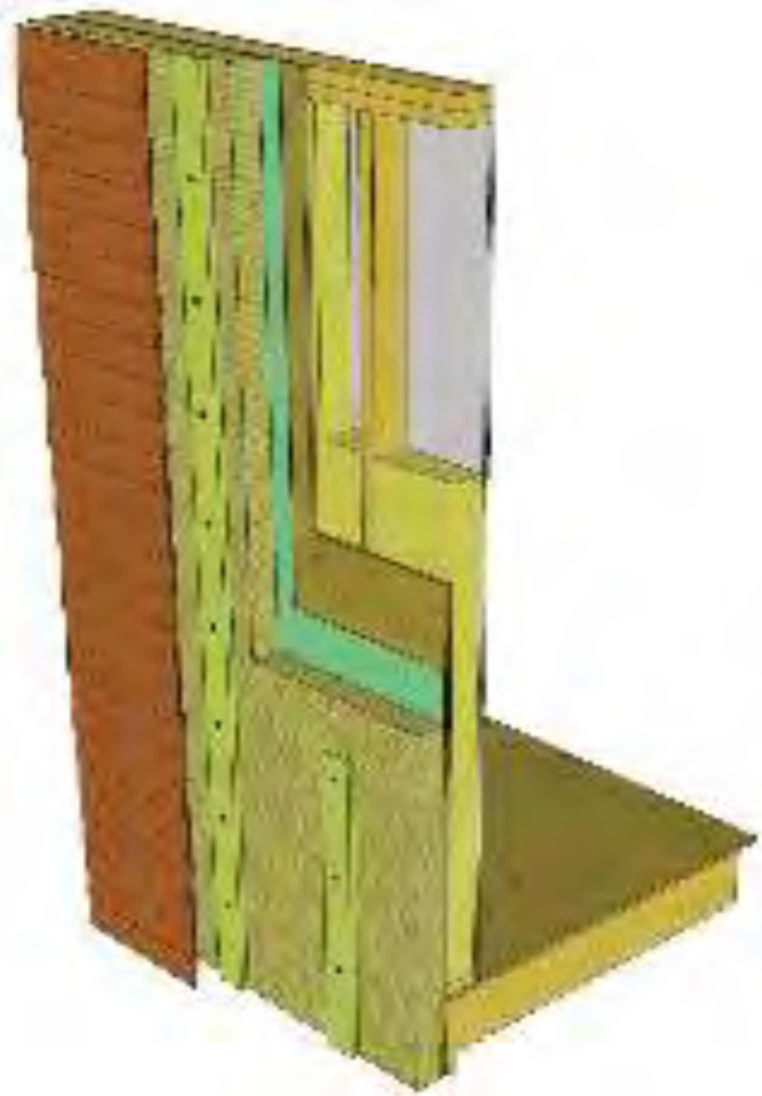
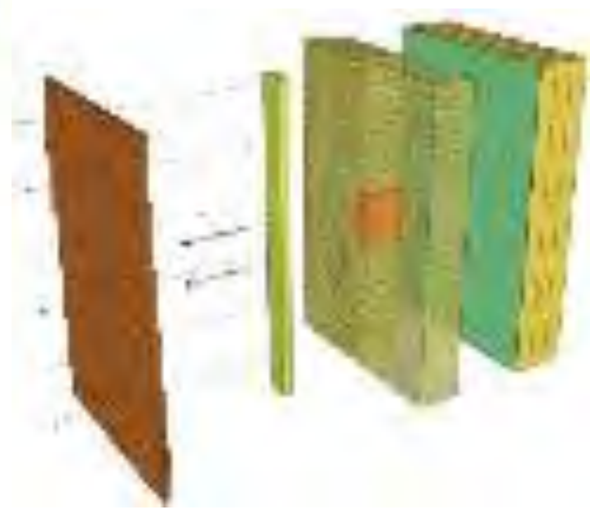




Cladding Attachment: Screws through Insulation

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

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Screws through Insulation - Corners

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Screws through Insulation - Corners

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Screws through Insulation – Details

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→ New Roxul Comfortboard IS & CIS Guides out soon

Exterior Insulation Finish System (EIFS)

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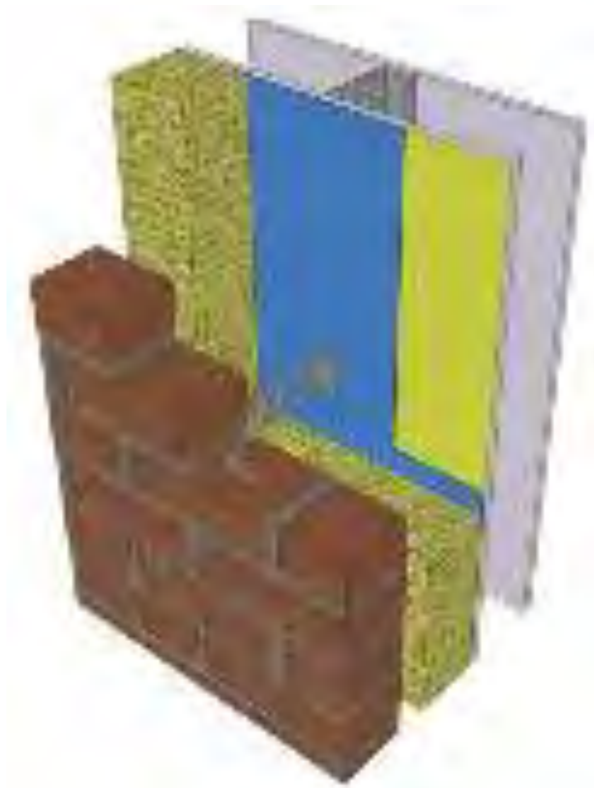
Cladding Attachment: Masonry Ties & Shelf Angles



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

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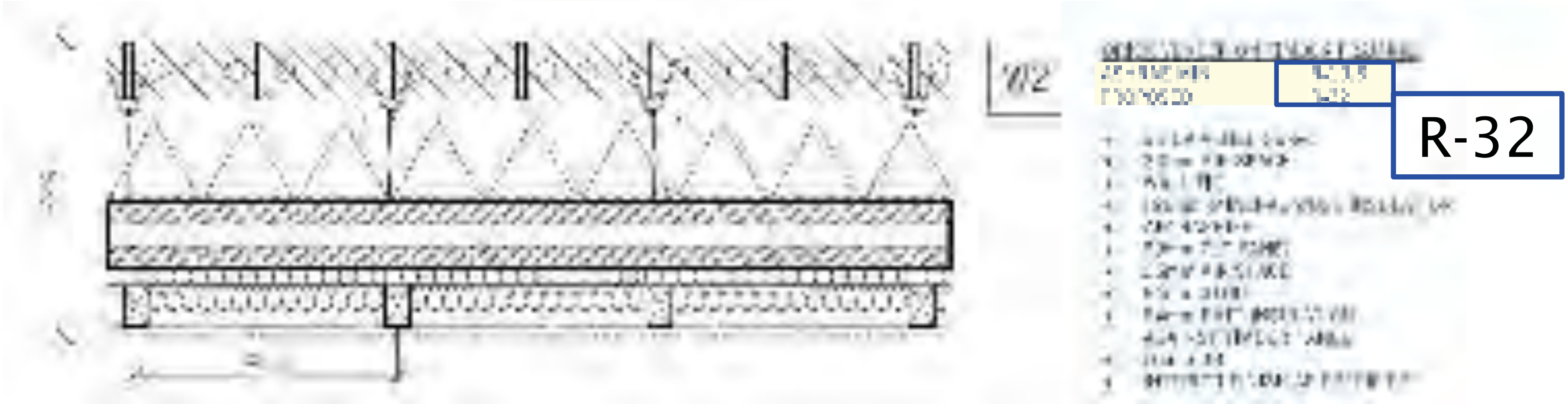
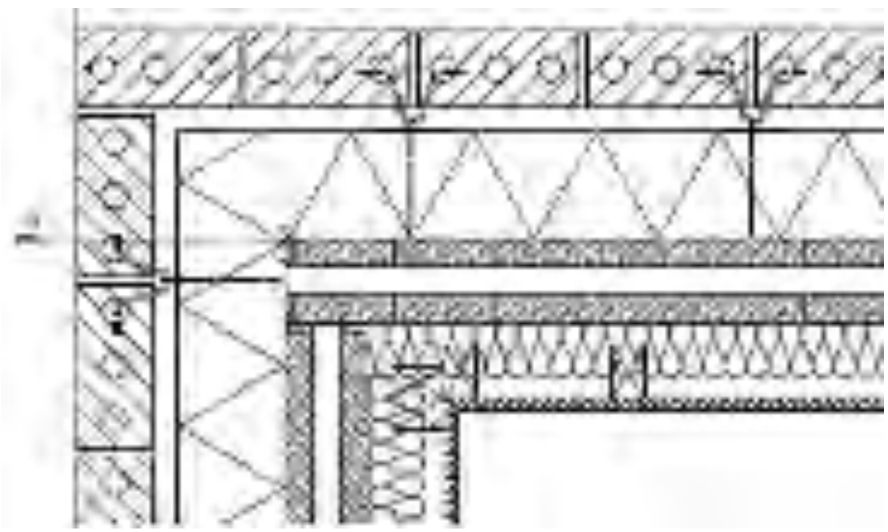
- → Ronald McDonald House
- → 4 Buildings with residential and common areas
- → 3 storey tilt-up Cross Laminated Timber (CLT) structure

Michael Green Architecture (MGA)

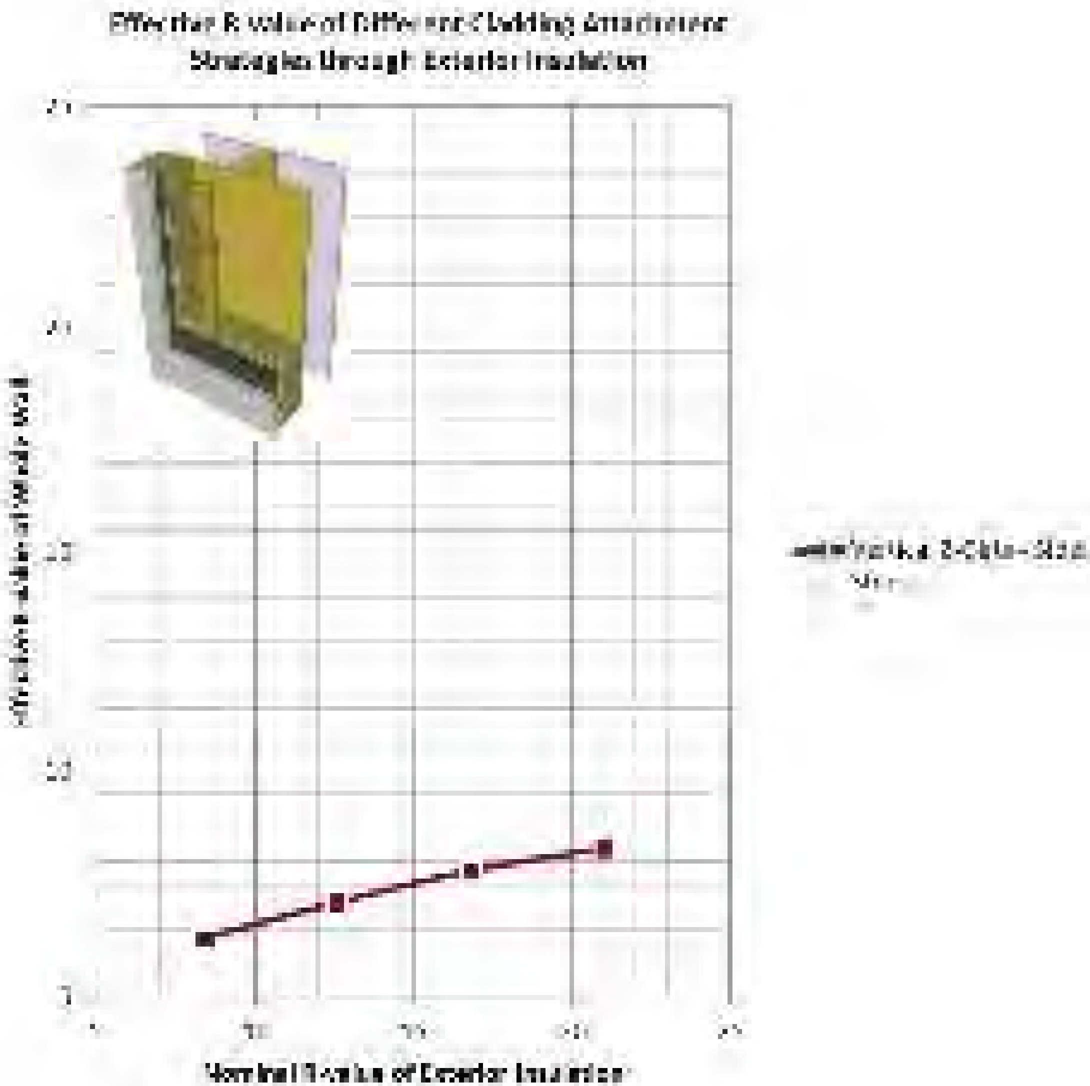
Building Enclosure Assemblies - Walls

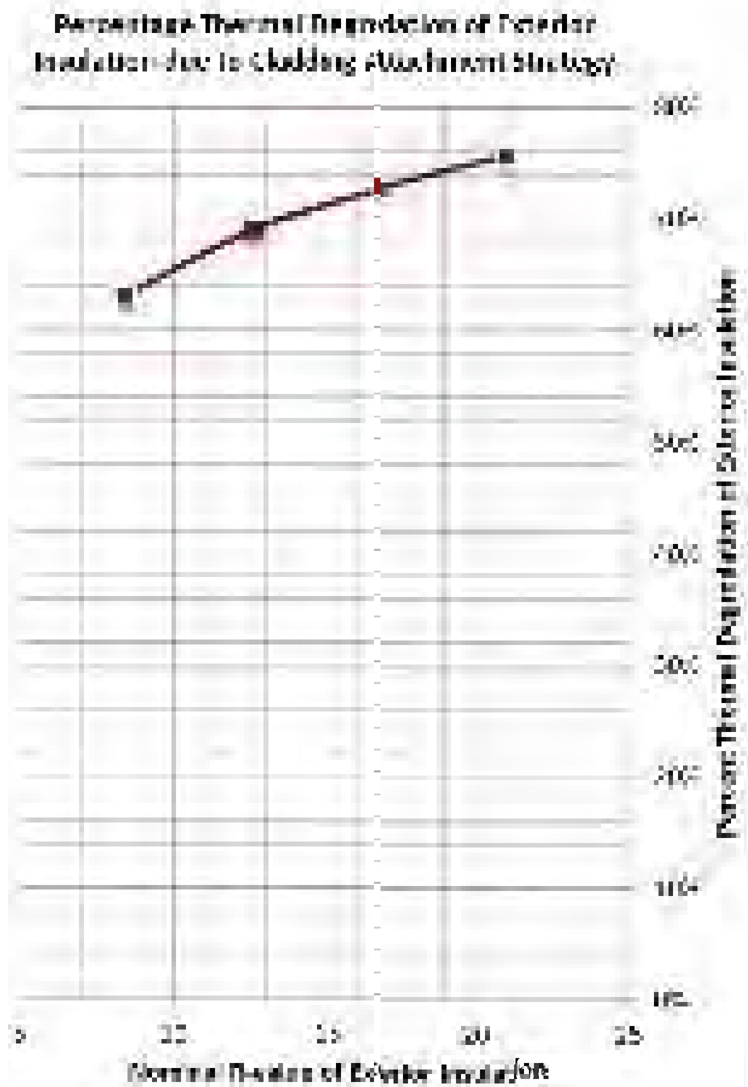




Cladding Attachment: Masonry

Thermal Comparison of Options





Cladding Attachment Recommendations

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Substrate / Cladding Type	Wood Backup (OSB/Plywood)	Steel Stud Backup	Concrete or Concrete Block Backup
Light weight *(up to fiber cement panels, <10psf)*	Clip & Rail good Screws good	Clip & Rail good Screws okay, but difficult to hit stud	Clip & Rail good Screws can be difficult to install
Medium weight *(stucco, cultured stone, 10-30 psf)*	Clip & Rail good Screws with shear block or engineered	Clip & Rail good Screws with shear block or engineered	Clip & Rail good Screws can be difficult to install
Heavy weight *(Masonry, Stone Panels, >30 psf)*	Gravity supports, anchors & engineered connections only	Gravity supports, anchors & engineered connections only	Gravity supports, anchors & engineered connections only

Other Thermal Bridging Considerations

Windows, spandrel panels, balconies, slab edges

Windows

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→ Windows have a significant impact of overall R-value as weakest link in the enclosure

→ Little benefit to improving wall R-values when heat loss through the windows dominates

Where is Heat Loss Occurring?

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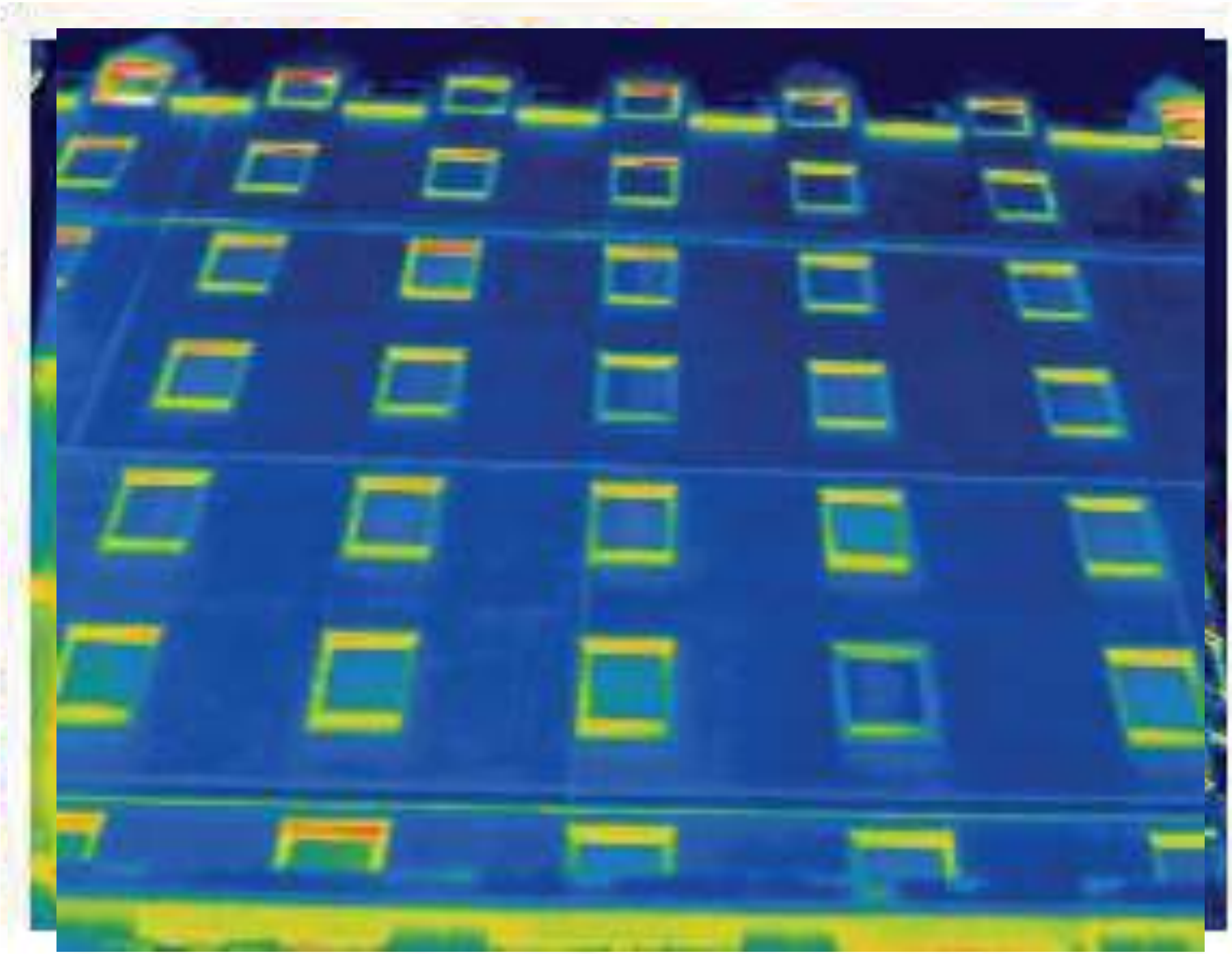

Yellow/red/white = hot = high heat flow/high U-value Blue = Cold = low heat flow/low U-value

Window Impacts in Highly Insulated Walls

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Spandrel Panels

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- 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

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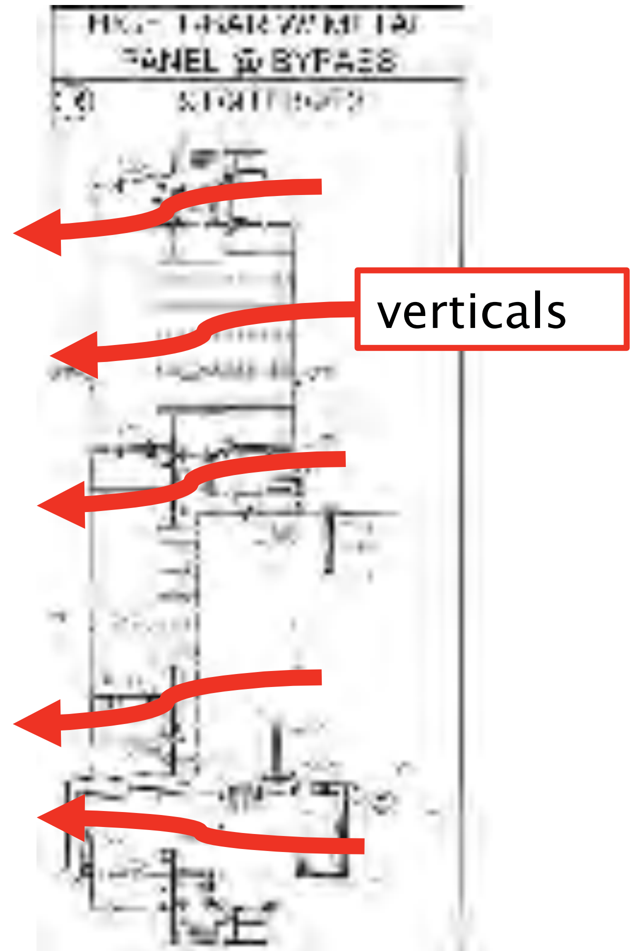
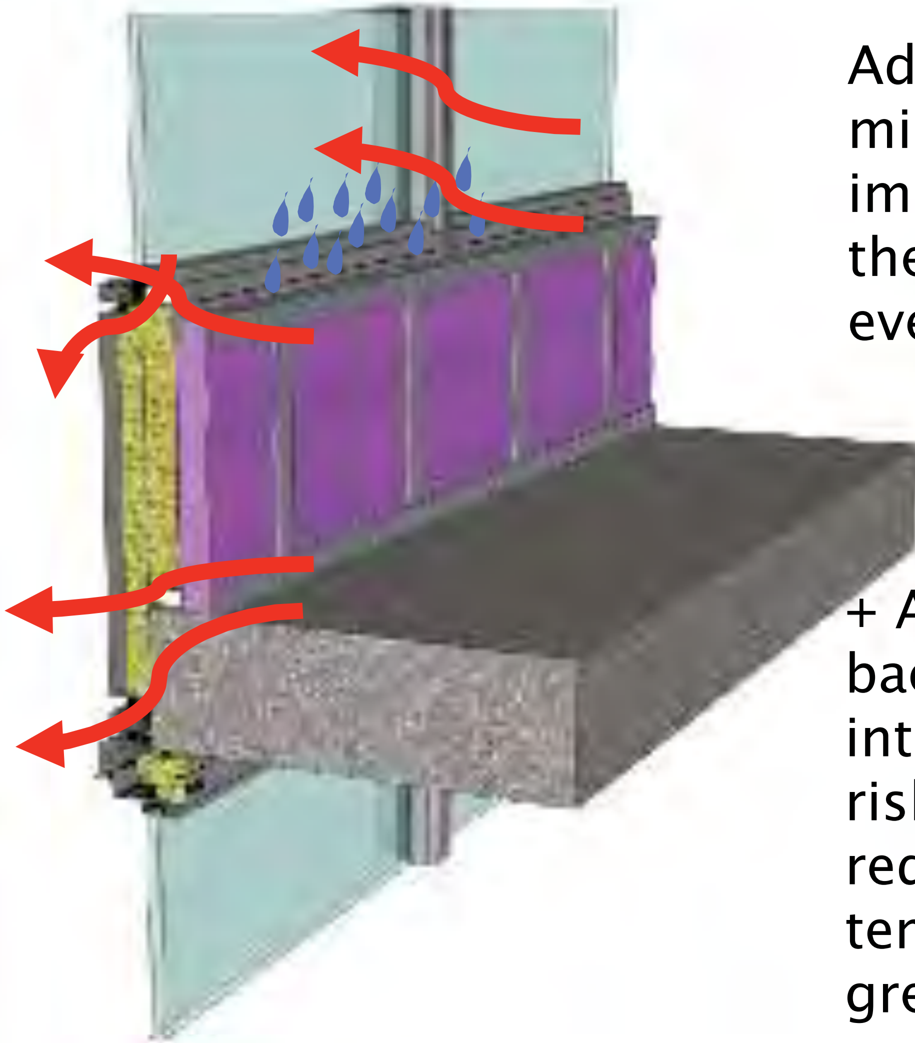
- → Insulation within back-pans or to exterior of slab edge is bridged by aluminum frames
- → Insulation reduction of 50% and greater with depreciating returns is typical
- → **R-3 to R-5** effective R-value for any amount of insulation is a general rule of thumb

Spandrel Panel Effective R-Values



Spandrel Panel Thermal Band-Aid Solution?



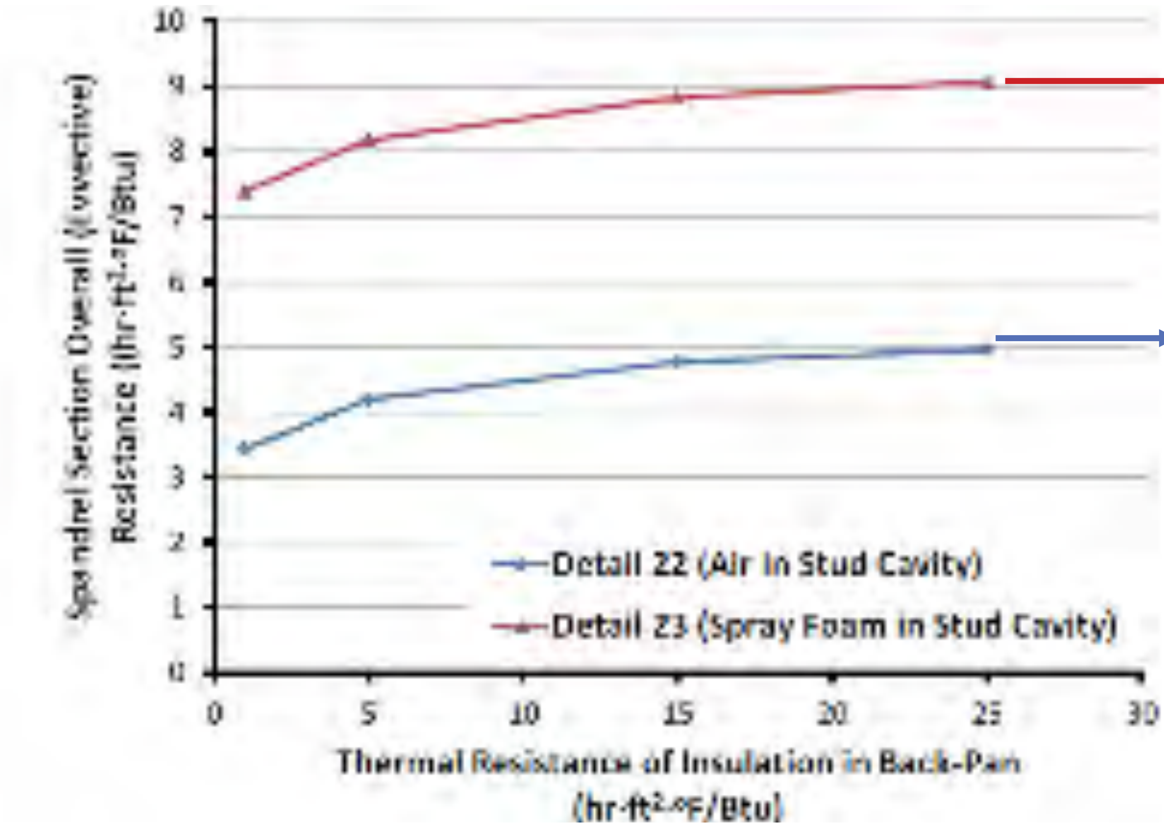
Added insulation provides minimal overall thermal improvement considering thermal bridging (R-4 max even for >R-20 of SPF)

+ 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

R-Values for Spandrel Panels

RDH

→ Overall R-values are limited even with back-pan insulation and interior insulation

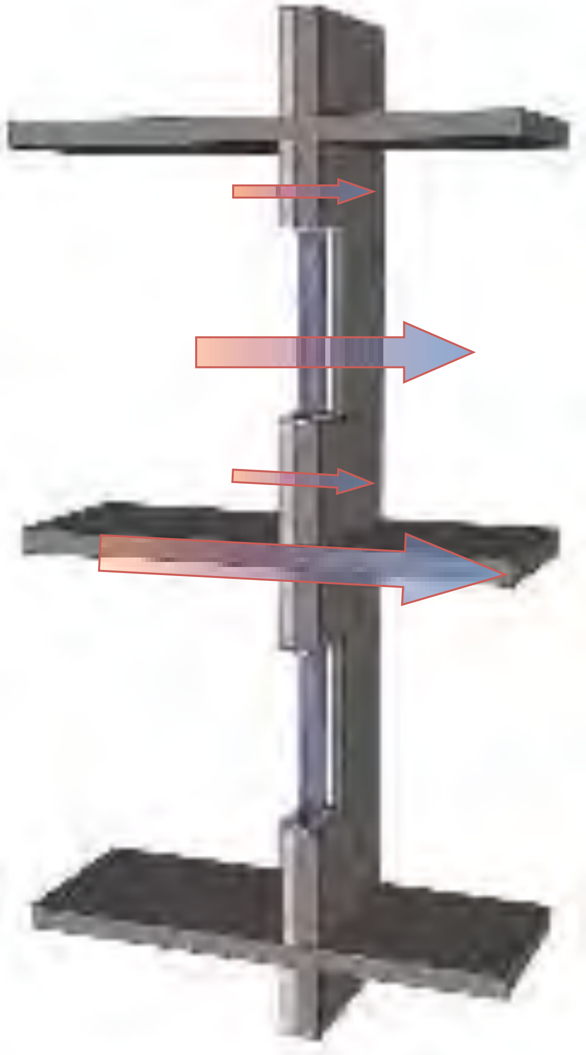


With interior spray foam: Max R-9

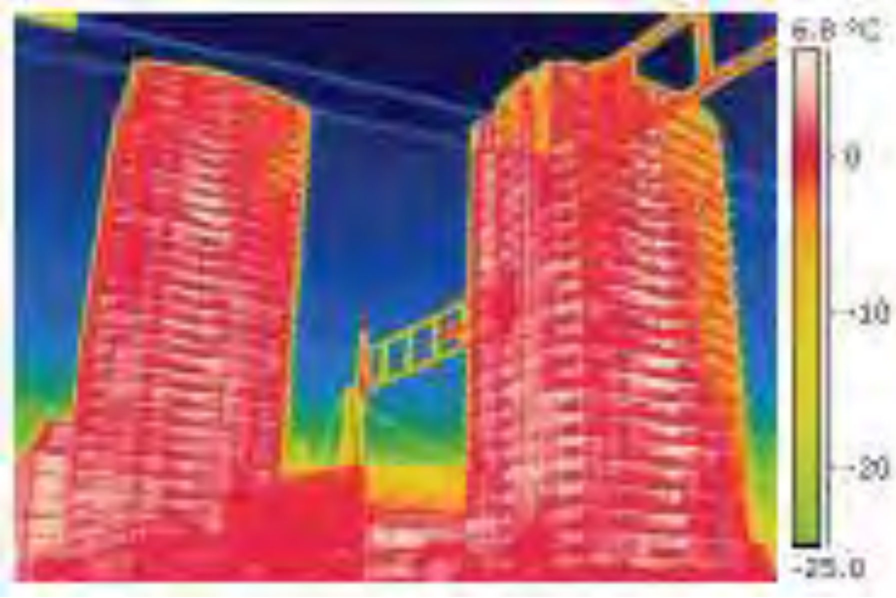
Without interior spray foam: Max R-5

Source: ASHRAE Research Project 1365

Balconies & Slab Edge Projections



Thermal Bridging at Balconies



What Thermal Impact Can Balconies Possibly Have?

RDH

- → 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

RDH

Exterior insulation over concrete wall

R-values for 8'8" High Wall - No Balcony or Eyebrow (Center of Wall)

Insulation Strategy	Effective R-value
3" EPS (R-12), Exterior Insulation	**R-13.9**
4" EPS (R-16), Exterior Insulation	**R-18.0**
6" EPS (R-24), Exterior Insulation	**R-25.8**

R-values for 8'8" High Wall with Balcony or Eyebrow (Overall)

Insulation Strategy	Effective R-value
3" EPS (R-12), Exterior Insulation	**R-7.4** ***(-47%)***
4" EPS (R-16), Exterior Insulation	**R-8.6** ***(-52%)***
6" EPS (R-24), Exterior Insulation	**R-10.6** ***(-59%)***

Impact of Slabs & Balconies – Interior Insulated

RDH

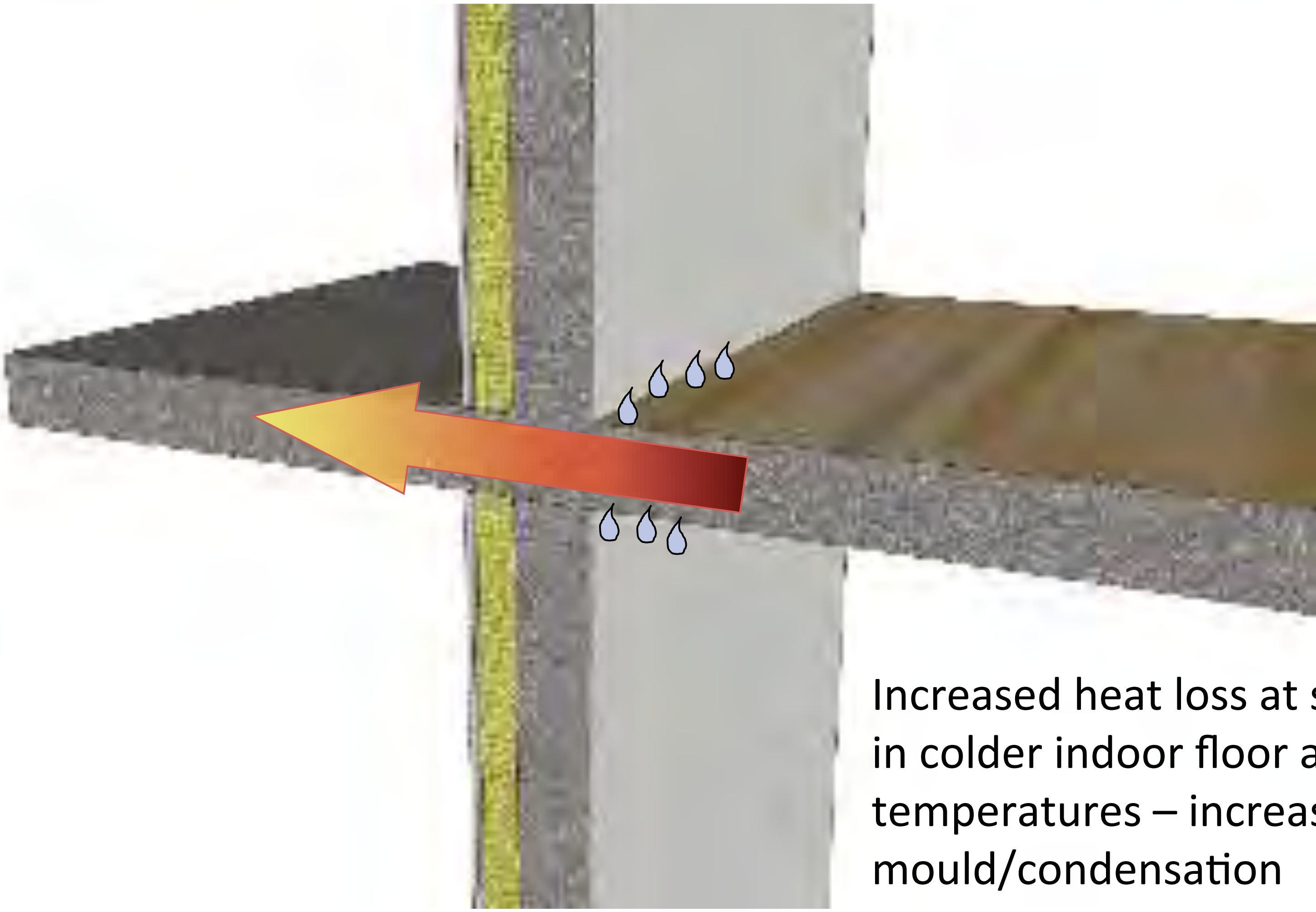
XPS/batt insulation to interior of exposed concrete wall

R-values for 8'8" High Wall - No Balcony or Eyebrow (Center of Wall)

Insulation Strategy	Effective R-value
1" XPS (R-5) + R-12 batts/steel studs	**R-14.3**
2" XPS (R-10) + R-12 batts/steel studs	**R-19.7**
3" XPS (R-15) + R-12 batts/steel studs	**R-24.7**

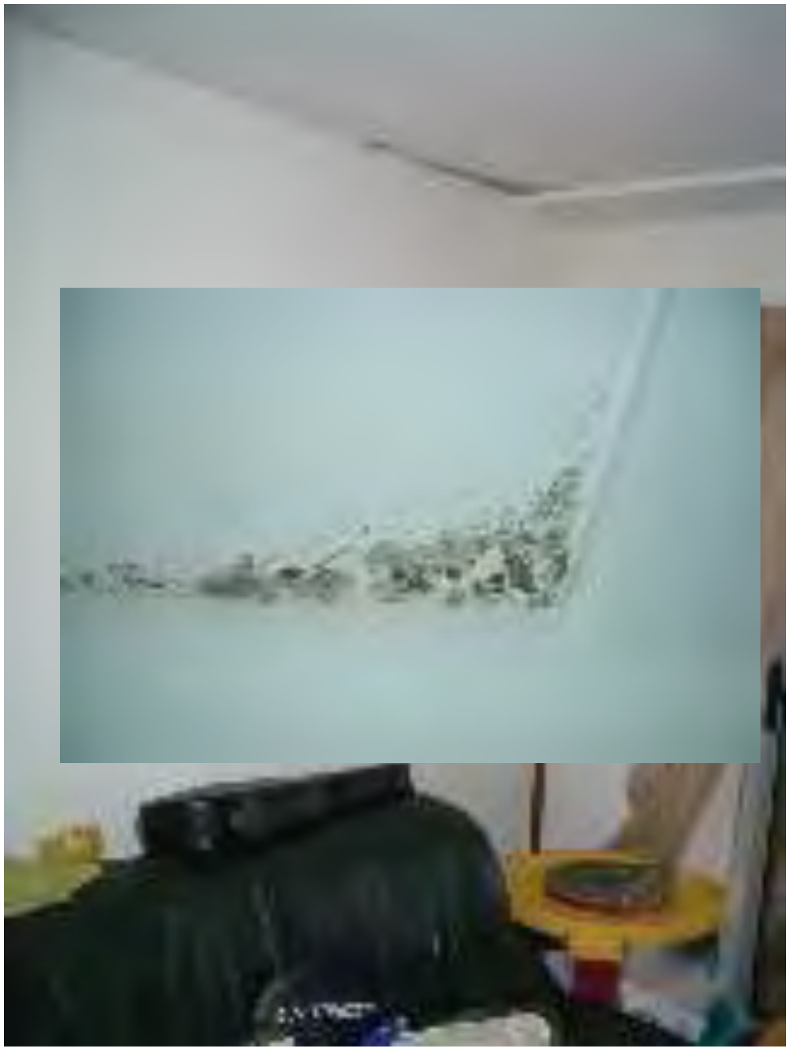
R-values for 8'8" High Wall <u>with Balcony or Eyebrow (Overall)</u>

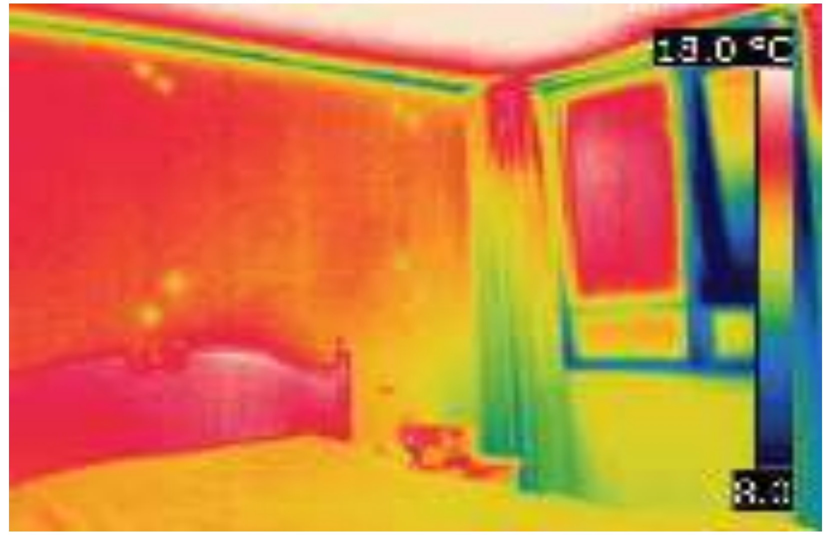
Insulation Strategy	Effective R-value
1" XPS (R-5) + R-12 batts/steel studs	**R-7.5 (-48%)**
2" XPS (R-10) + R-12 batts/steel studs	**R-8.9 (-55%)**
3" XPS (R-15) + R-12 batts/steel studs	**R-10.0 (-60%)**



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?

RDH

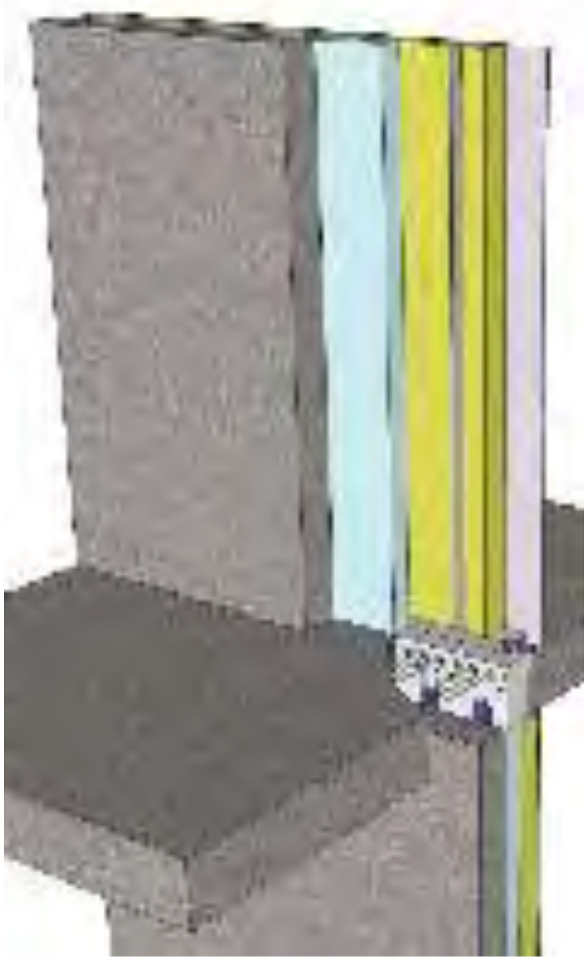
- → Wrap with insulation
- → Use off-set point supports and hang the balcony precast units with threaded rods tied back to the columns of the structural frame
- → Offset point supports rather than cantilevering the slab
- → Stand-alone support structure

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

RDH



R-values for 8'8" High Wall with 6' Balcony

Wall Insulation Strategy	**Effective R-value**
1" XPS (R-5) + R-12 batt/studs (R-14.3)	**R-7.5**
2" XPS (R-10) + R-12 batt/studs (R-19.7)	**R-8.9**
3" XPS (R-15) + R-12 batt/studs (R-24.7)	**R-10.0**

R-values for 8'8" High Wall with 6' Balcony & Thermal Break

Wall Insulation Strategy & Thermal Break R-value	**Effective R-values**	
	R-2.5 thermal break	**R-5 thermal break**
1" XPS (R-5) + R-12 batt/studs (R-14.3)	R-11.0	R-12.1
2" XPS (R-10) + R-12 batt/studs (R-19.7)	R-14.4	R-16.6
3" XPS (R-15) + R-12 batt/studs (R-24.7)	R-17.0	R-19.5

Summary

RDH

- 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

RDH

SLIDES NOT USED

Design Guides & Other Resources

Building Enclosure Design Guide

- 1999/2001 *Wood Frame Envelopes in the Coastal Climate of British Columbia - Best Practice Guide* (CMHC)
  - Emphasis on moisture control in Pacific Northwest
- 2011 *Building Enclosure Design Guide – Wood-frame Multi-Unit Residential Buildings* (HPO)
  - Emphasis on best practices, moisture and new energy codes
  - Will be updated later this year

Cross Laminated Timber Handbooks

RDH

- 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

Tall Wood Building Guide

RDH

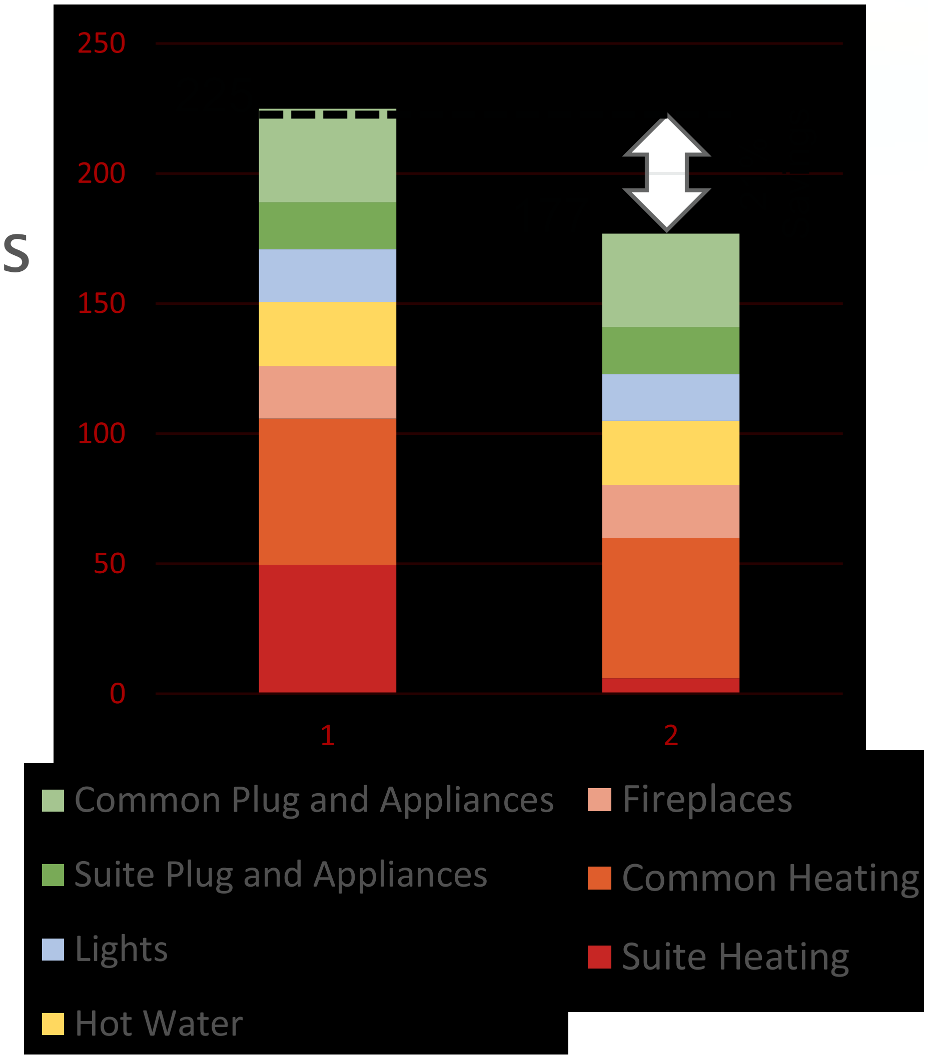
- 2014 *Tall Wood Buildings Guide* (FPInnovations) – highrise wood and hybrid wood buildings
- Building enclosure chapter #6 focuses on design fundamentals for durable and energy efficient high-rise mass timber buildings
  - Moisture management & control
  - Heat flow & thermal bridging
  - Condensation control
  - Air flow control & air barrier systems
  - Noise & Fire control
  - Assemblies & Details
  - Claddings, Roofing
  - Wood Durability

Misc. Slides Not Used

Modeled Annual Energy Savings

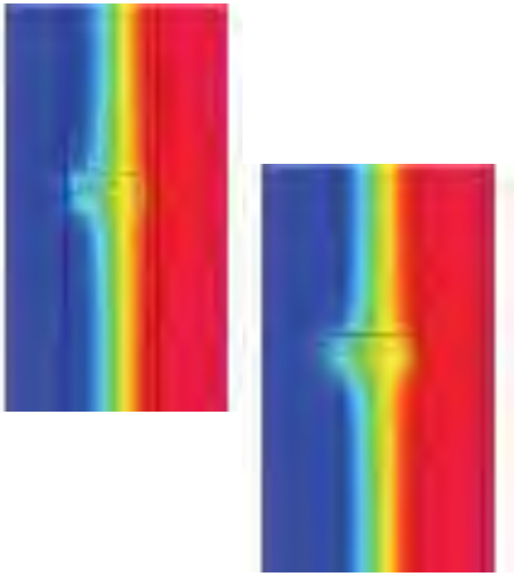
RDH

- 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



Thermal Analysis of Effective R-values

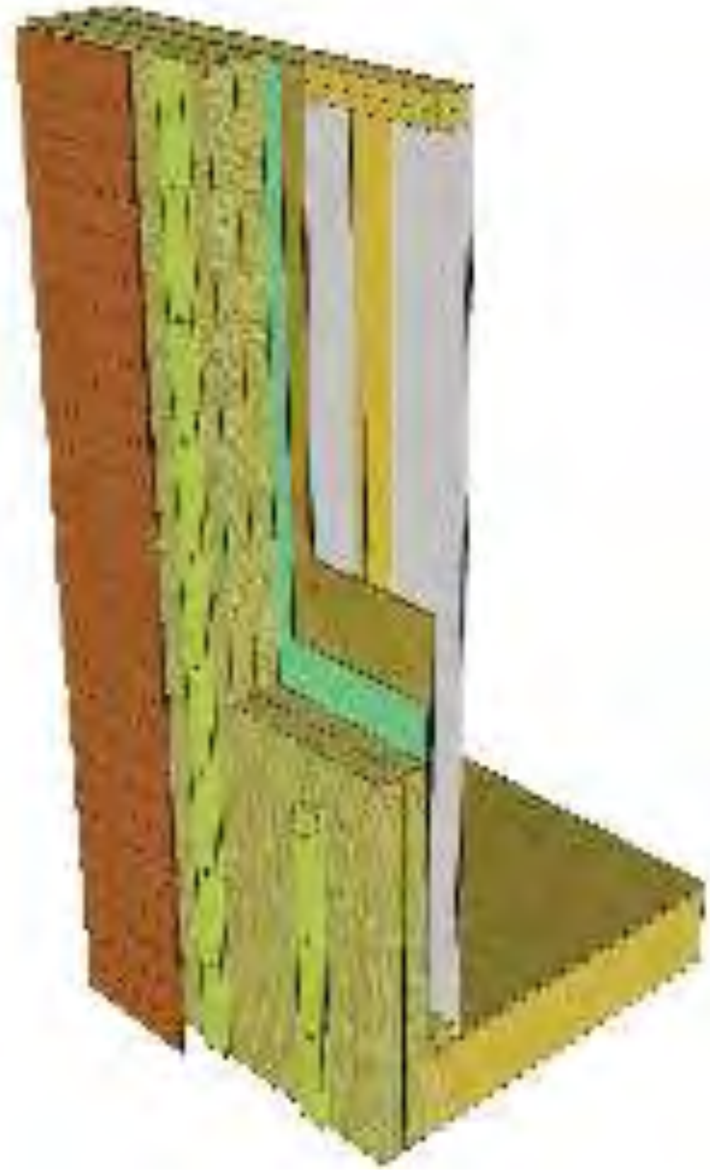
- Effective R-values of building enclosure assemblies & details can be determined by:
  - Hand methods – simple wood frame walls, not suitable for many assemblies/details
  - Laboratory (Guarded hot-box testing) – good for confirmation, expensive and not efficient for design/analysis purposes
  - Two-dimensional 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

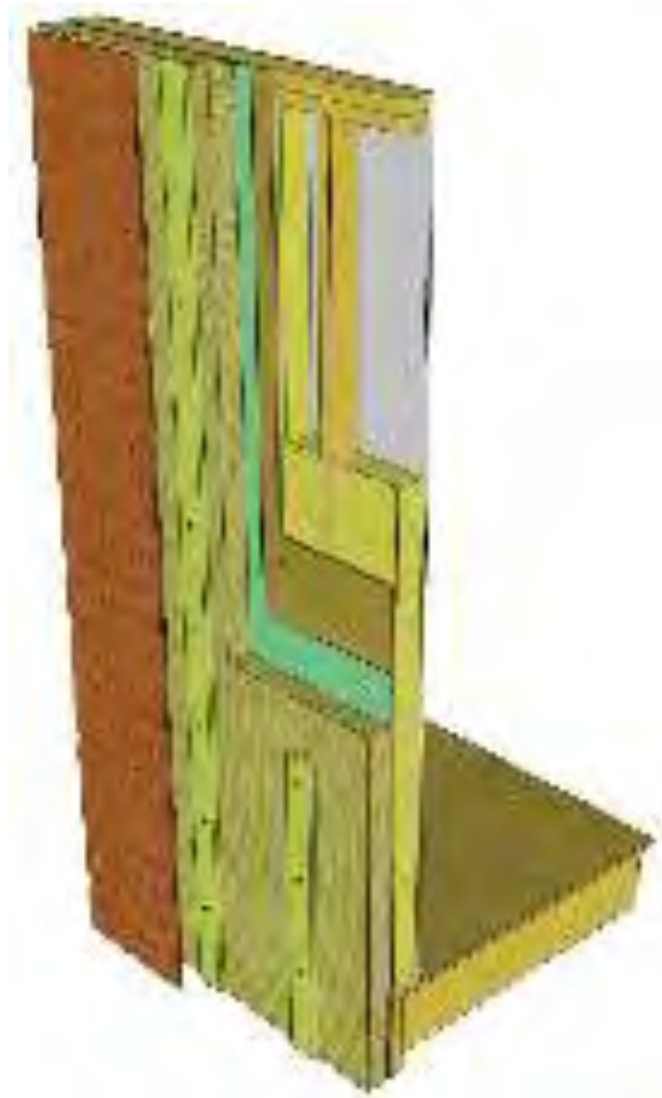
RDH

- 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

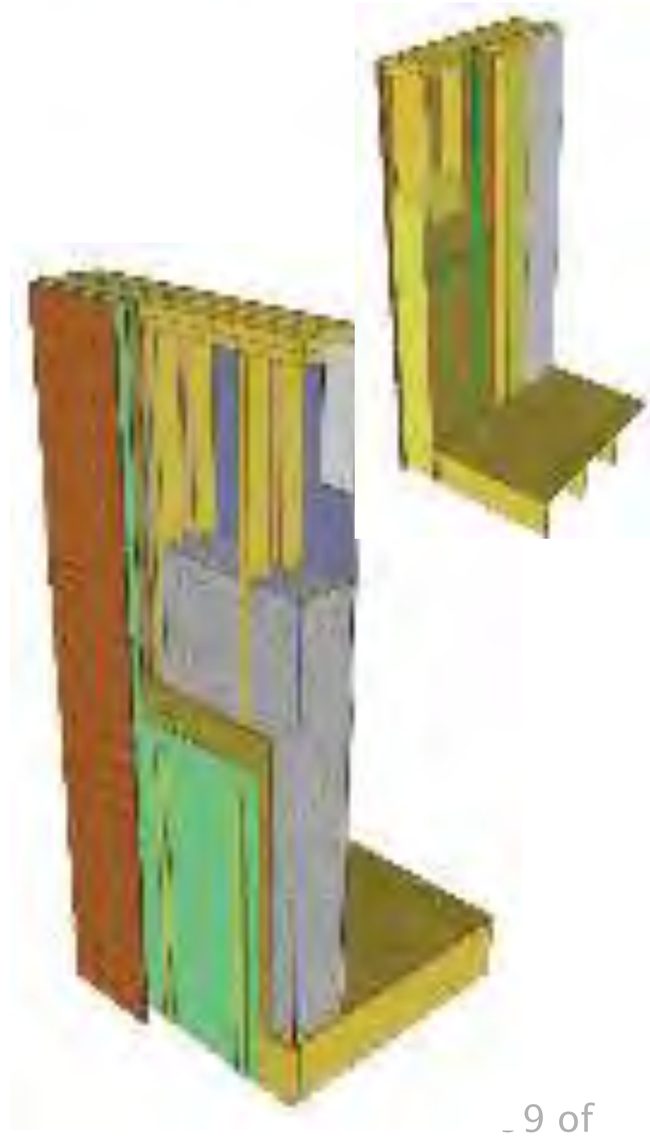
- Key Considerations:
  - Exterior insulation type
  - Cladding attachment
  - Sequencing & detailing
- Heat Control: Exterior and stud space Insulation (designed)
- Air Control: House-wrap adhered/ sheet/liquid membrane on sheathing, sealants/tapes etc. Often vapor permeable
- Vapor Control: Poly or VB paint at interior, plywood/OSB sheathing
- Water Control: Rainscreen cladding, WRB membrane, surface of insulation



Key Considerations – Double Stud/Deep Stud

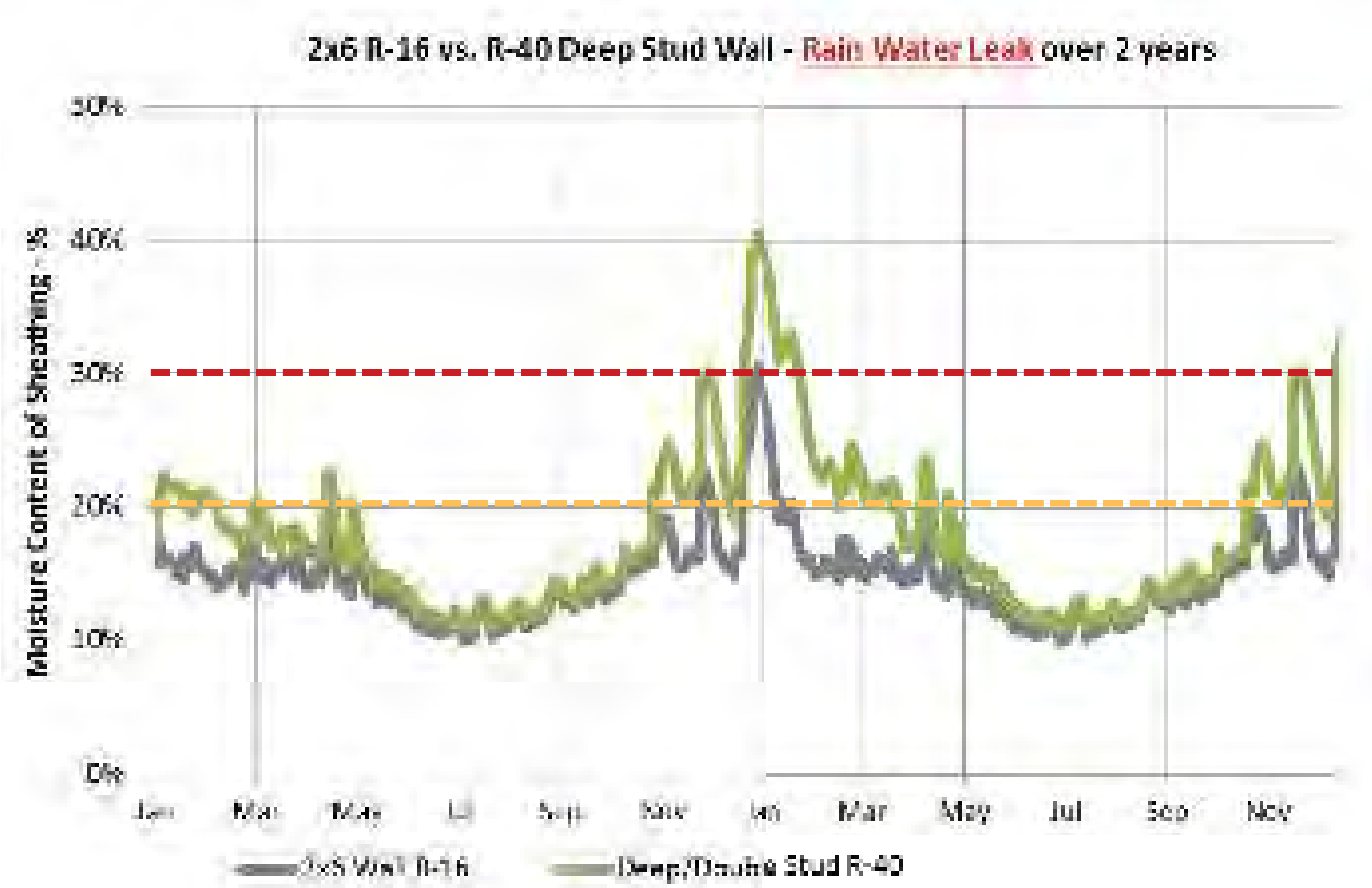
RDH

- 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

RDH

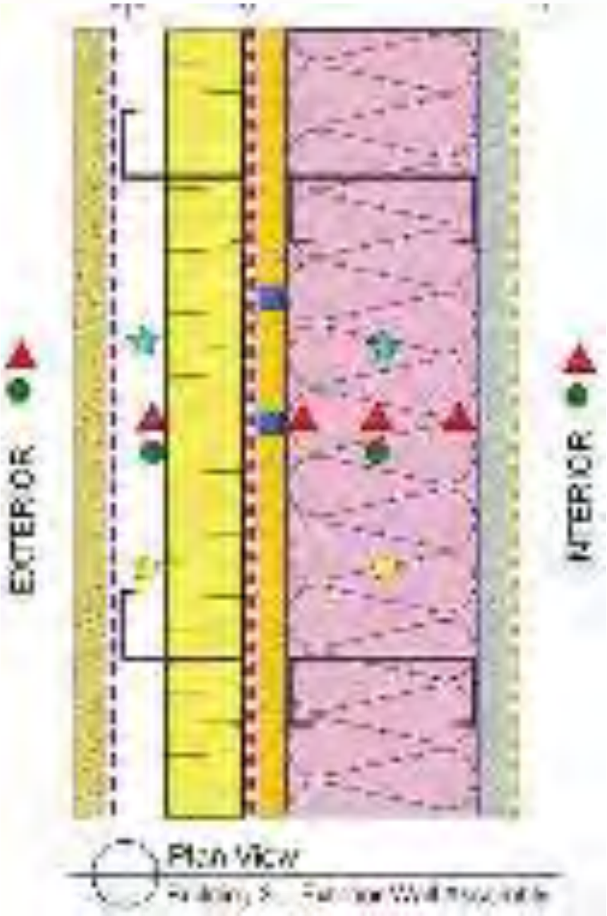


Trial Exterior Insulation Rehab - Late 1990s

RDH

Trial Exterior Insulation Rehab – Late 1990s

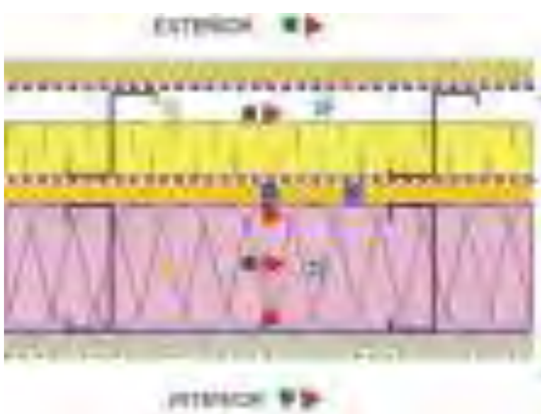
Trial Split Insulated Assembly



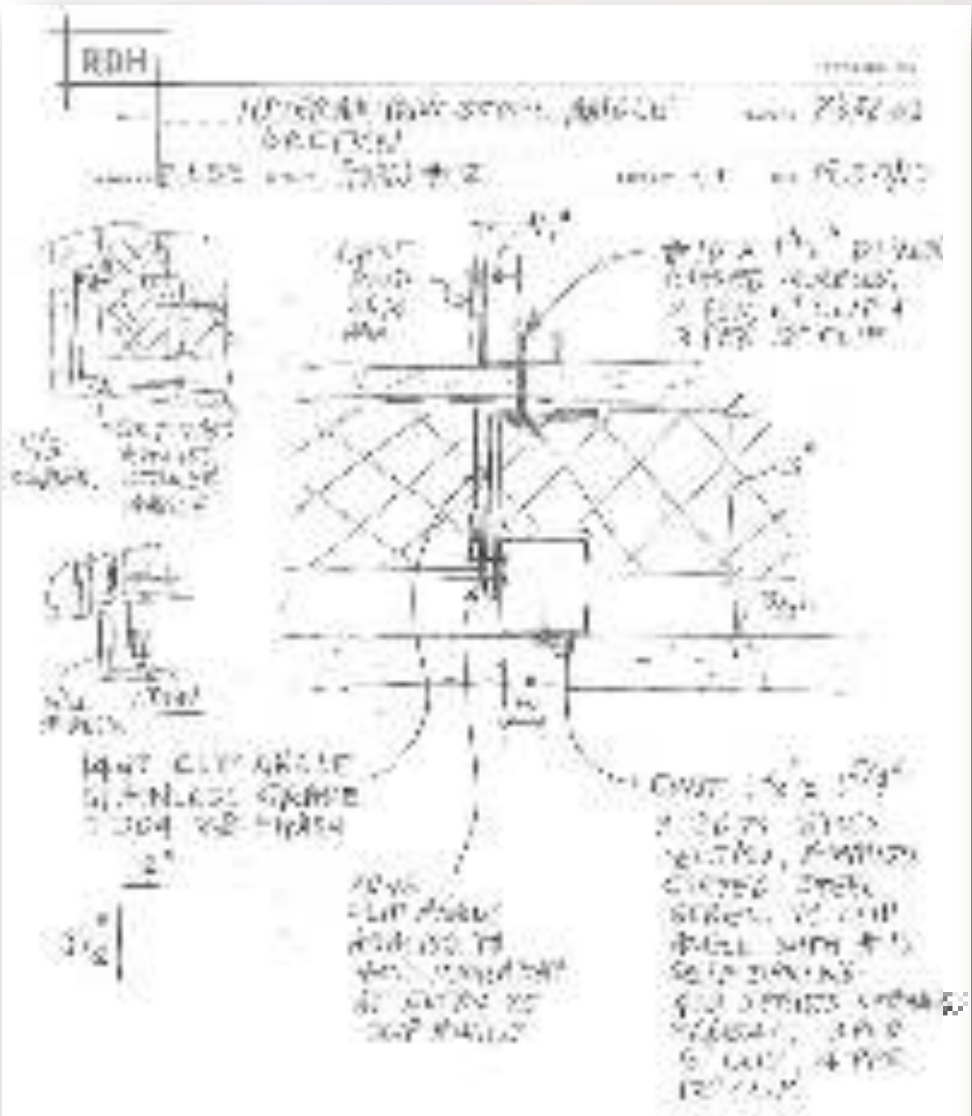
Trial Split Insulated Assembly

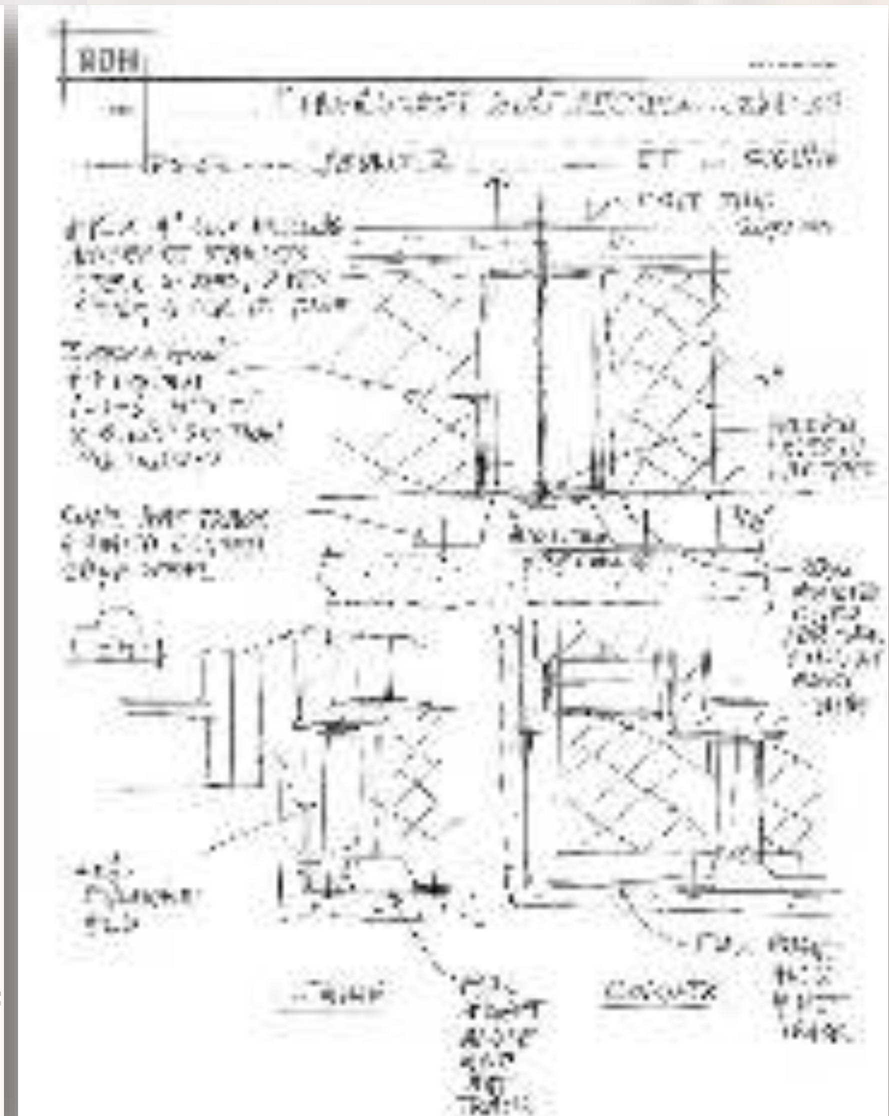
RDH

Lessons Learned About Indoor Humidity & Drying



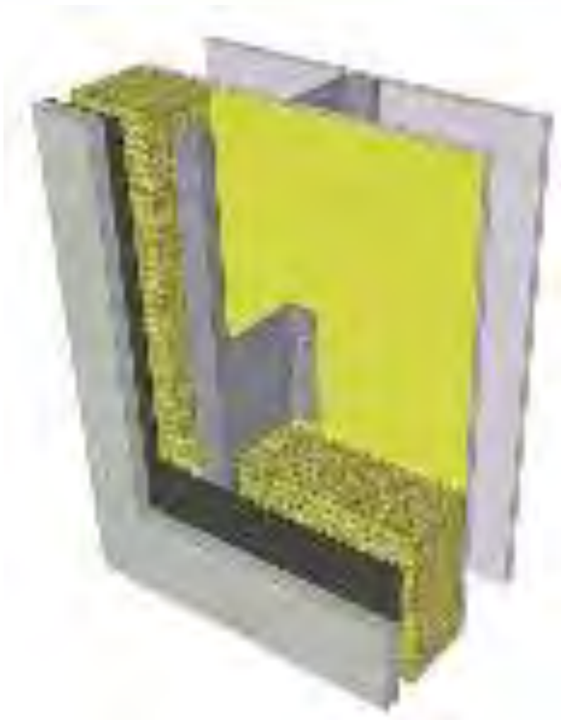
Trial Thermally Improved Cladding Attachments

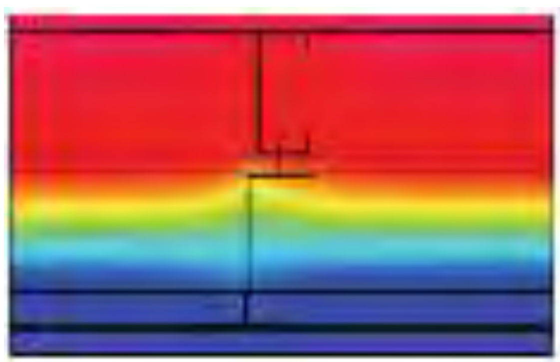


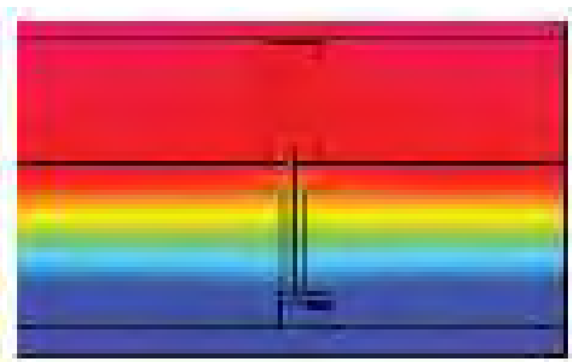


Cladding Attachment & Detailing Considerations

Cladding Attachment: Clip & Rail, Non-Conductive







Cladding Attachment: Clip & Rail, Non-Conductive

Cladding Attachment: Screws through Insulation

RDH

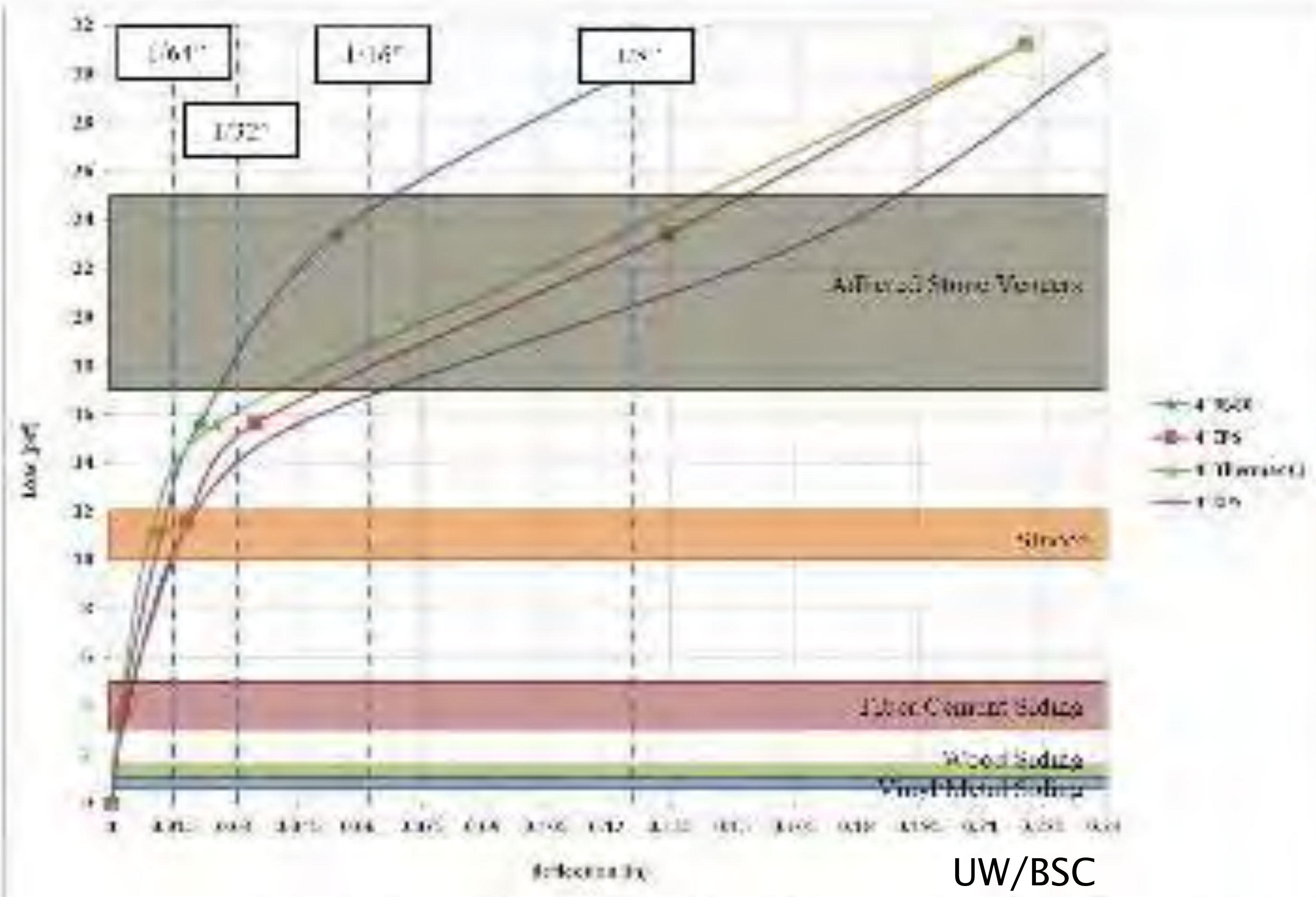


Figure 9: Short term deflection testing results (4" thick insulation)

Cladding Attachment: Screws through Insulation

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Screws through Insulation – Corners & Details

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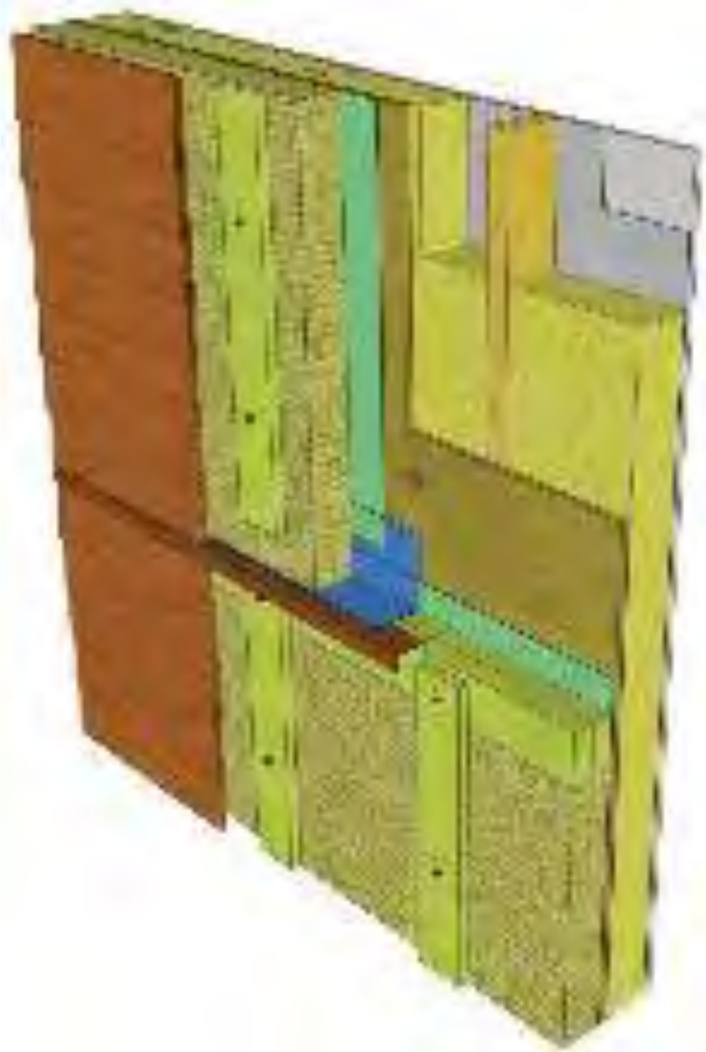
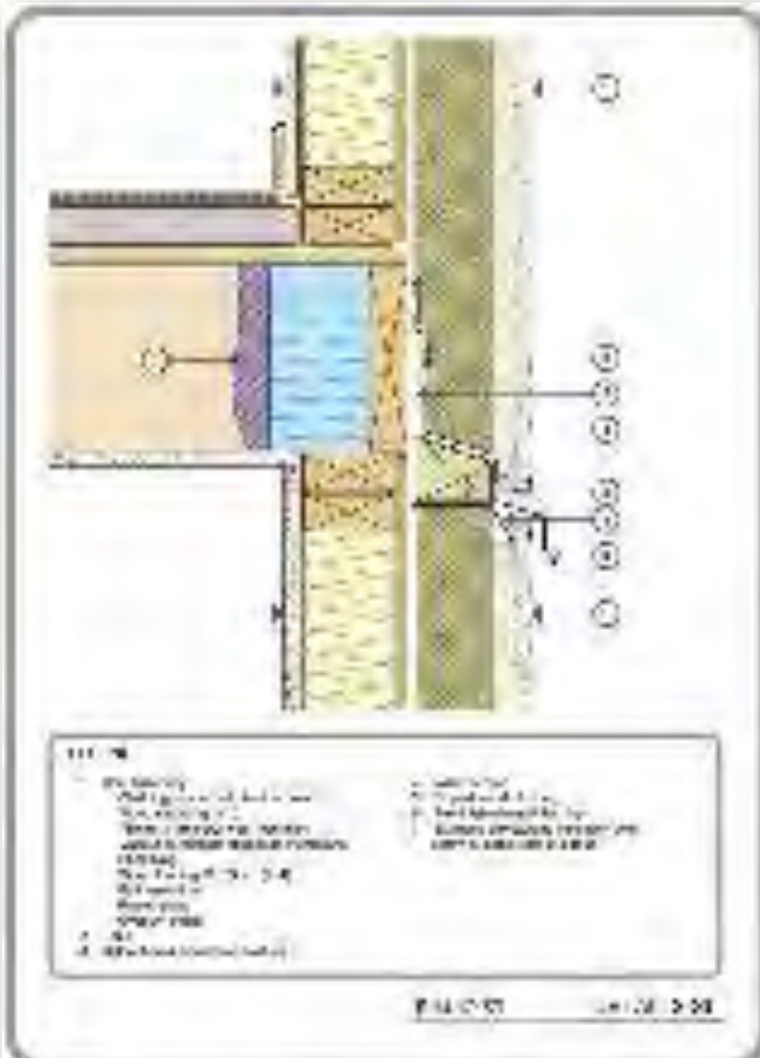
Screws through Insulation: Shear Blocks

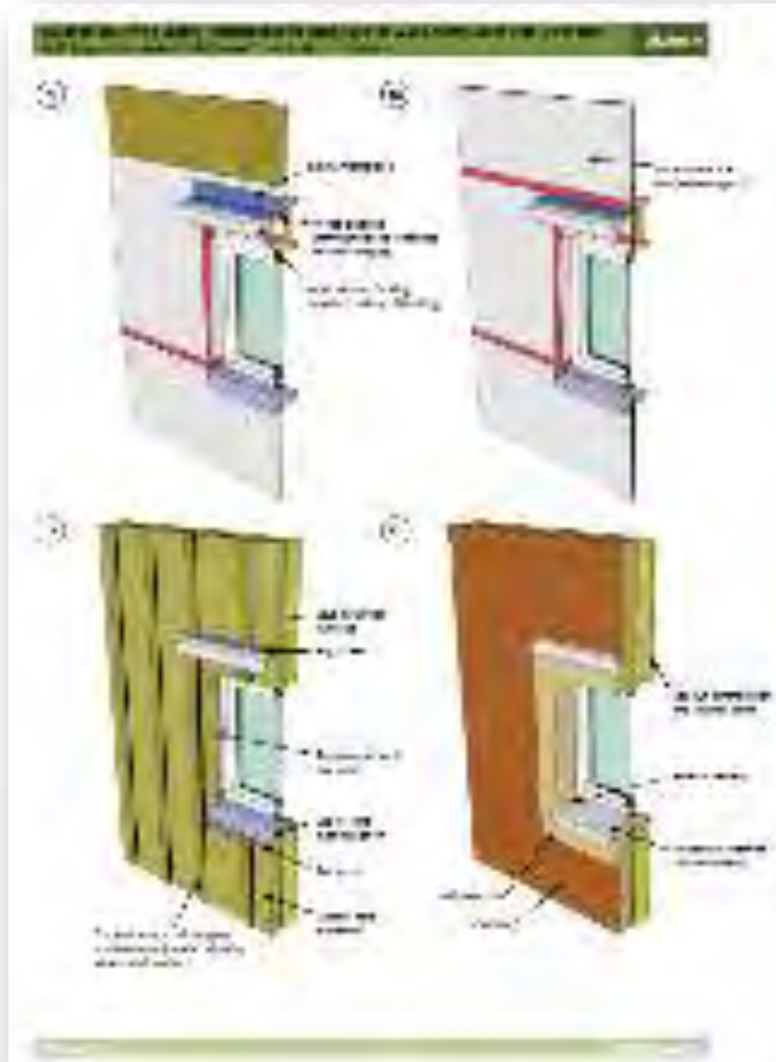
RDH



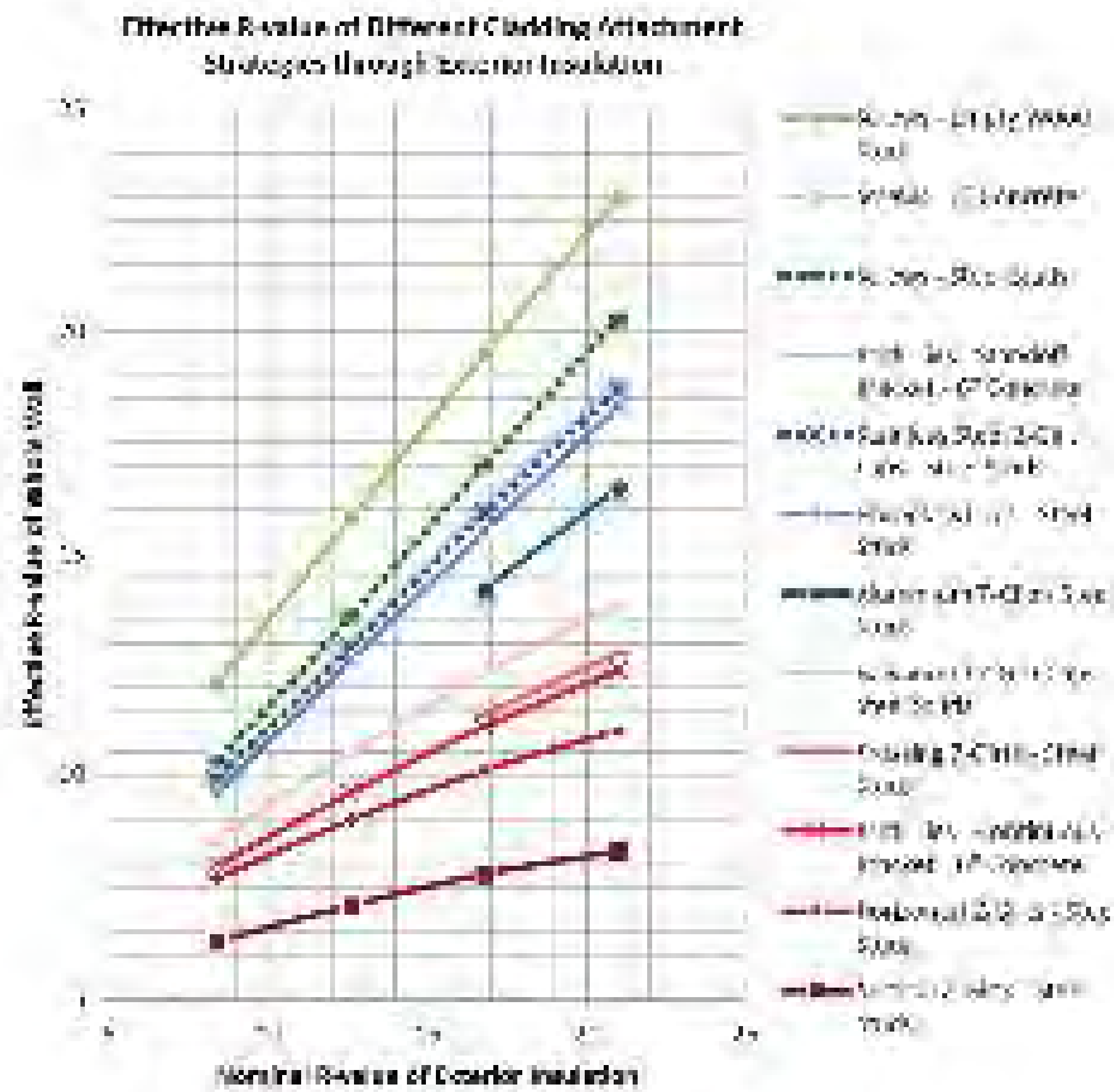
- → With heavier weight claddings – may consider shear blocks to limit deflection and creep
  - → Not necessary with light-weight claddings
- → Shear block material:
  - → Continuous or intermitted wood blocks, metal clips etc.

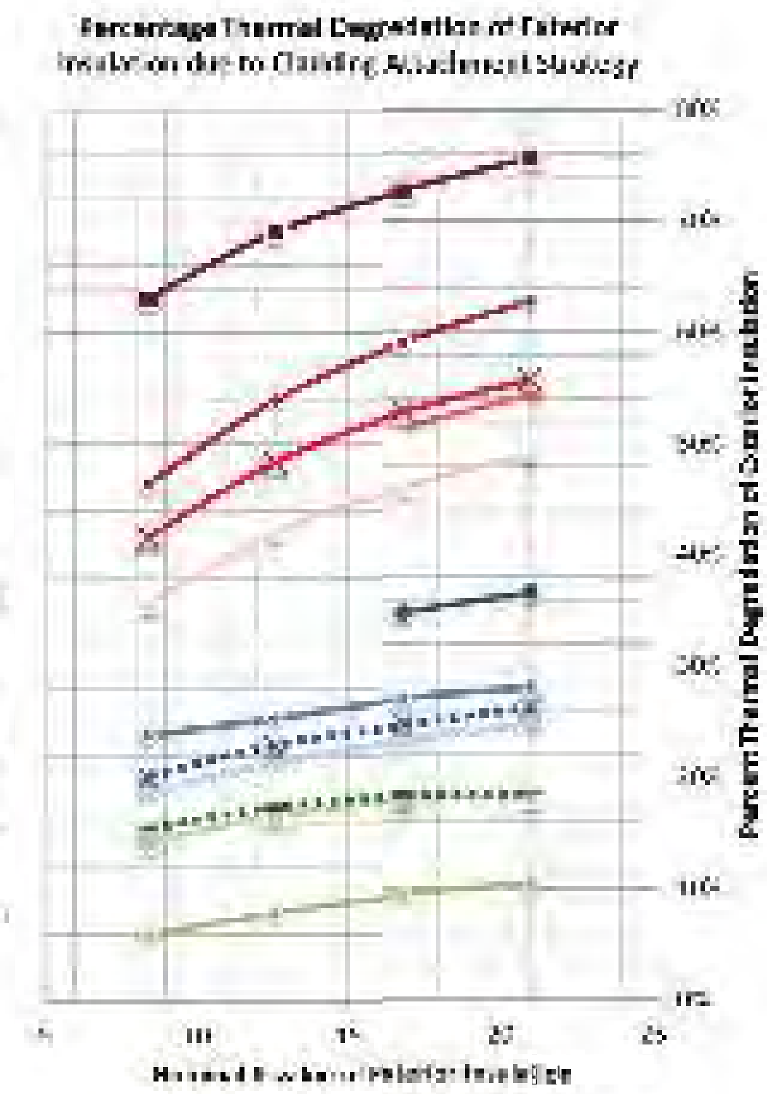
Other Considerations - Flashings





Thermal Comparison of Options





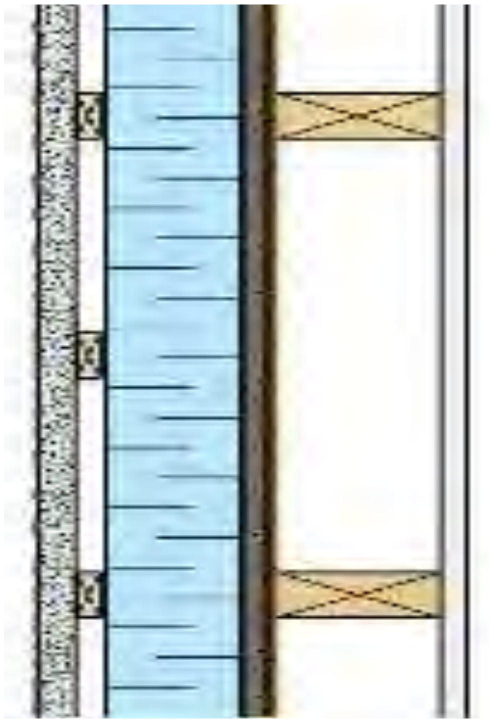
CLT Construction

RDH

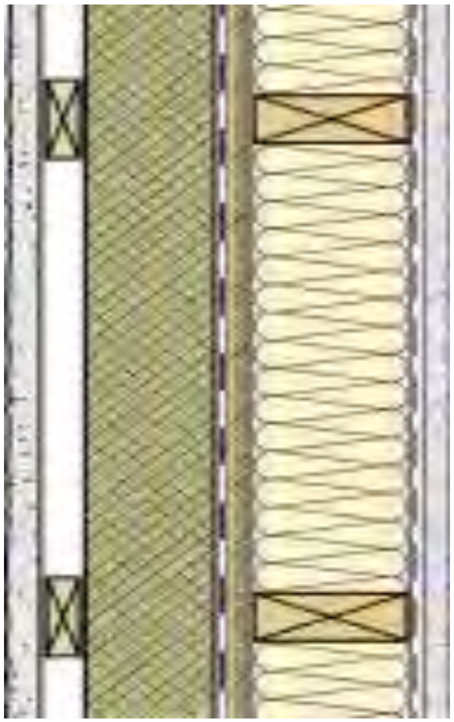
Cladding Attachment: Masonry

Assemblies and Cladding Attachment – Slides Not Used

Interior Insulation



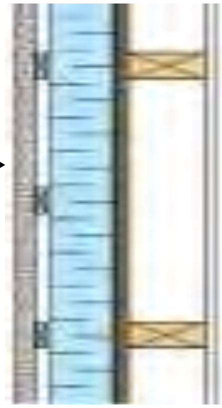
Exterior Insulation



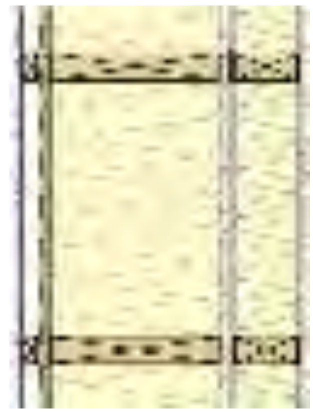
Split Insulation

Getting to Higher R-values – Insulation Placement

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



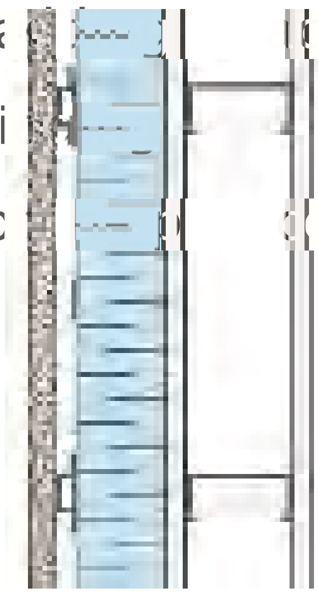
Deep/Double Stud– **R-20 to R-40+ effective**
- Constraints wall thickness
- Good for wood, wasted for steel

Split Insulation–
R-20 to R-40+ effective
- Constraints: cladding attachment
- Good for wood, palatable for steel

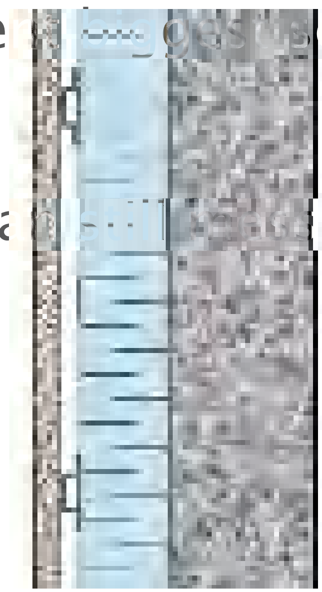
New vs Retrofit Considerations

Exterior Insulated Walls

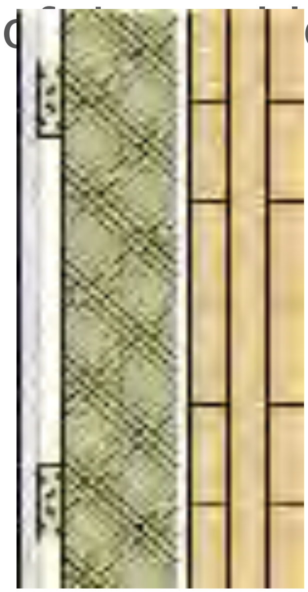
- Insulation outboard of structure and control layers (air/vapor/water)
- Thermal mass at interior where useful
- Excellent performance in all climate zones
- Cl… hme… source o… loss/ bri…
- No… ea, ca… it up



Steel Stud



Concrete

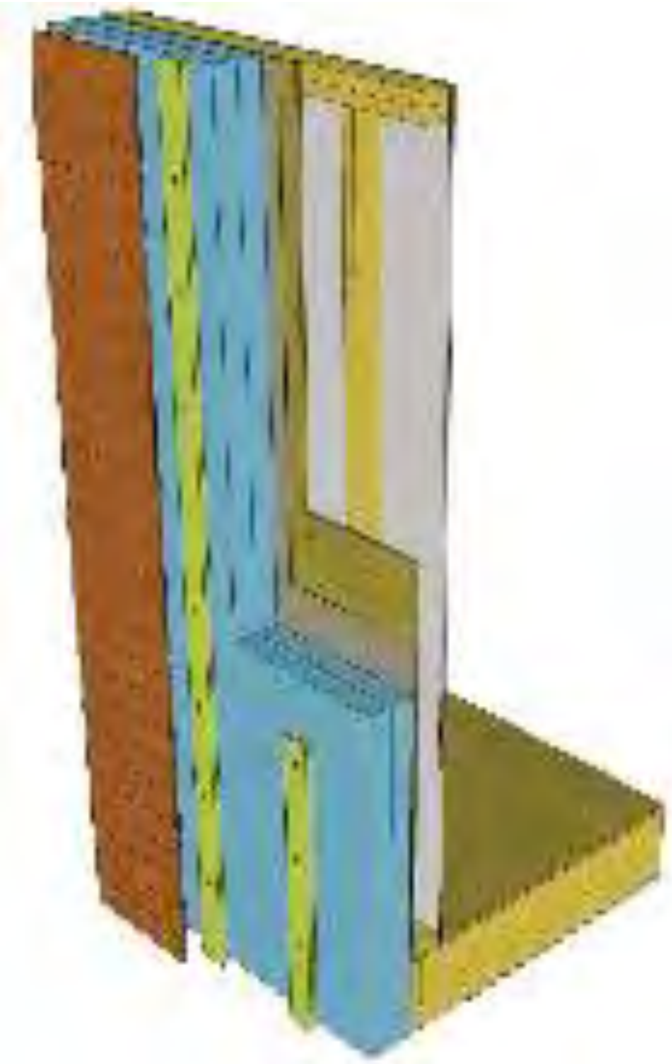


Heavy Timber (CLT)

Exterior Insulation Assemblies

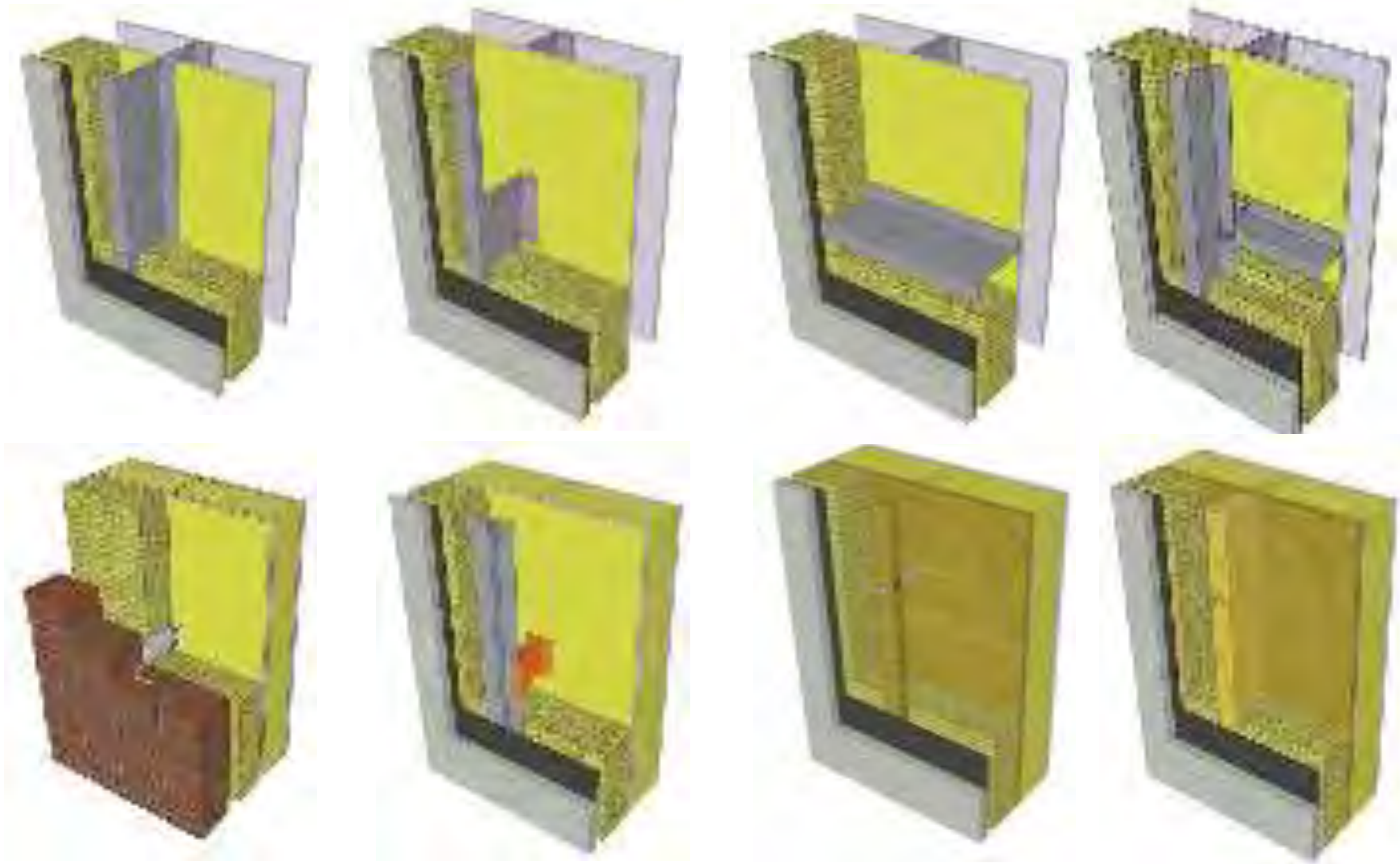
RDH

- 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)



Cladding Attachment through Exterior Insulation

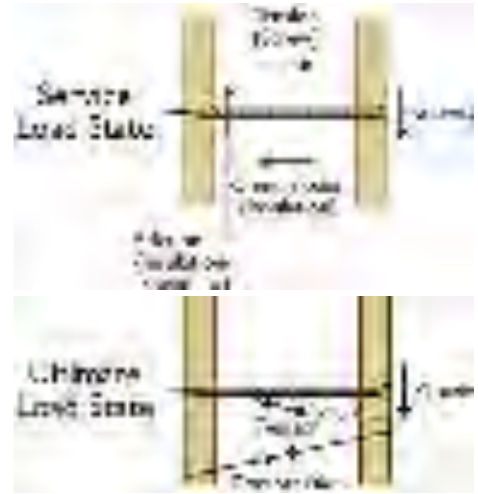
→ Many Possible Strategies – Wide Range of Performance

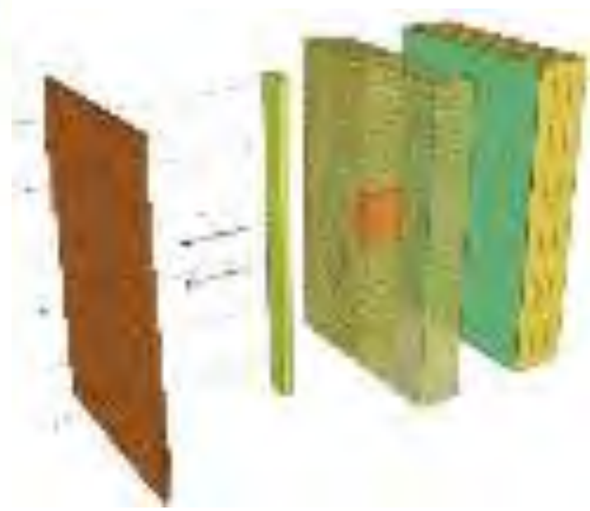


Minimizing Thermal Bridging through Exterior Insulation

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

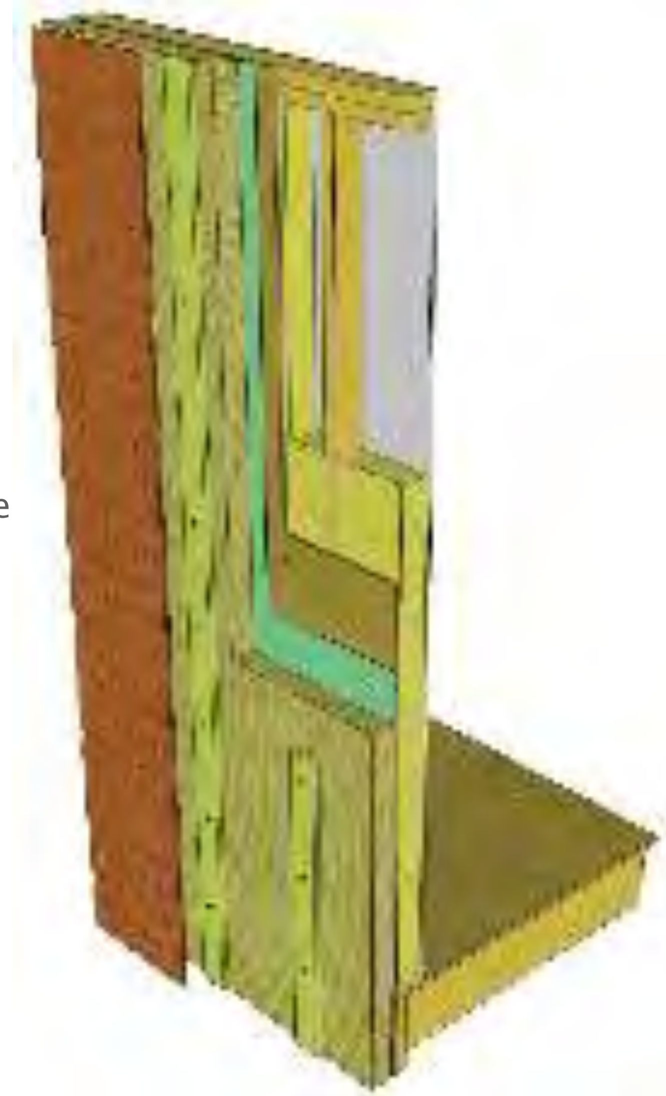




Rigid shear block type connection through insulation, cladding to

Key Considerations - Split Insulation Assemblies

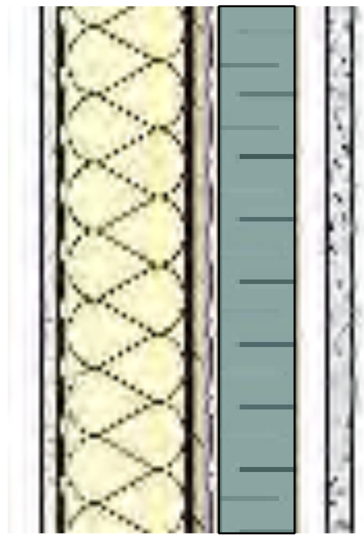
- Key Considerations:
  - Exterior insulation type
  - Cladding attachment
  - Sequencing & detailing
- Heat Control: Exterior and stud space Insulation
- Air Control: House-wrap adhered/sheet/liquid membrane on sheathing, sealants/tapes etc. Often vapor permeable
- Vapor Control: Poly or VB paint at interior, plywood/OSB sheathing
- Water Control: Rainscreen cladding, WRB membrane, surface of insulation



Split Insulation Assemblies – Exterior Insulation

RDH

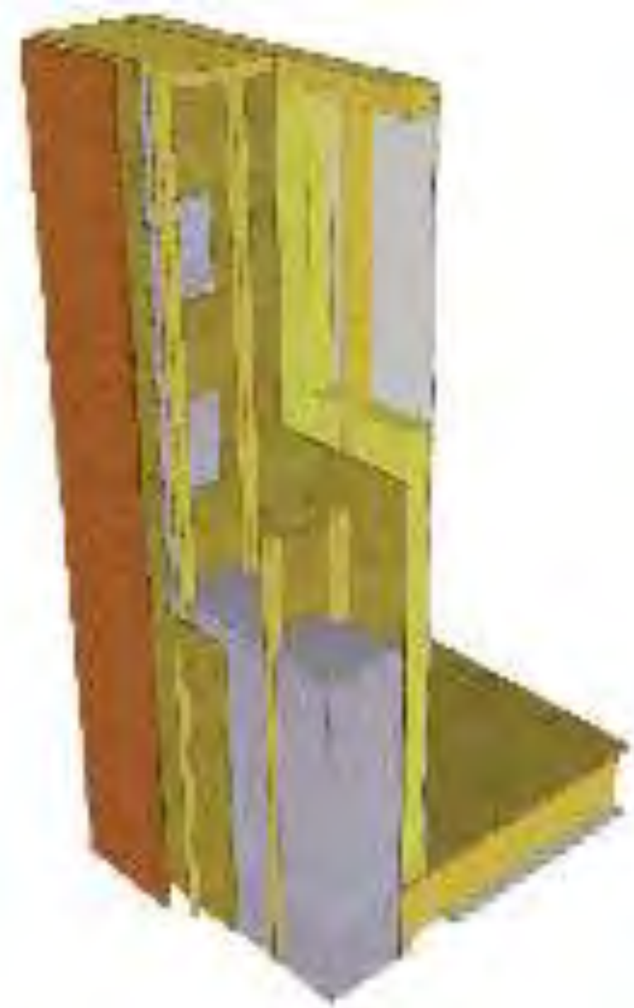
- → Foam insulations (XPS, EPS, Polyiso, ccSPF) are vapor impermeable
  - → Is the vapor barrier on the wrong side?
  - → Does your wall have two vapor barriers?
  - → How much insulation should be put outside of the sheathing? – More the better, but room?
- → Rigid Mineral or Glass Fiber Insulation 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

Split Insulation – Larsen Truss

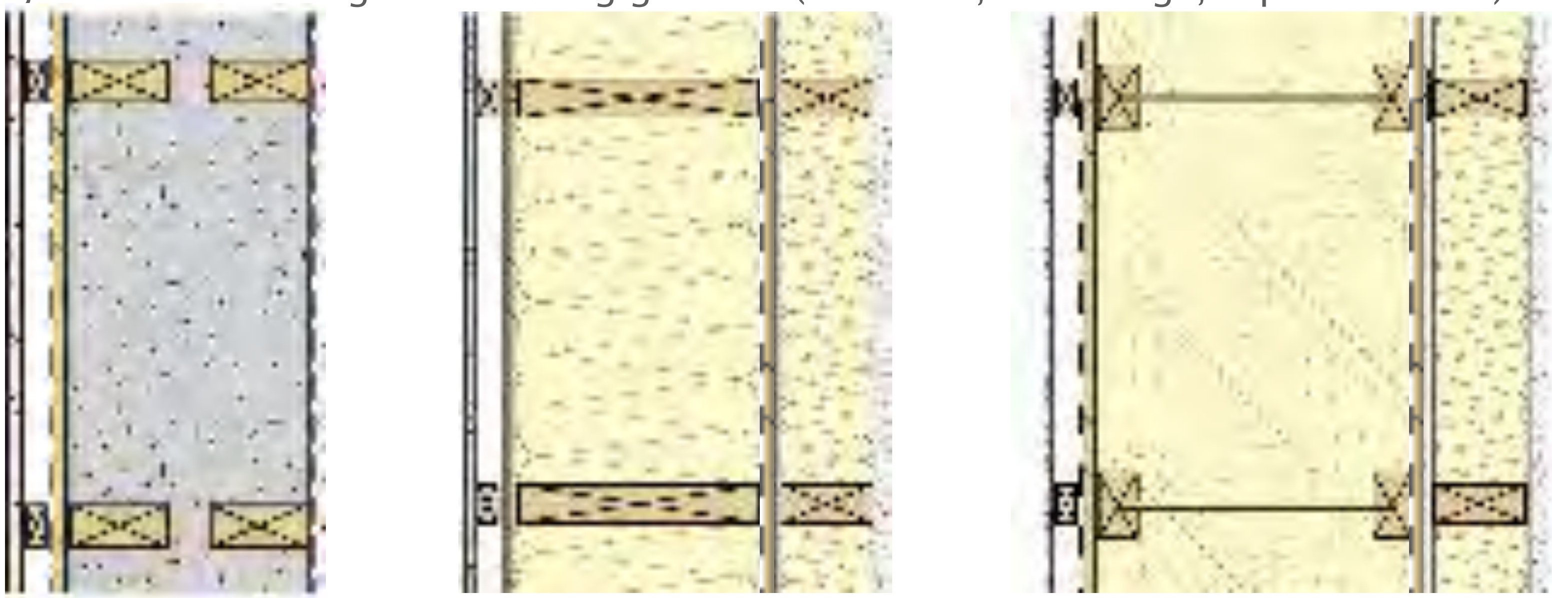
→ Several other alternate strategies to build highly insulated walls including Larsen Trusses and other exterior trussed assemblies filled with low-density fibrous fill or sprayfoam insulation



Double/Deep Stud Insulated

RDH

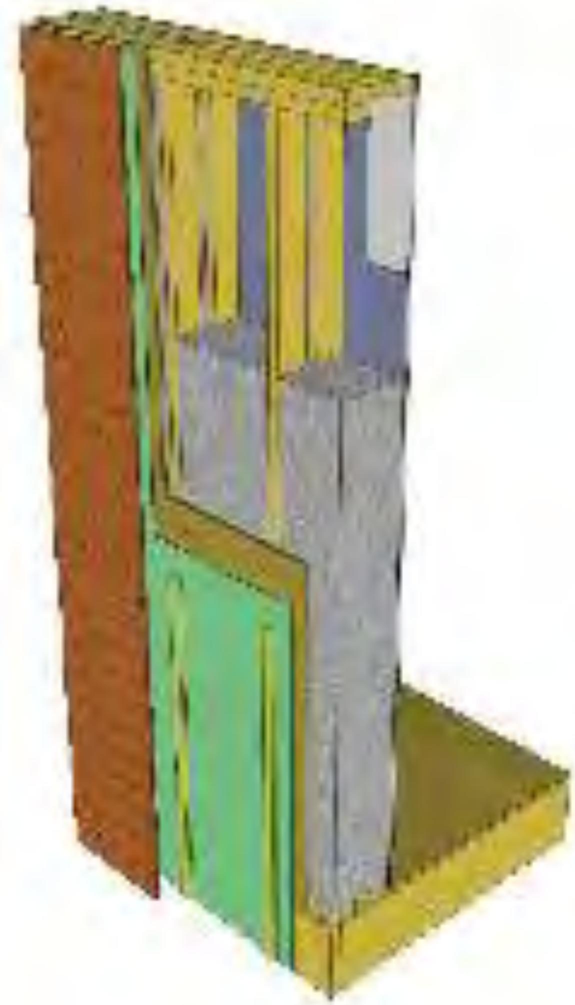
- → Double 2x4/2x6 stud, Single Deep 2x10, 2x10, I-Joist etc…
- → Common wood-frame wall assembly in many passive houses
- → Lends itself well to pre-fabricated wall/roof assemblies
- → Interior service wall – greater control over interior airtightness
- → Higher risk for damage if sheathing gets wet (rainwater, air leakage, vapor diffusion)



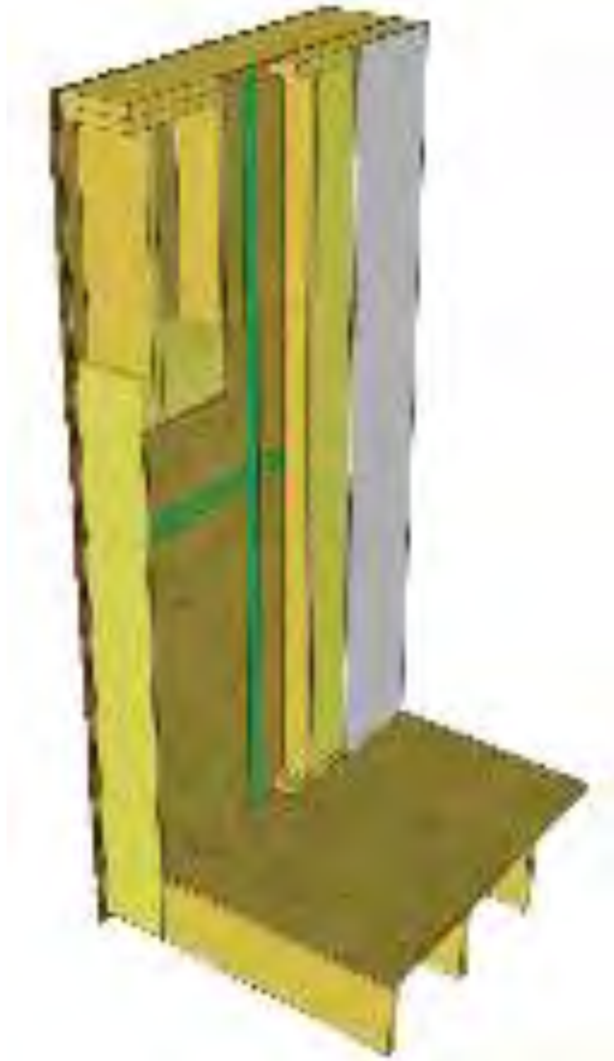
Key Considerations – Double Stud/Deep Stud

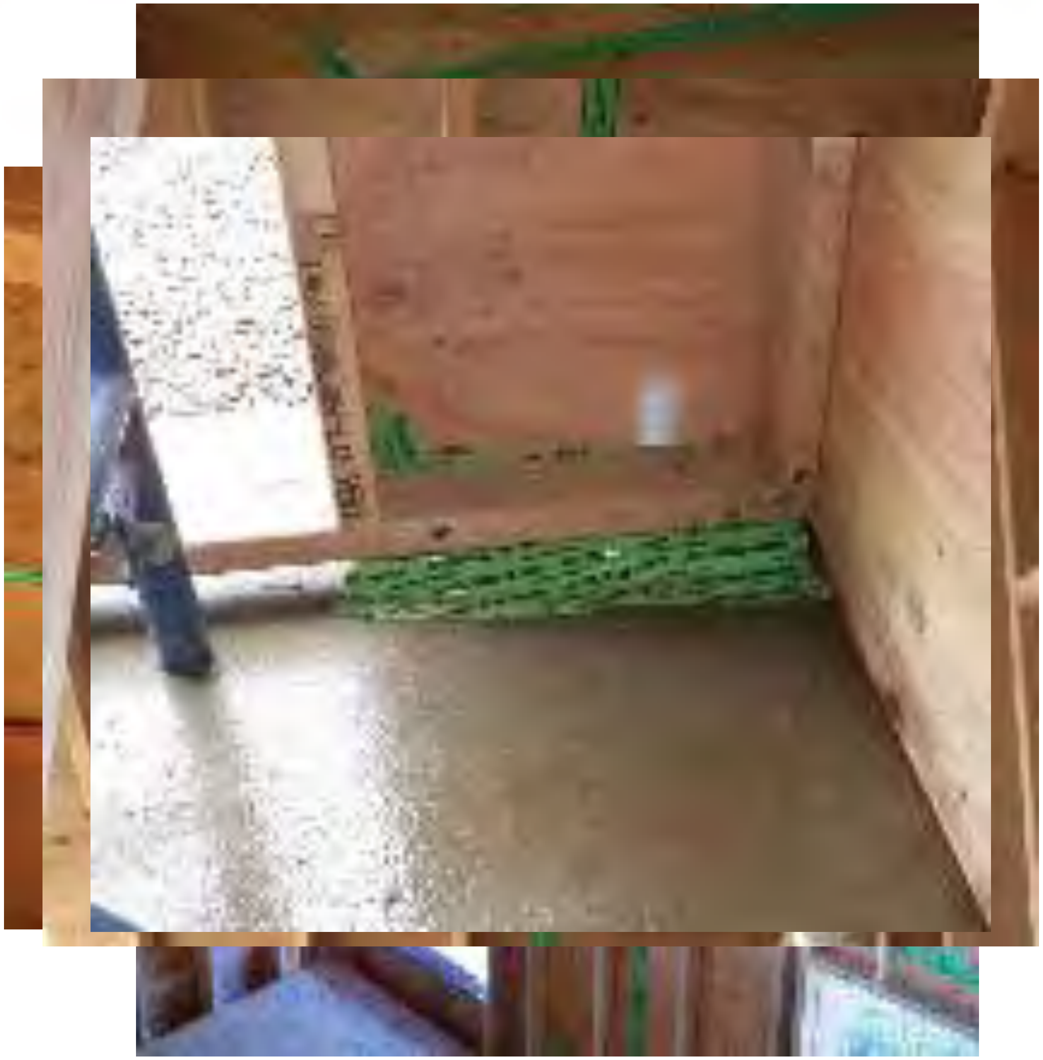
RDH

- 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.

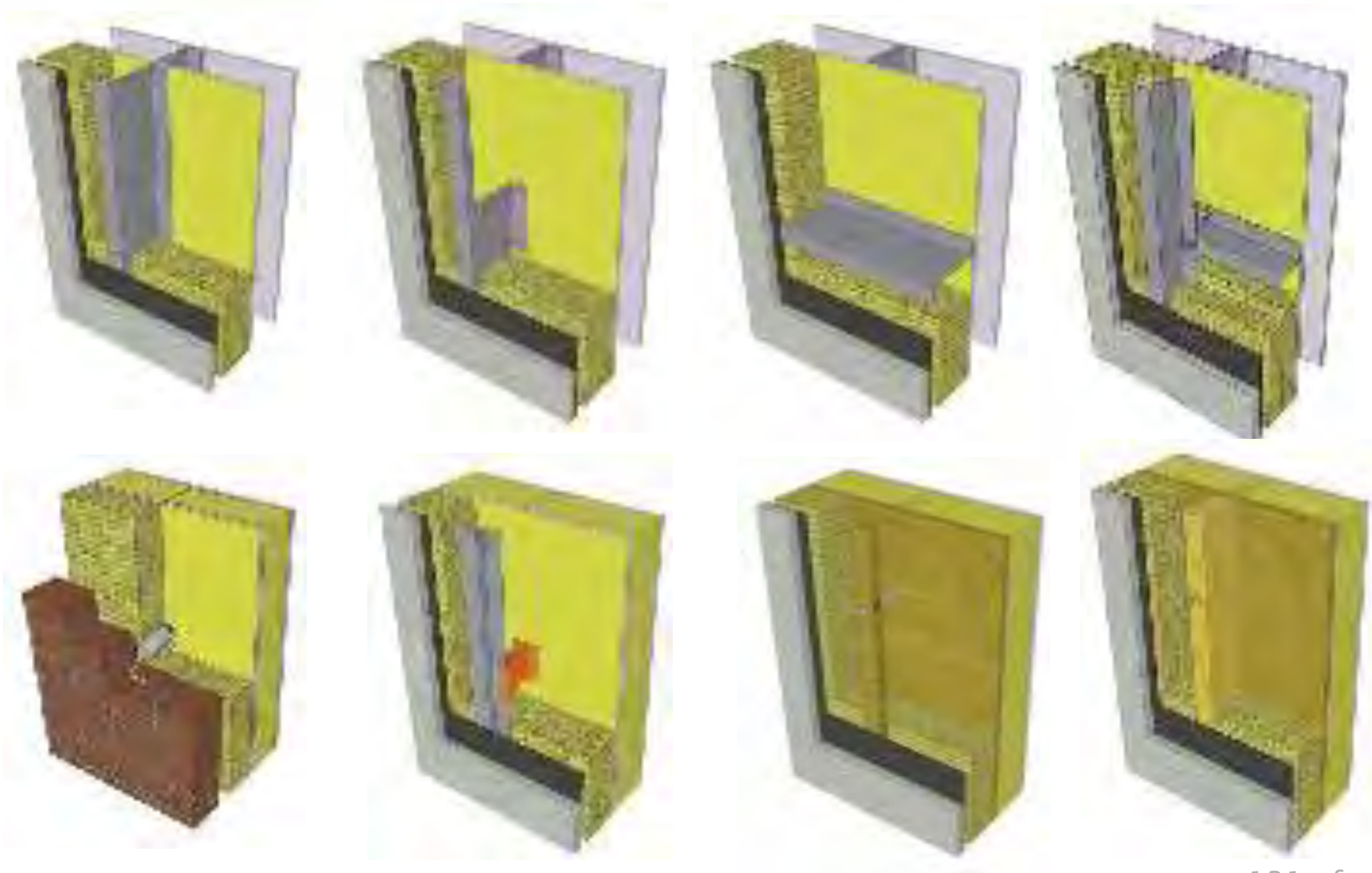


Air Barrier Strategies – Double Stud/Deep Stud Wall





No ASHRAE Tables for These Cladding Attachments



Context – What R-values are Required?

RDH

- → 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)
- → Model National Energy Code for Buildings 1997(MNECB) and National Energy Code for Buildings 2011 (NECB)

Excerpt from 90.1-2007 Table 5.5-5 – City of Vancouver, Effective R-values

RDH

Building Enclosure Component	Climate Zone 5 – Residential Buildings	
	Minimum Assembly R-value $ft^2 \cdot {}^\circ F \cdot h/Btu$	**Minimum Insulation R-value $ft^2 \cdot {}^\circ F \cdot h/Btu$**
Roof – Insulation Above Deck	R-20.8	R-20 c.i.
Roof – Attic	R-37.0	R-38
Above Grade Wall – Wood-Frame	R-19.6	R-13 + 7.5 c.i.
Above Grade Wall – Steel Frame	R-15.6	R-13 + 7.5 c.i.
Above Grade Wall – Mass	R-12.5	R-13.3 c.i.
Below Grade Wall – Concrete	R-8.4	R-7.5 c.i.
Windows	**Maximum Window U-value** $Btu/h \cdot ft^2 \cdot {}^\circ F$	
› Non Metal Frame (Vinyl, Fibreglass and Wood)	U-0.35	
› Metal Framed Windows (Aluminum)	U-0.55	
› Metal frames (Curtainwall & Storefront)	U-0.45	

Context: R-Values

- Down Jacket

R 3-5

- Acoustic Ceiling Tile

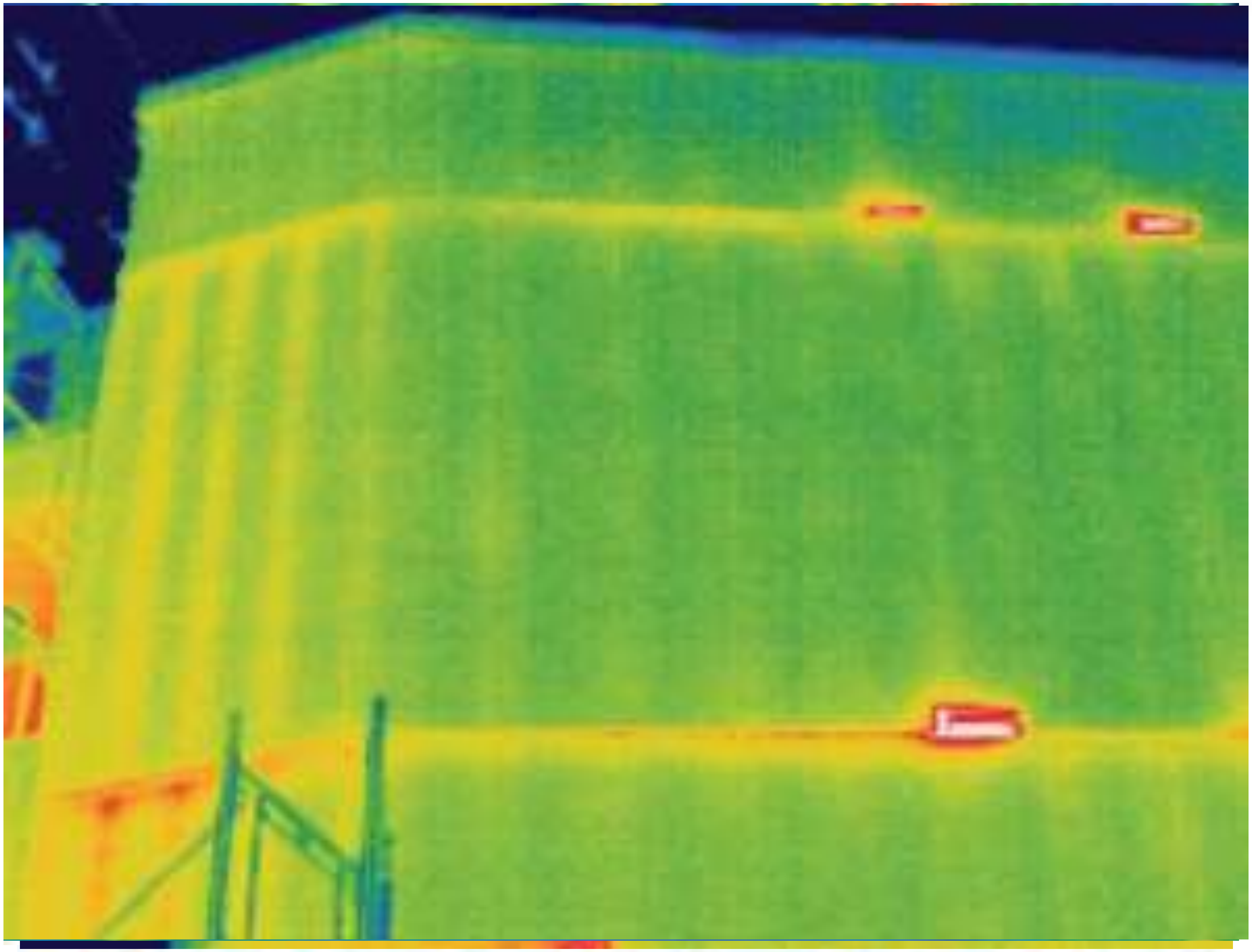
R-2

- Fiberglass Batt Insulation

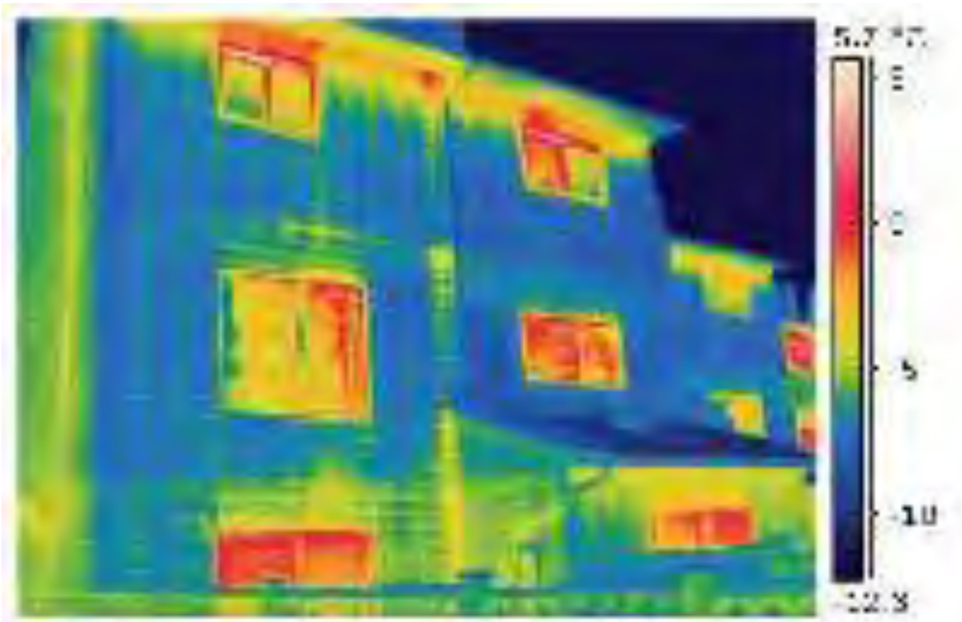
~R-12, 3 ½”

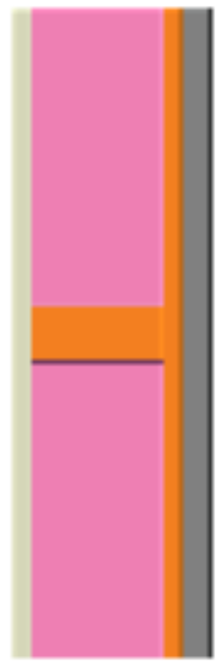
~R-20, 5 ½”

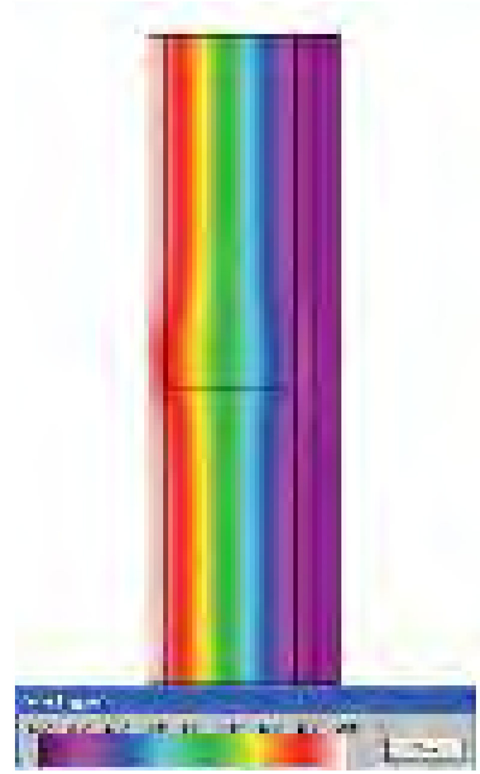
Seeing Heat Loss – Infrared Thermography



Yellow/red/white = hot = high heat flow/high U-value– Blue = Cold = low heat flow/low U-value


5.7 °C
0
5
-10
-12.3





Current Thermal Performance – Effective R-values

Wall Assembly / Insulation Rated R-value	Effective Wall R-value *	
	Studs at 16", 25% F.F.	Studs at 24", 22% F.F.
2x4 w/ R-12 batts/SPF	10.7	-
2x4 w/ R-14 batts	11.5	-
2x4 w/ sprayfoam (R-5/in)	12.6	-
2x6 w/ R-19 batts	15.5	16.1
2x6 w/ R-22 batts	**16.6**	**17.4**
2x6 w/ sprayfoam (R-5/in)	18.3	19.3
2x6 w/ sprayfoam (R-6/in)	18.6	19.8

* 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)

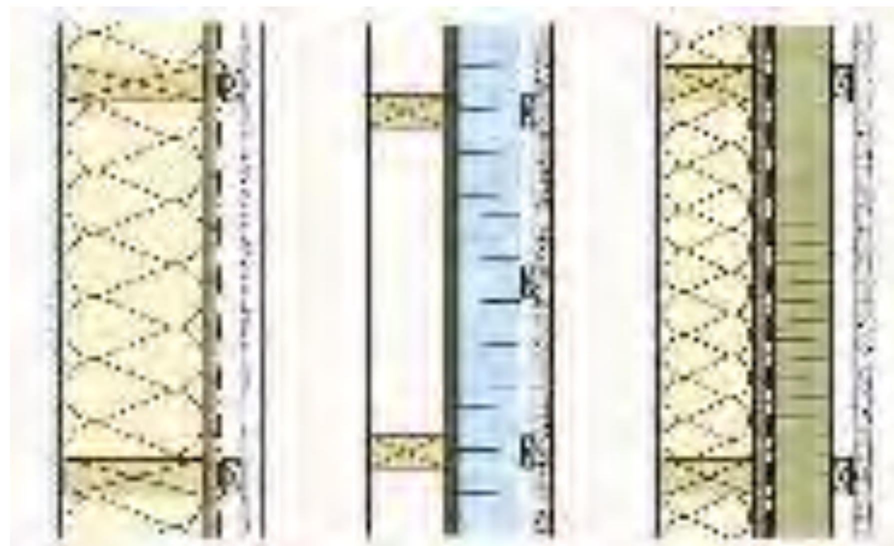
RDH

Wood Framing Depth	Nominal Insulation R-value (RSI)	Effective R-value for Base Wall Assembly	Effective R-value of Base Wall Plus Continuous Insulation (Includes bringing effect of strapping/fasteners/ clips)				
			R-5 c.i.	R-8 c.i.	R-10 c.i.	R-12 c.i.	R-15 c.i.
	R-value (RSI) 						
31/2" (89 mm)	None	R-3.4 (0.6)	R-8.6 (1.5)	R-11.6 (2.0)	R-13.7 (2.4)	R-15.6 (2.8)	R-18.9 (3.3)
	R-11 (1.9)	R-10.4 (1.8)	R-15.9 (2.8)	R-18.9 (3.3)	R-20.8 (3.7)	R-22.7 (4.0)	R-26.3 (4.6)
	R-13 (2.3)	R-11.2 (2.0)	R-16.9 (3.0)	R-20.0 (3.5)	R-22.2 (3.9)	R-24.4 (4.3)	R-27.0 (4.8)
	R-15 (2.6)	R-12.0 (2.1)	R-17.9 (3.1)	R-21.3 (3.7)	R-23.3 (4.1)	R-25.6 (4.5)	R-28.6 (5.0)
51/2" (140 mm)	R-19 (3.3)	R-14.9 (2.6)	R-20.8 (3.7)	R-23.8 (4.2)	R-26.3 (4.6)	R-27.8 (4.9)	R-31.3 (5.5)
	R-21 (3.7)	R-15.9 (2.8)	R-22.2 (3.9)	R-25.6 (4.5)	R-27.8 (4.9)	R-29.4 (5.2)	R-33.3 (5.9)

RDH

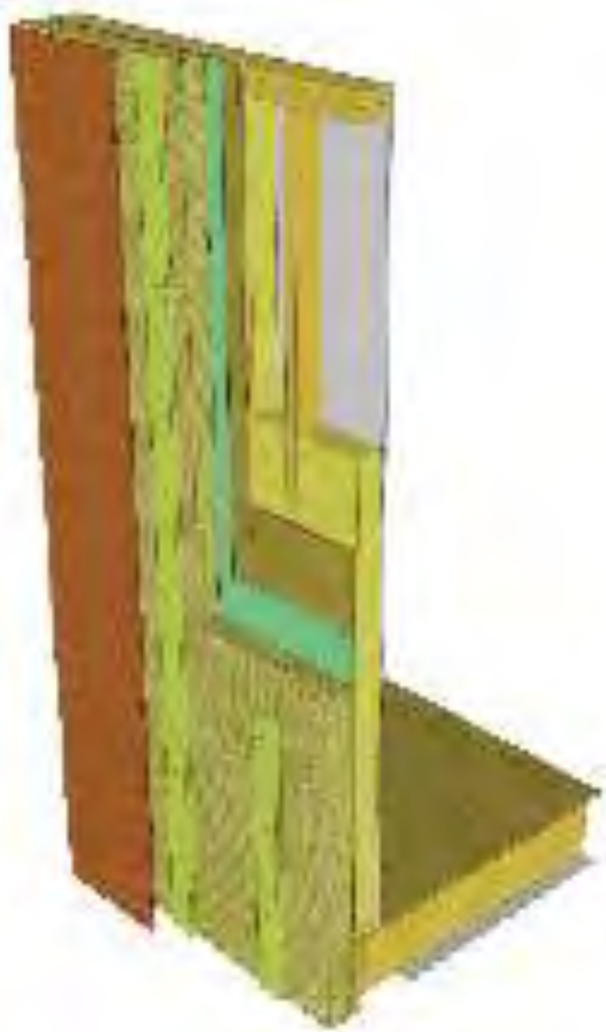
→ Framing factors >>25%, cannot use ASHRAE tables

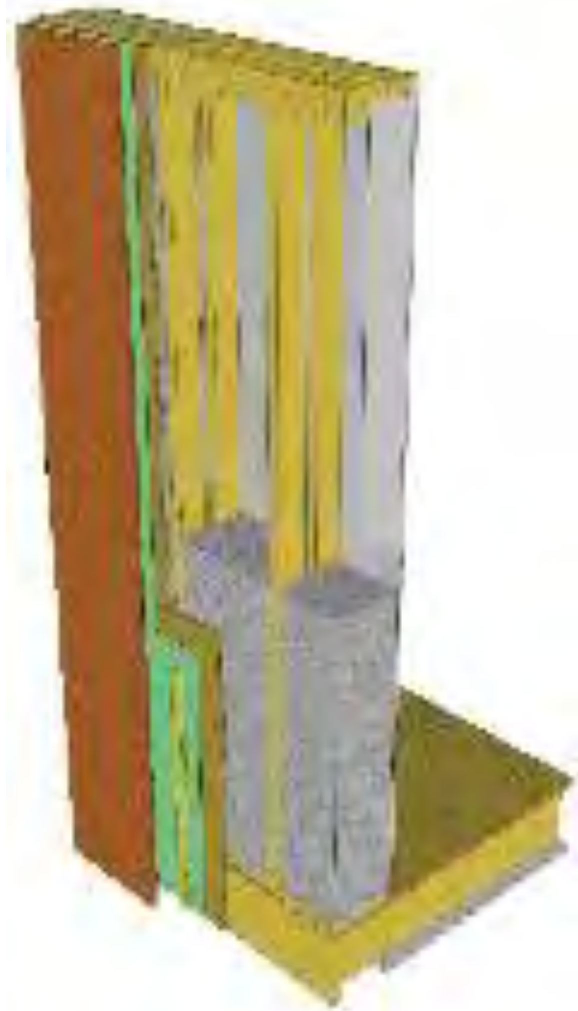
- Tables within ASHRAE 90.1 provide some exterior/ split insulated R-values
- Wood-frame Best Practice Guide provides further guidance
- Thermal simulation needed
- Energy codes do not provide guidance on durability and moisture control!



Interior Insulated | Exterior Insulated | Split Insulated

Higher R-value Wood Frame Walls – Best Practices

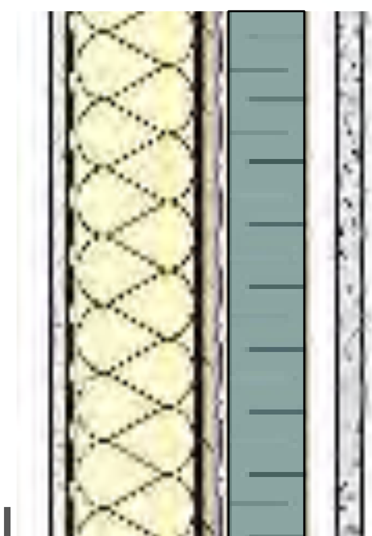




Split Insulation Assemblies

RDH

- → 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

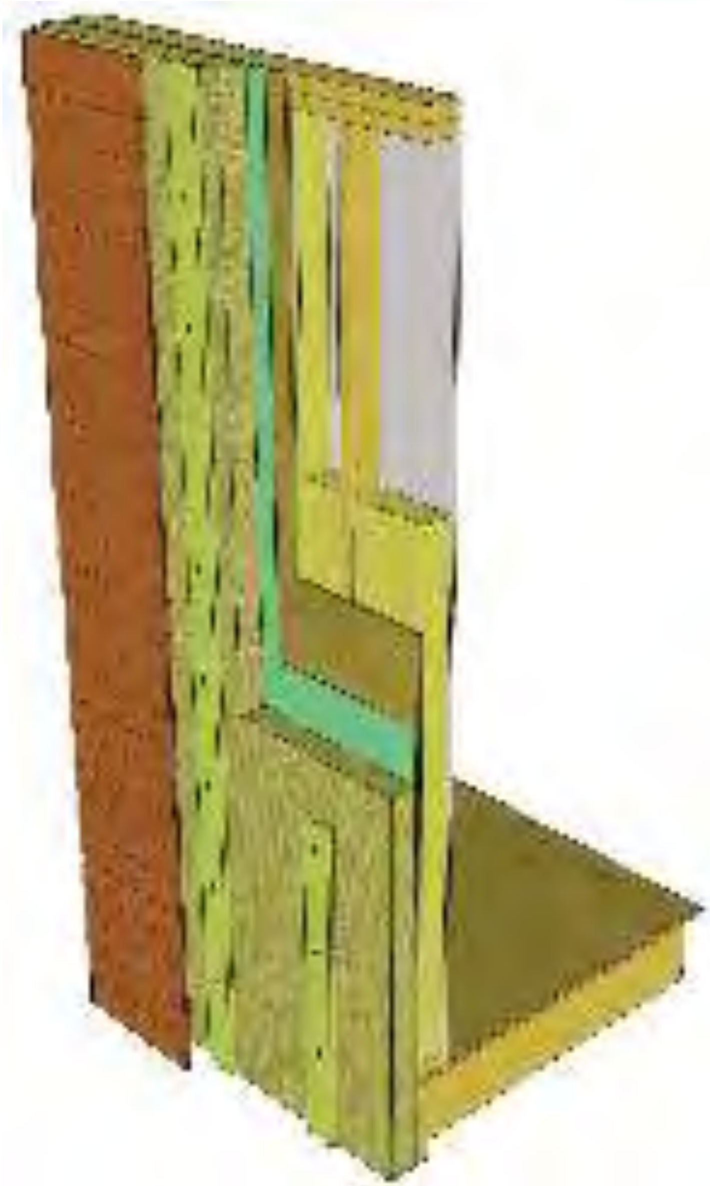


- → Foam sheathing is at a **higher risk of moisture entrapment** than baseline 2x6 wall or mineral fiber (rain, air, initially wet)
- → Vapour permeance properties of WRB and air-barrier

Split Insulation Walls

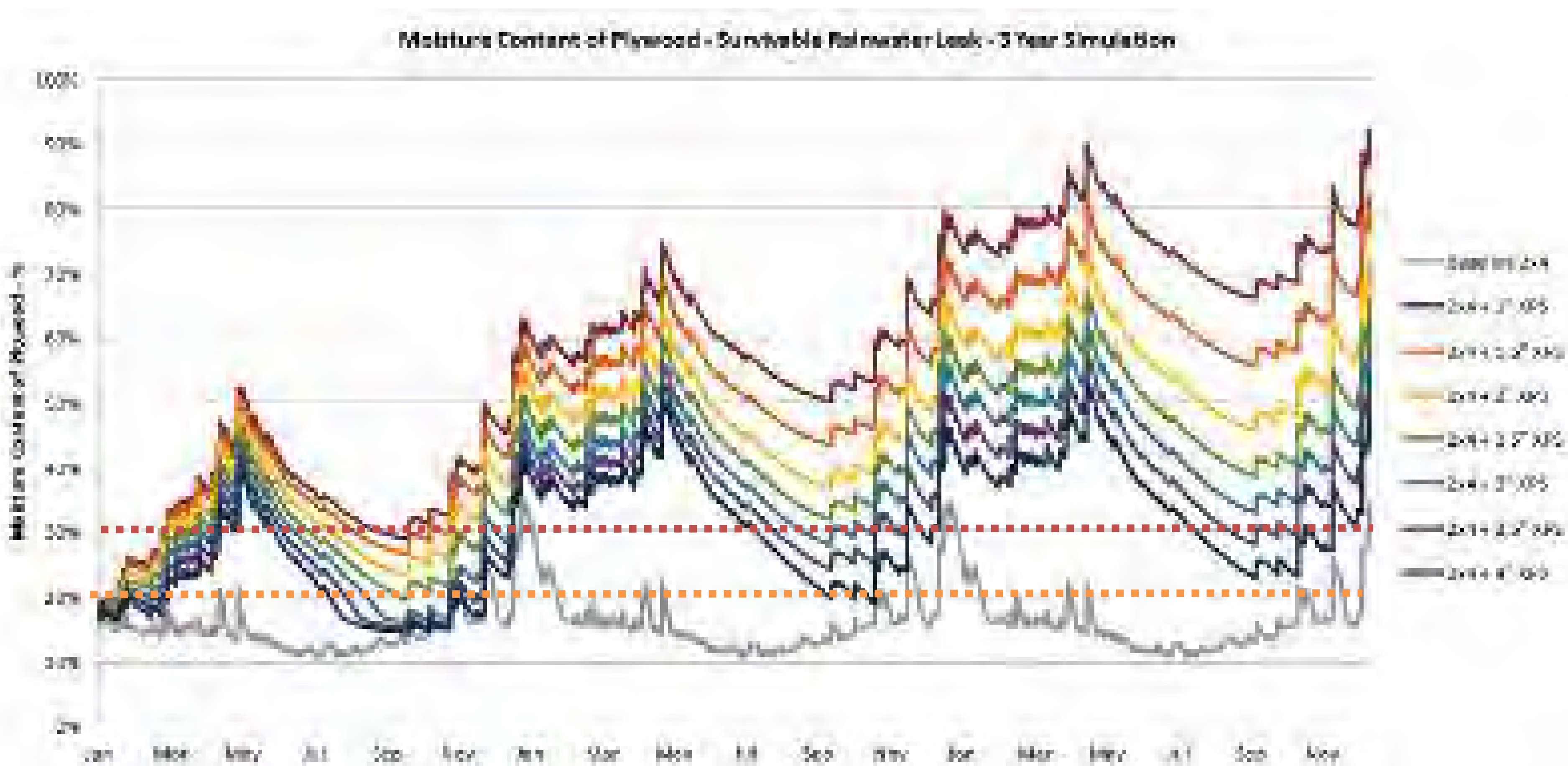
RDH

- 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



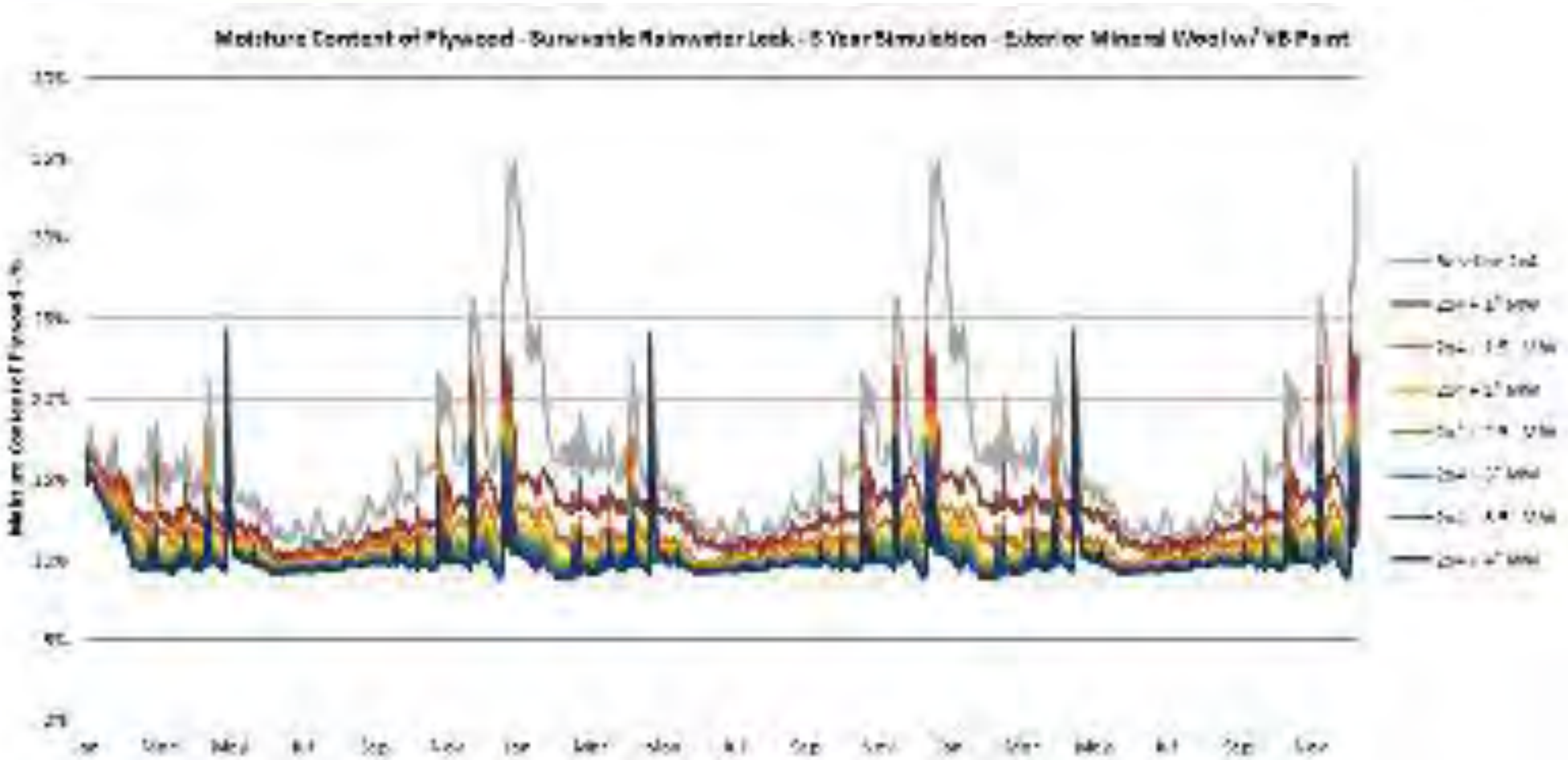
XPS/Foam as Exterior Insulation

RDH



Rigid Mineral/Glass Fiber as Exterior Insulation

RDH



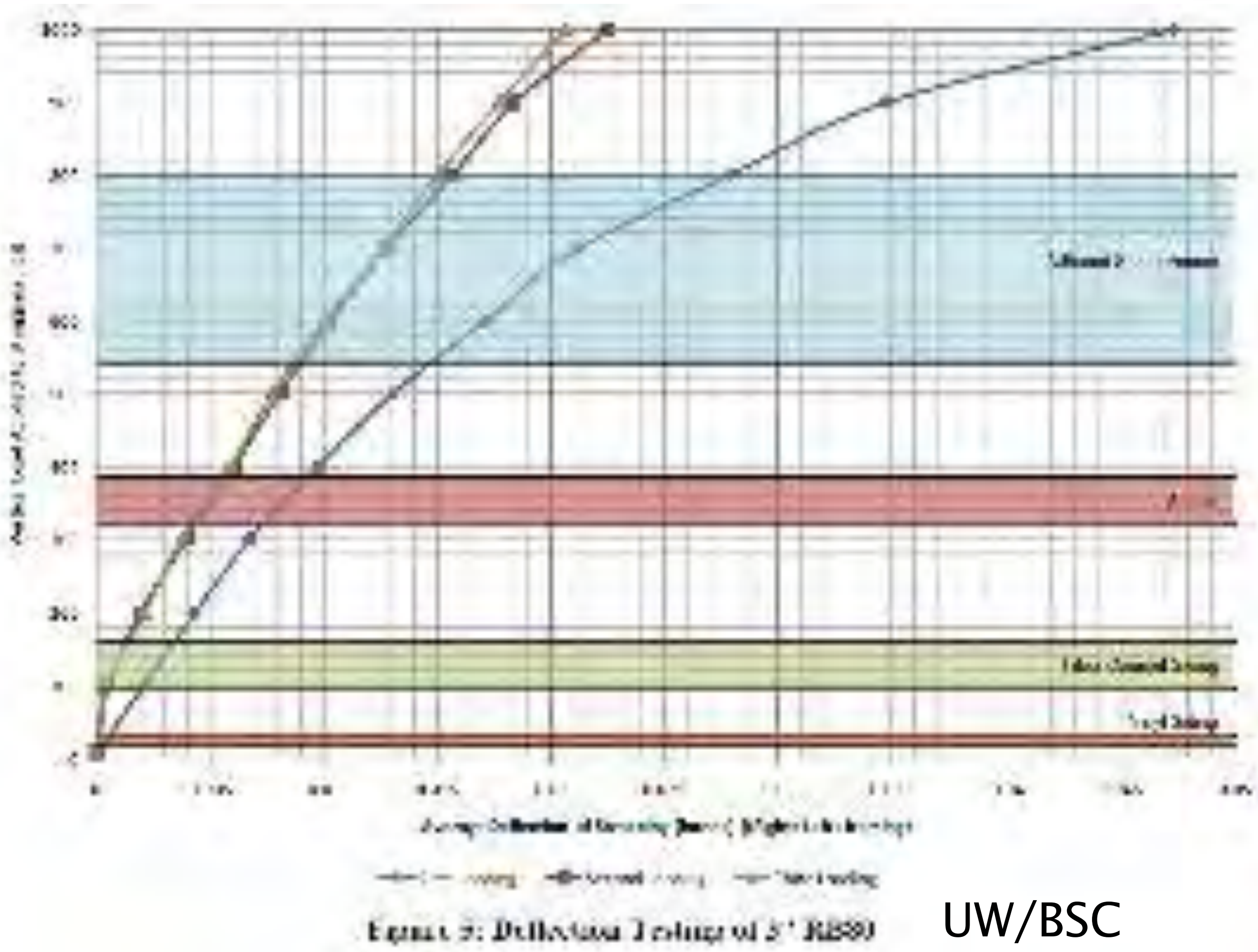
Attaching Cladding Through Exterior Insulation

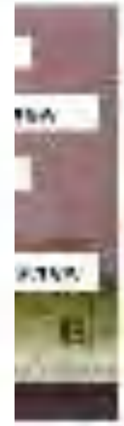
RDH

- 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

RDH

→ Medium Density Mineral Fiber (i.e. Roxul Rockboard





UW/BSC

Split Insulation

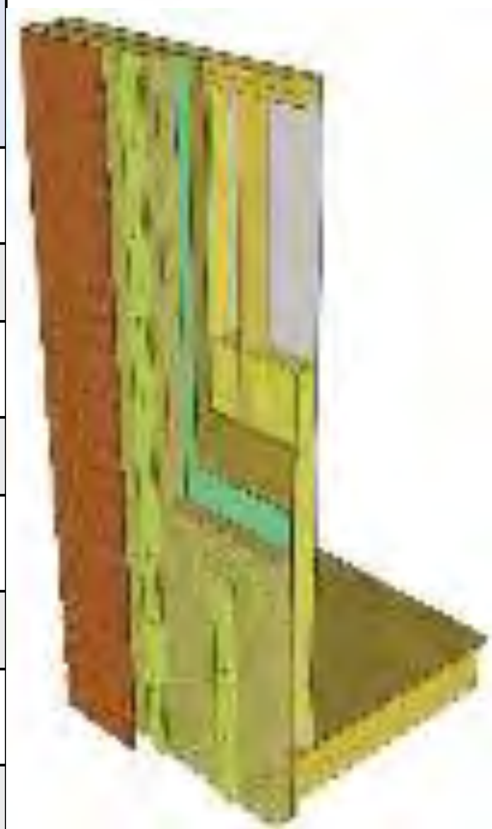
RDH

Split Insulation

Split Insulation R-values above R-20: Screws through Insulation

Exterior Insulation R-value added to exterior of sheathing	**Effective Wall R-value Accounting for Thermal Bridging & Fasteners**	
	2x4 stud wall @ 16” o.c. with R-14 batts	2x6 stud wall @ 16” o.c. with R-22 batts
1” Mineral Wool (R-4)	-	21.9
1” XPS (R-5)	-	21.0*
1.5” Mineral Wool (R-6)	**-**	**22.9**
1.5” XPS (R-7.5)	**-**	**24.3***
2” Mineral Wool (R-8)	19.6	-
2” XPS (R-10)	21.4*	
2.5” Mineral Wool (R-10)	21.5	
3” Mineral Wool (R-12)	**23.2**	
2.5” XPS (R-12.5)	**23.7***	

* Potential Elevated Moisture risk



Split Insulation R-values above R-20: Brick Ties

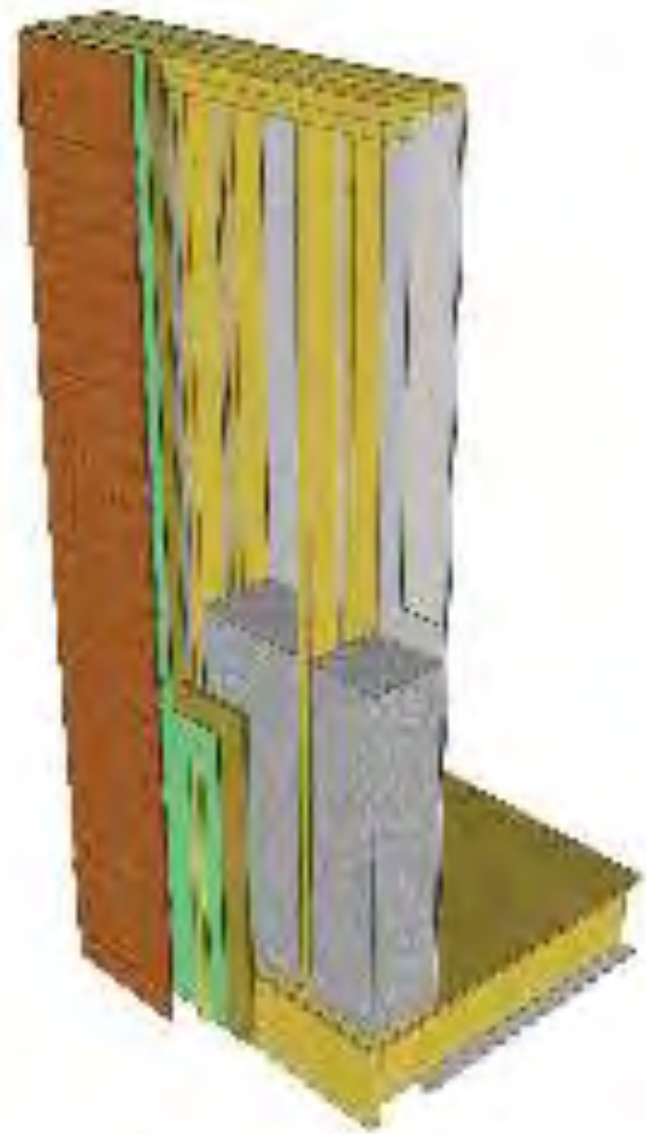
Exterior Insulation R-value added to exterior of sheathing	Effective Wall R-value Accounting for Thermal Bridging & Fasteners	
	2x4 stud wall @ 16" o.c. with R-14 batts	2x6 stud wall @ 16" o.c. with R-22 batts
1" Mineral Wool (R-4.2)	-	21.9
1" XPS (R-5)	**-**	**22.6***
1.5" Mineral Wool (R-6.3)	**-**	**23.7**
1.5" XPS(R-7.5)	-	-
2" Mineral Wool (R-8.4)	20.2	-
2" XPS (R-10)	21.4*	
2.5" Mineral Wool (R-10.5)	21.9	
3" Mineral Wool (R-12.6)	**23.4**	
2.5" XPS (R-12.5)	**23.3***	

* Potential Elevated Moisture risk

Double Stud Wall, 2x8, 2x10 Wall Assemblies

RDH

- Key Considerations:
  - Insulation Type
  - Air-sealing
  - Rainscreen detailing
- Heat Control: Double stud cavity fill in
- Air Control: breathable House-wrap/m sheathing, poly on interior, tapes, seala air-barriers (in and out) recommended
- Vapour Control: Poly at interior
- Water Control: Rainscreen cladding, W membrane, flashings etc.



Double Stud Walls

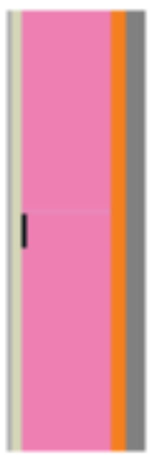
Double Stud and 2x8/2x10 Framing R-values

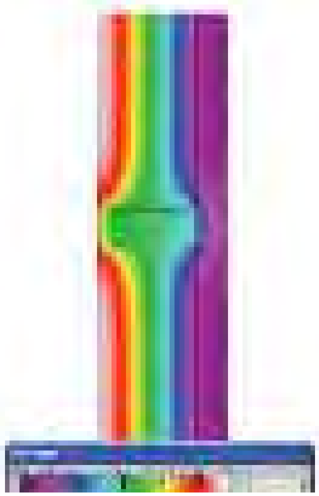
RDH

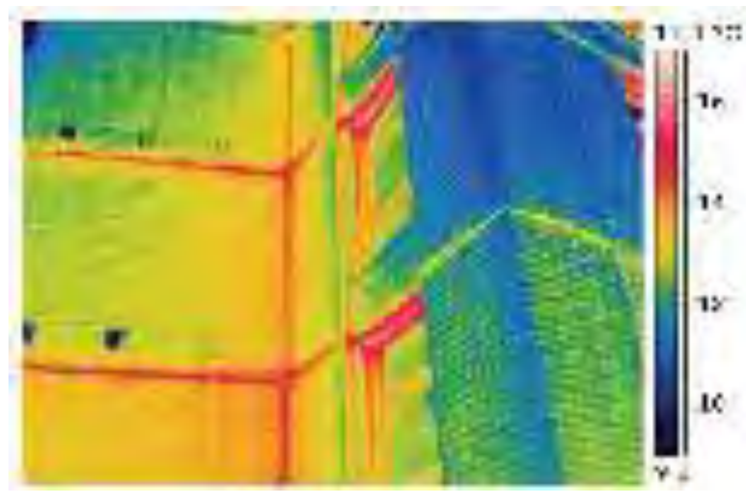
Wall Assembly / Insulation Rated R-value	Effective Wall R-value
2x8 w/ R-26 fibrous insulation (R 3.4/inch)	21.1
2x8 w/ R-30 fibrous insulation (R 4/inch)	**22.8**
2x8 w/ R-38 sprayfoam insulation (R 5/inch)	**25.4**
2x10 w/ R-31 fibrous insulation (R 3.4/inch)	**25.4**
2x10 w/ R-37 fibrous insulation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

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

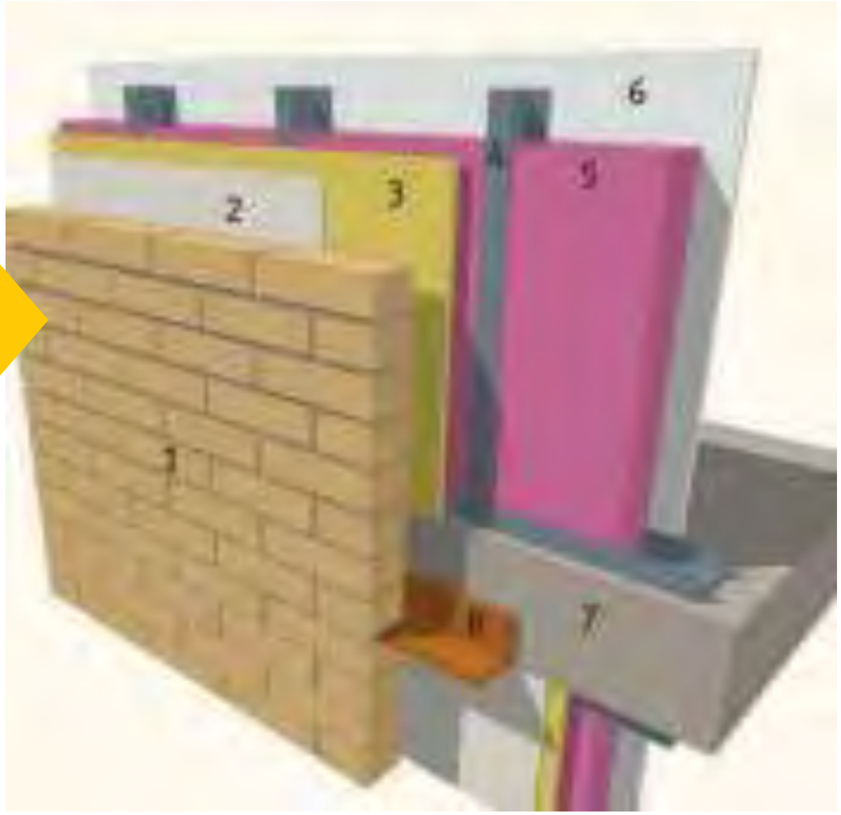
Steel Framed Walls







R-12 or R-14 batt insulation



R 3 – 4 effective

- Steel stud wall assembly with concrete slab

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

→ Assumes steel stud spacing at 16" o.c. and accounts for top and sill track

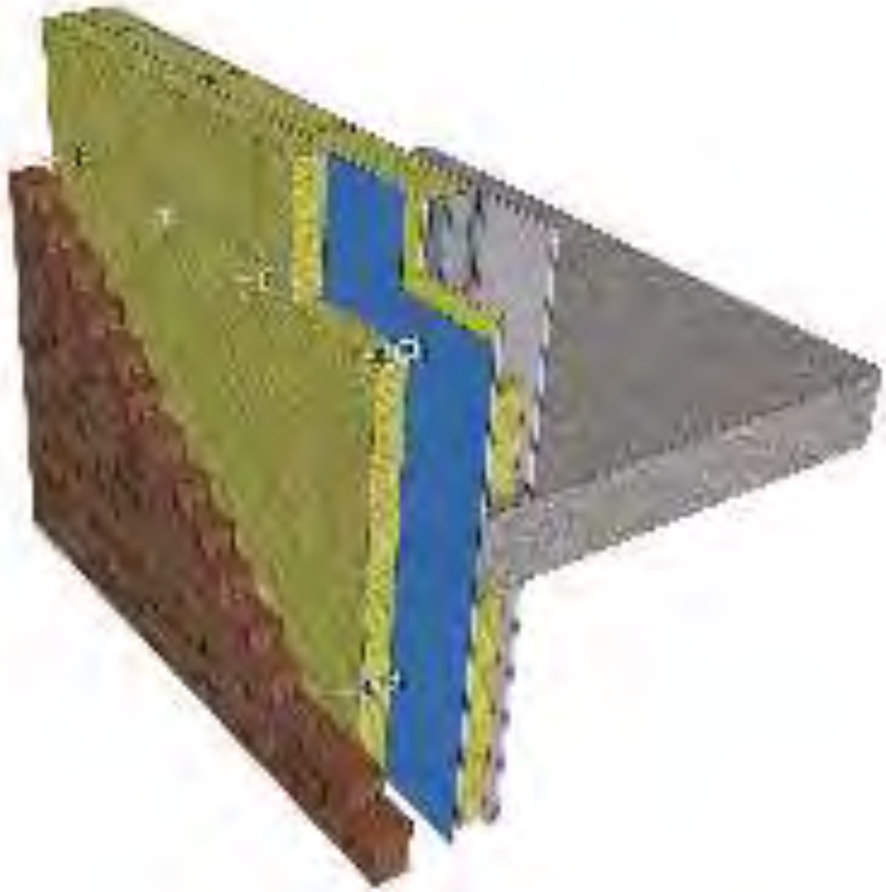
Wood Framing Depth	Nominal Insulation R-value	Effective R-value for Base Wall Assembly	Effective R-value of Base Wall Plus Continuous Insulation (Includes bringing effect of fasteners/ clips)		
			R-5 c.i.	R-10 c.i.	R-15 c.i.
	R-value		R-value		
3 ½"	None	**R-2.8**	R-7.8	R-12.8	R-17.9
	R-11	**R-7.6**	R-12.5	R-17.5	R-22.7
	R-13	**R-8.1**	R-13.0	R-18.2	R-23.3
	R-15	**R-8.5**	R-13.5	R-18.5	R-23.3
5 ½"	R-19	**R-9.2**	R-14.1	R-19.2	R-24.4
	R-21	**R-9.4**	R-14.5	R-19.6	R-24.4

Problem Spots: Structural Steel Framing

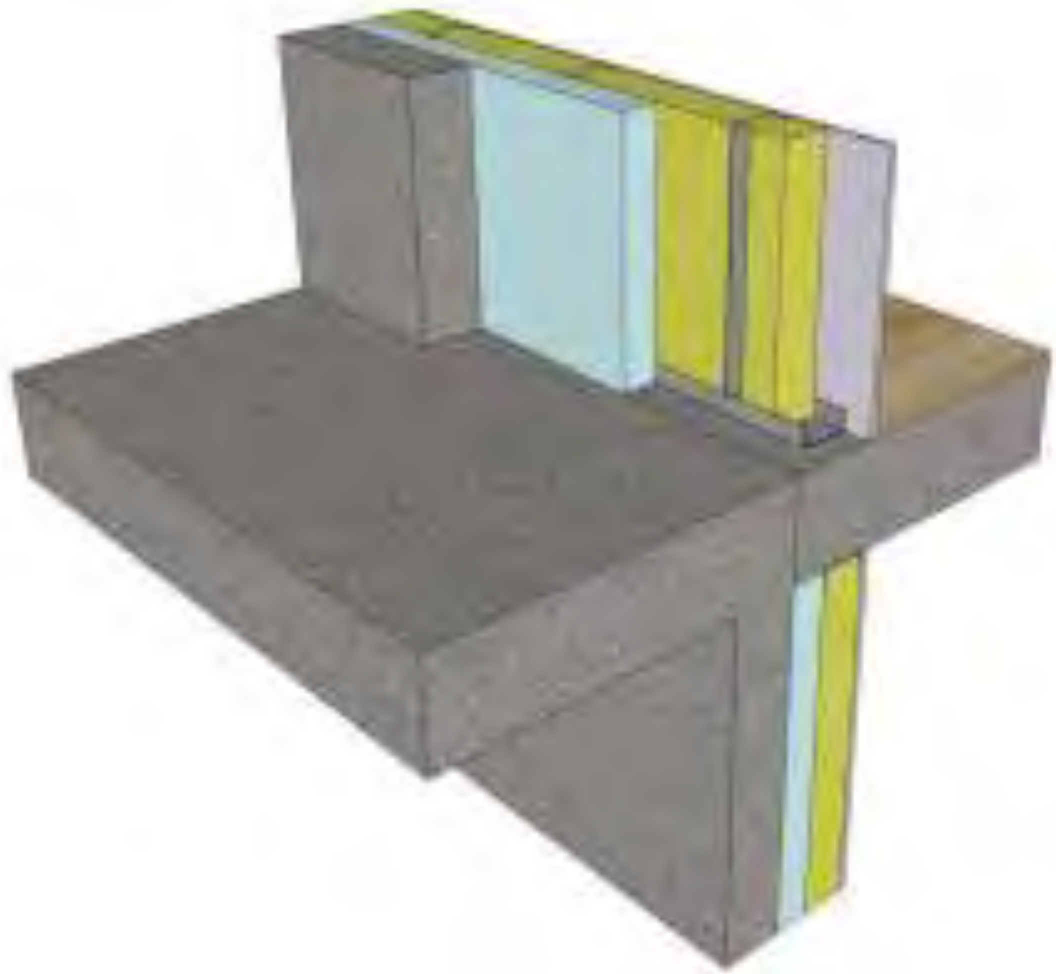
Continuous Insulation – c.i.

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.

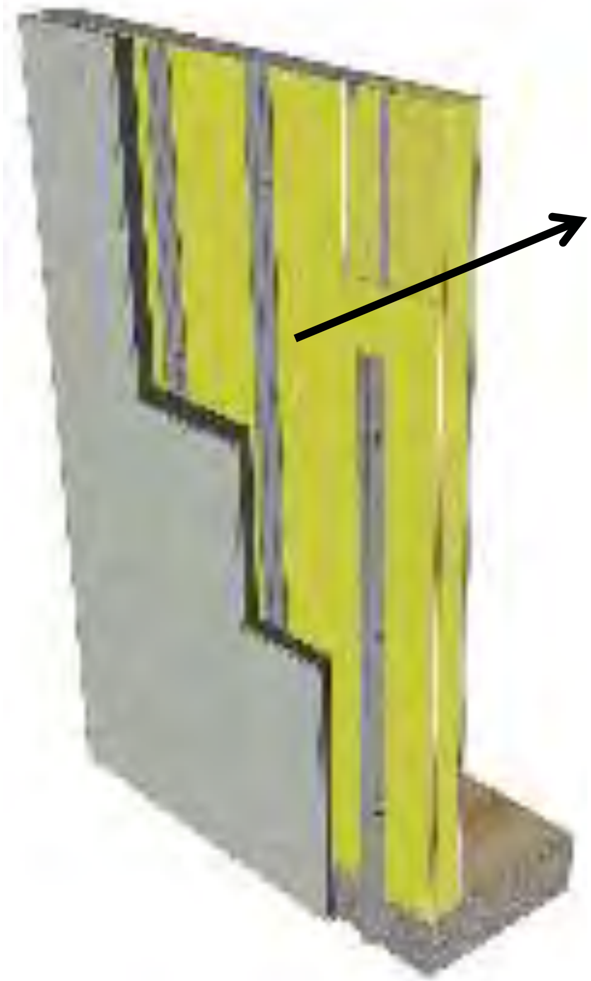
Continuous Insulation Examples



Non-Continuous Insulation – Examples



Steel Stud Wall Assembly Effective R-values

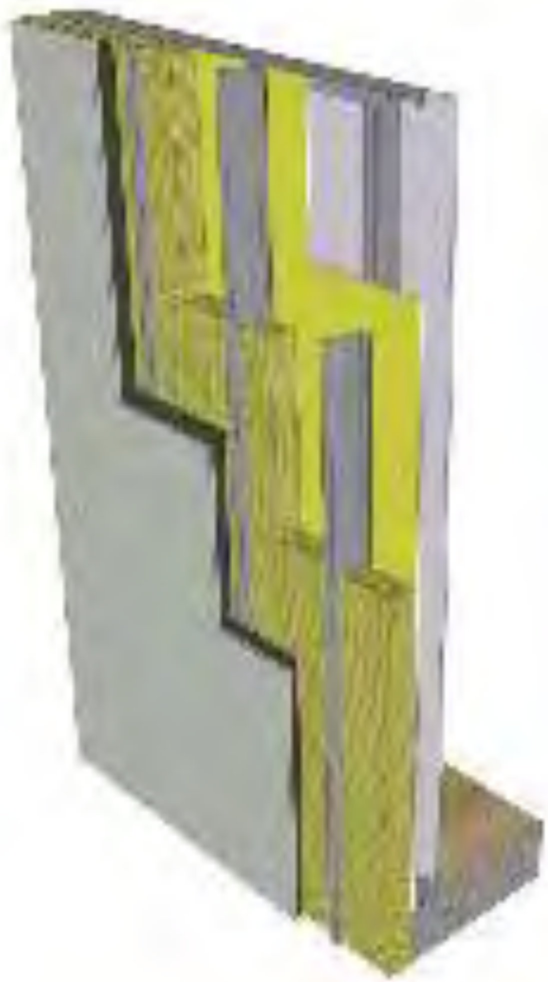


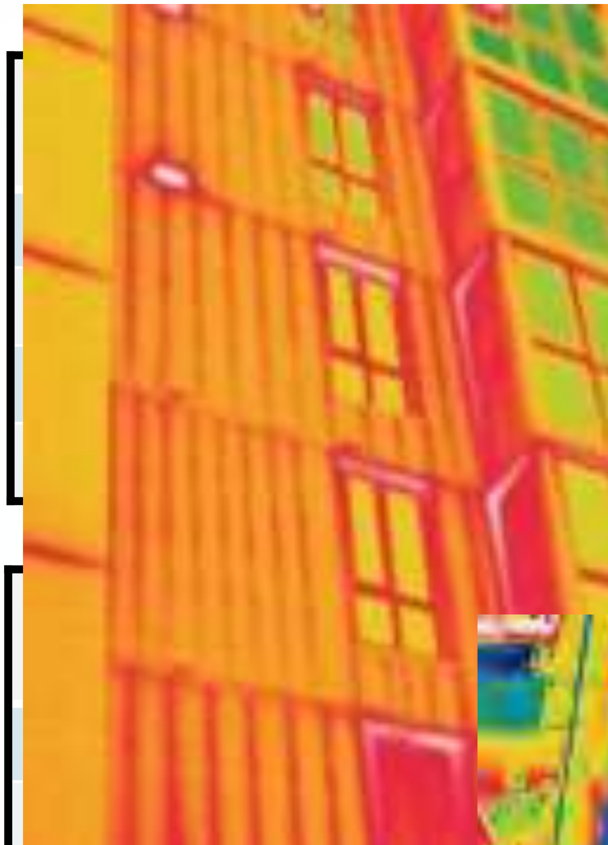
Middle of Wall (away from slab edge): *Could use ASHRAE 90.1 Tables*	
3 5/8" Steel Studs , Empty Cavity	R-3.2
3 5/8" Steel Studs with R-12 Batts	R-7.9
6" Steel Studs with R-20 Batts	R-9.6

Overall Effective – Including Slab Edges *3D Thermal Modeling*	
3 5/8" Steel Studs , Empty Cavity	R-2.9
3 5/8" Steel Studs with R-12 Batts	R-5.5
6" Steel Studs with R-20 Batts	R-6.4

Exterior Vertical Girt Assemblies

RDH



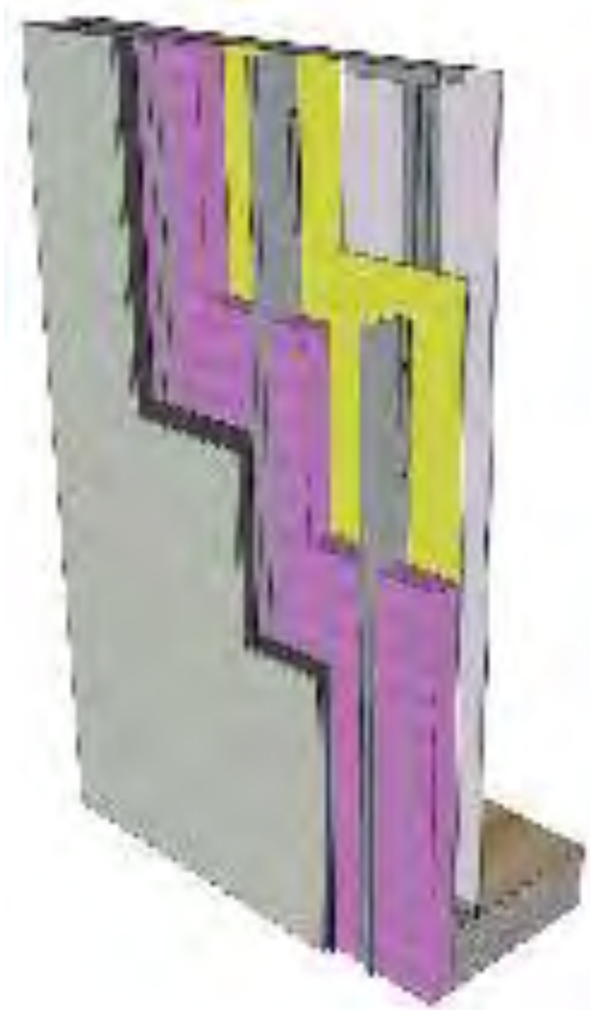


ng Slab Edges *s , Empty Cavity*	
	R-5.9
	R-6.7
	R-7.3
	R-7.9

ng Slab Edges	
4” Mineral Wool (R-	
5” Mineral Wool (R-	

Exterior insulation ar
properties affect safe insulation ratios

Exterior Vertical Girt Assemblies – Sprayfoam?

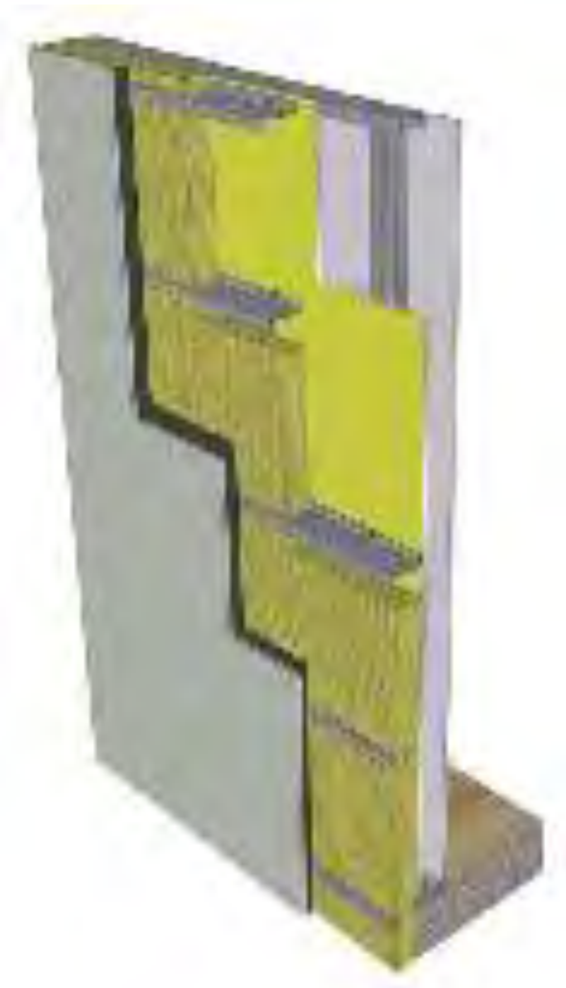


Overall Effective – Including Slab Edges ***Backup: 3 5/8" Steel Studs , Empty Cavity***	
2" Mineral Wool (R-8.4)	**R-5.9**
3" Mineral Wool (R-12.6)	**R-6.7**
4" Mineral Wool (R-16.8)	**R-7.3**
5" Mineral Wool (R-21.0)	**R-7.9**

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**

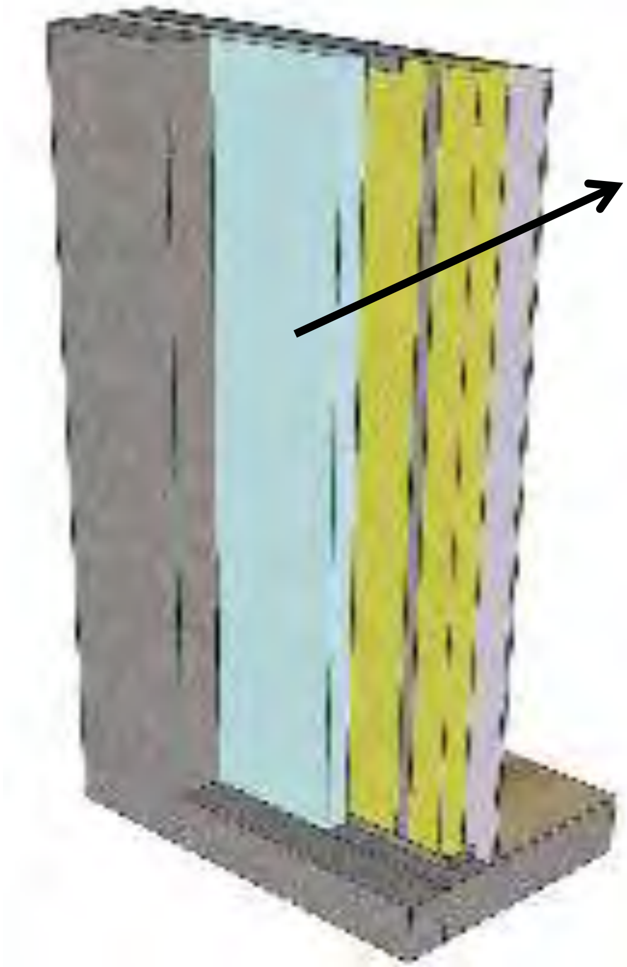
Sprayfoam and Steel Z-Girts – Other Considerations

RDH



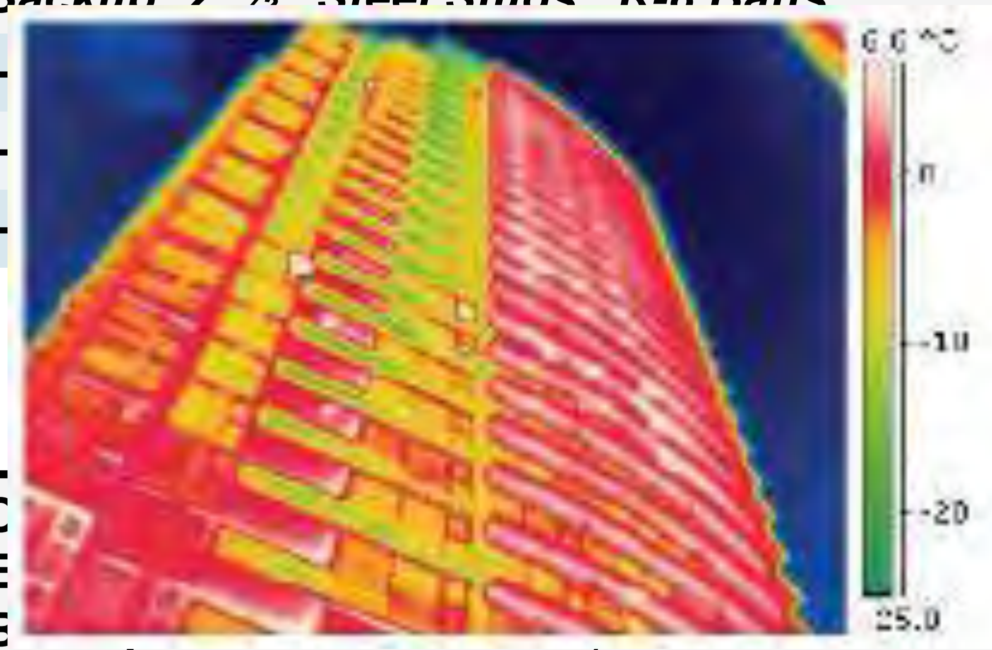
Overall Effective – Including Slab Edges *Backup: 3 5/8" Steel Studs , Empty Cavity*	
2" Mineral Wool (R-8.4)	R-8.2
3" Mineral Wool (R-12.6)	R-9.5
4" Mineral Wool (R-16.8)	R-10.7
5" Mineral Wool (R-21.0)	R-11.6

RDH



Center of Wall – Away from Slab Edge
Backup: 2 ½" Steel Studs, R-8 Batts

+	
+	
+	



C
E
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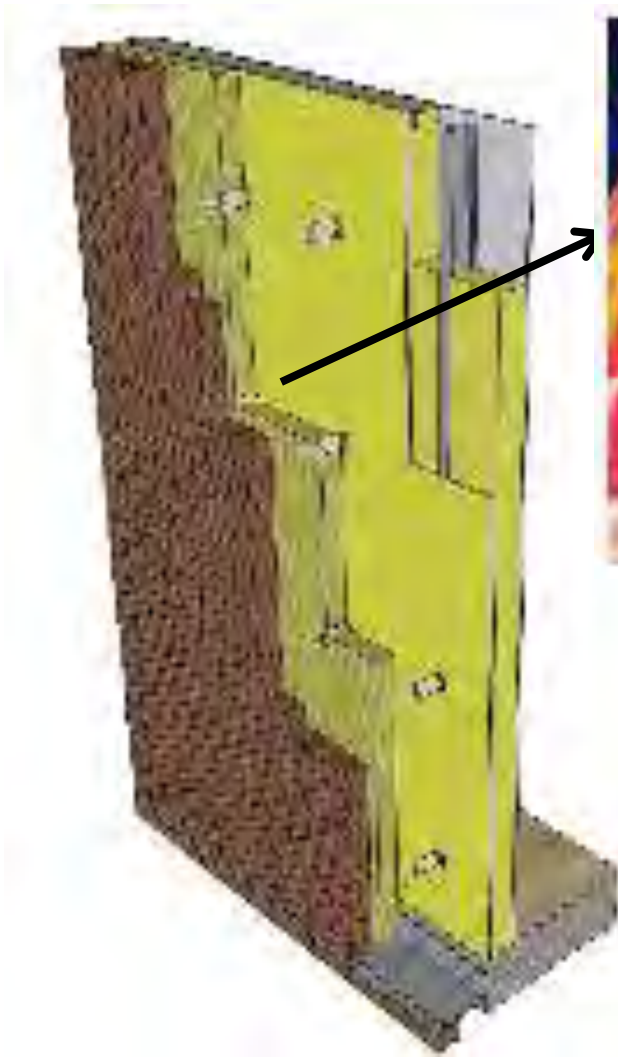
+1" XPS (R-5) at concrete	R-6.7
+2" XPS (R-10) at concrete	R-8.1
+3" XPS (R-15) at concrete	R-9.3

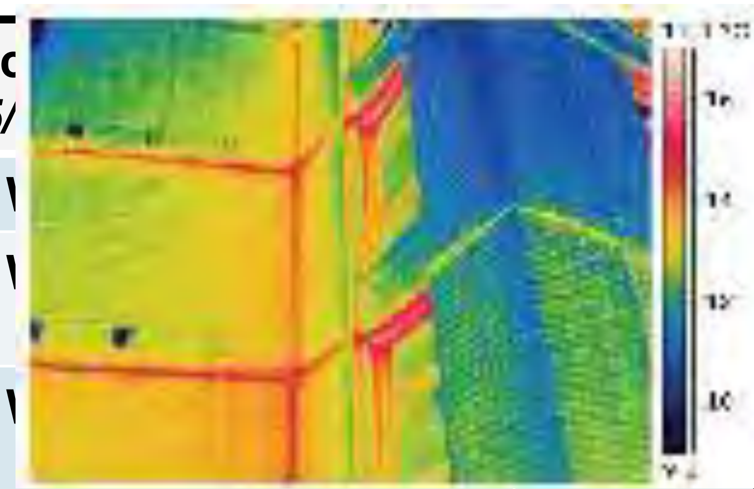
Shelf Angle Supported Brick Masonry

RDH

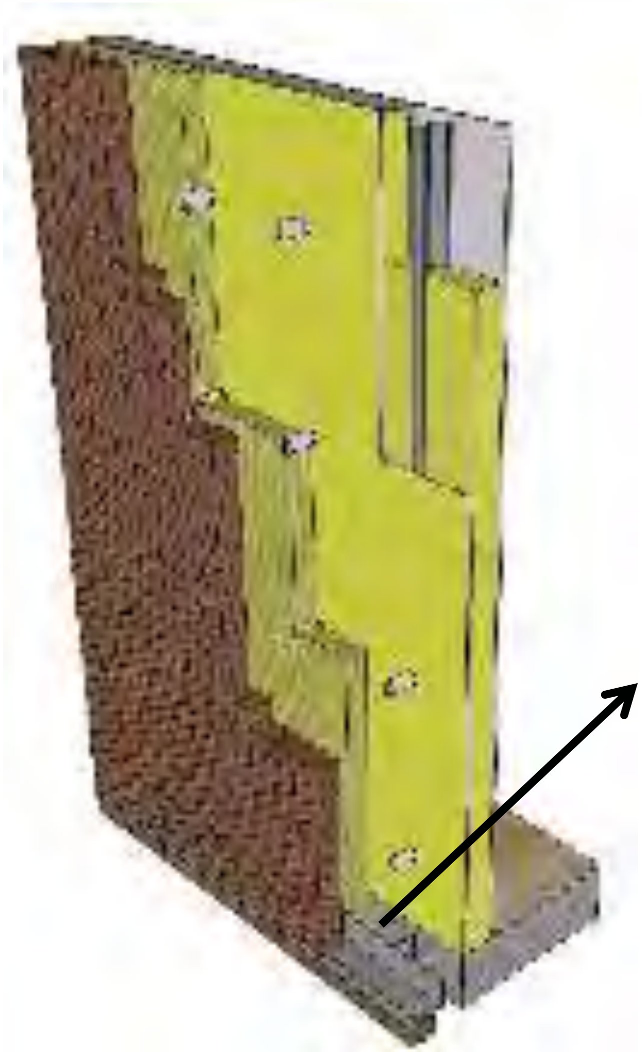


ge	
-12.1	
-15.8	
-19.5	

Overall Effec *Backup: 3 5/*
**+2" Mineral **
+3" Mineral \\ (R-12.6)
+4" Mineral \\ (R-16.8)



Brick Masonry – With Stand-off Shelf Angles

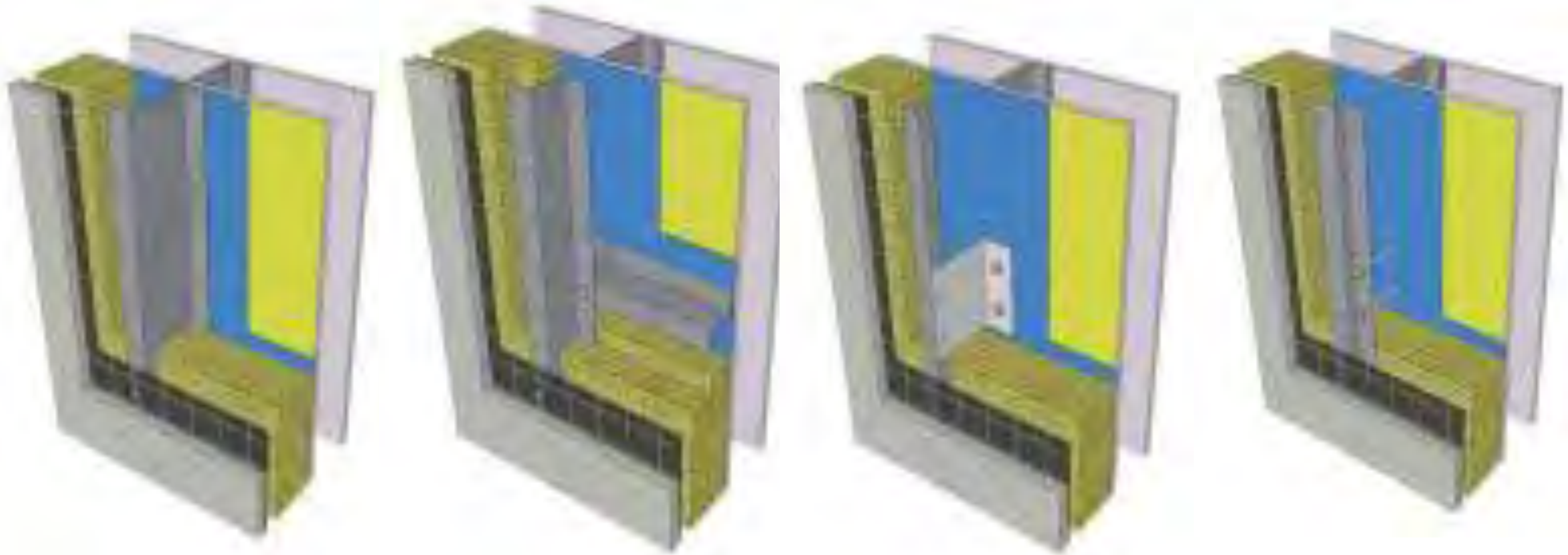


<u>Without</u> Stand-off Plates: **Overall Effective – Including Slab Edges** ***Backup: 3 5/8" Steel Studs , Empty***	
+2" Mineral Wool Exterior (R-8.4)	**R-8.6**
+3" Mineral Wool Exterior (R-12.6)	**R-10.1**
+4" Mineral Wool Exterior (R-16.8)	**R-11.5**

WITH Stand-off Plates: **Overall Effective – Including Slab Edges** ***Backup: 3 5/8" Steel Studs , Empty***	
+2" Mineral Wool Exterior (R-8.4)	**R-11.3**
+3" Mineral Wool Exterior (R-12.6)	**R-14.5**
+4" Mineral Wool Exterior (R-16.8)	**R-17.7**

Impact of Cladding Attachment – R-15 of Insulation

RDH



Current Practice

R-7.4

Better

R-10.3

Even Better

R-11.6 to 14.4

galvanized vs stainless

Most Efficient

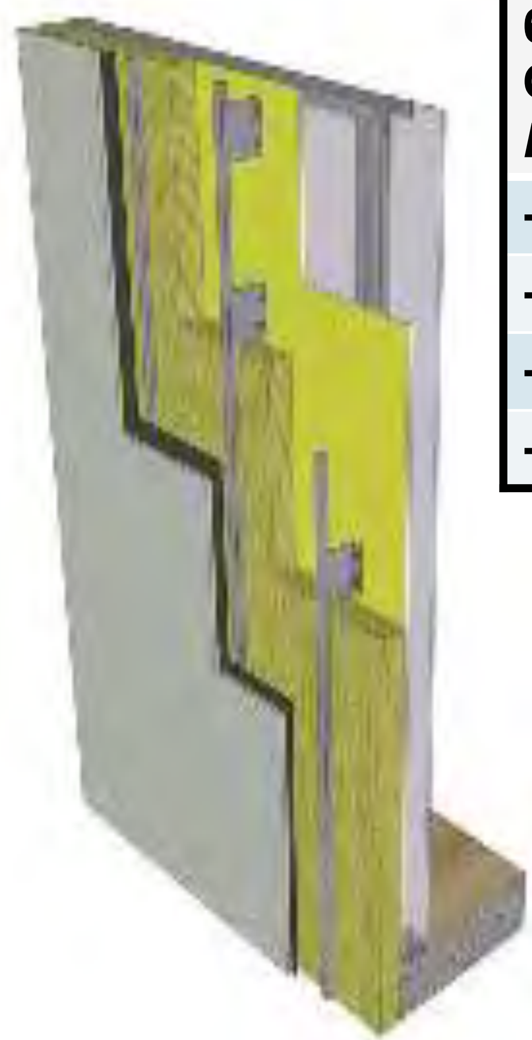
R-15.8

Screws only

Intermittent & Clip Supported Cladding Supports

- → 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

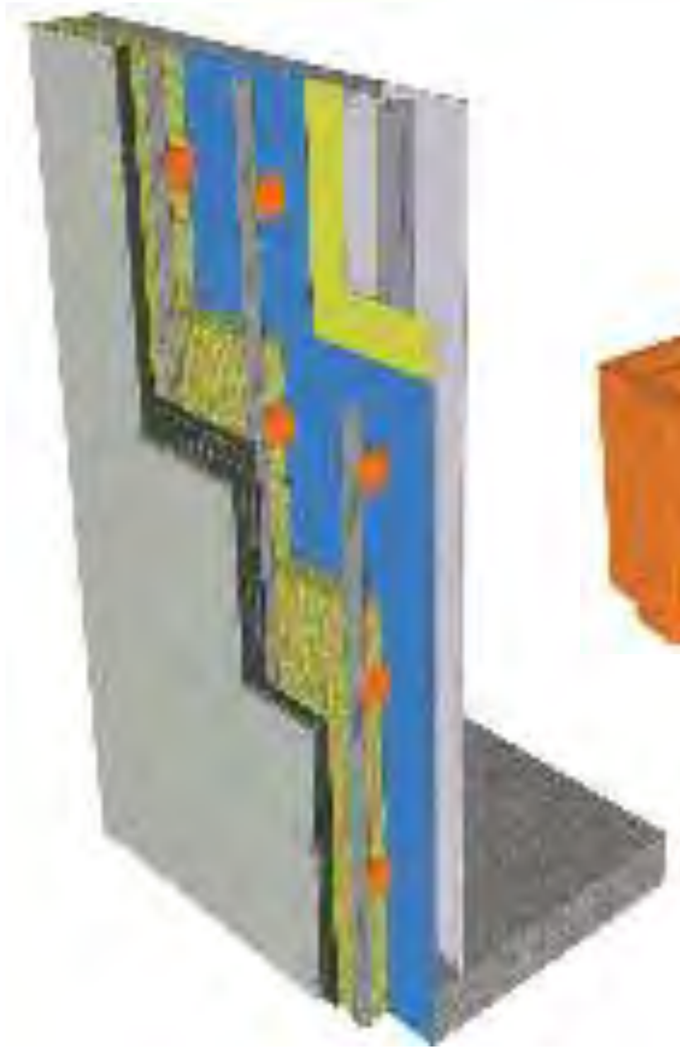
Intermittent Cladding Supports

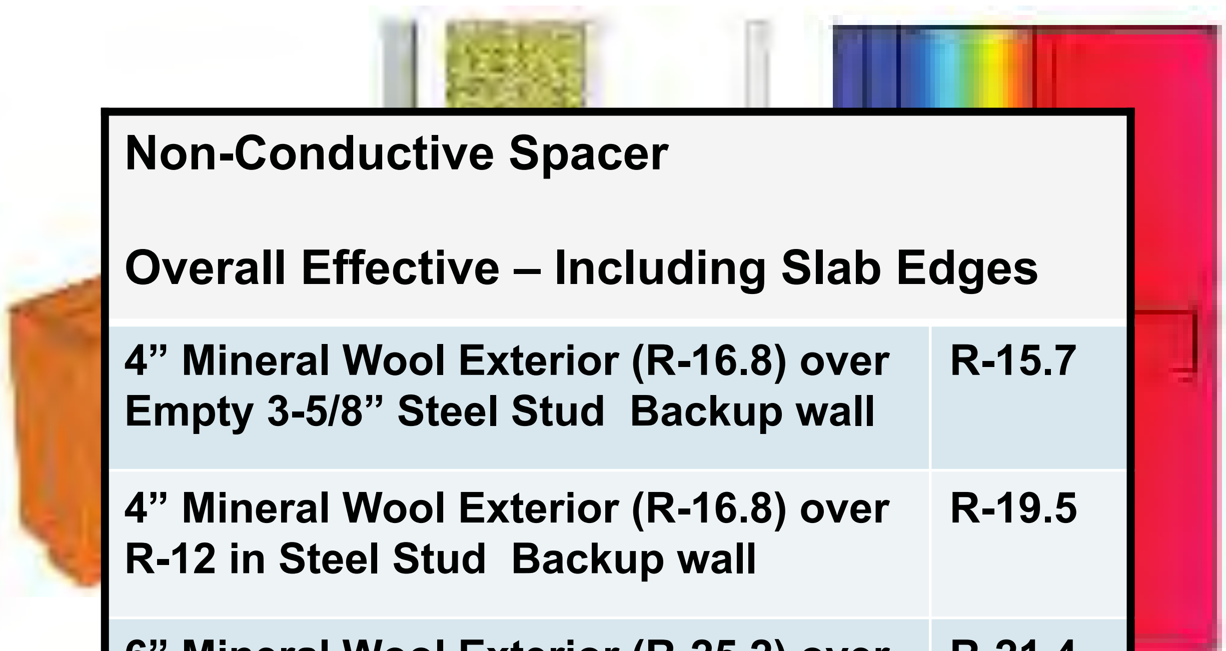


6" Long Galvanized Z-Bar Clips @ 24 " o.c. Overall Effective – Including Slab Edges *Backup: 3 5/8" Steel Studs , Empty*	
+2" Mineral Wool Exterior (R-8.4)	R-8.2
+3" Mineral Wool Exterior (R-12.6)	R-10.0
+4" Mineral Wool Exterior (R-16.8)	R-11.6
+5" Mineral Wool Exterior (R-21.0)	R-13.1

6" Long Galvanized Z-Bar Clips @ 24 " o.c. Overall Effective – Including Slab Edges *Backup: 3 5/8" Steel Studs , Fillled with R-12*	
+2" Mineral Wool Exterior (R-8.4)	R-11.3
+3" Mineral Wool Exterior (R-12.6)	R-13.0
+4" Mineral Wool Exterior (R-16.8)	R-14.6
+5" Mineral Wool Exterior (R-21.0)	R-16.0

Non Conductive Spacer





Non-Conductive Spacer Overall Effective – Including Slab Edges	
4" Mineral Wool Exterior (R-16.8) over Empty 3-5/8" Steel Stud Backup wall	R-15.7
4" Mineral Wool Exterior (R-16.8) over R-12 in Steel Stud Backup wall	R-19.5
6" Mineral Wool Exterior (R-25.2) over Empty 3-5/8" Steel Stud Backup wall	R-21.4
6" Mineral Wool Exterior (R-25.2) over R-12 in Steel Stud Backup wall	R-25.2

Intermittent Cladding Supports

Concrete Slab Edges, Balconies & Eyebrows

RDH