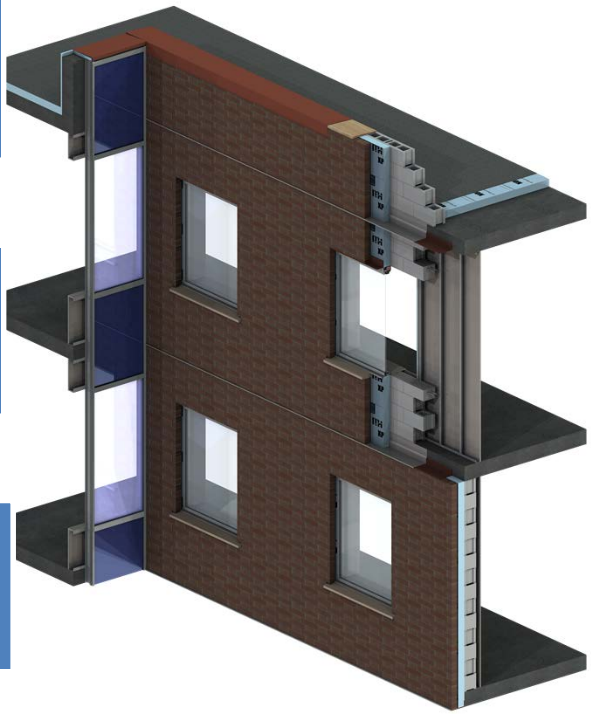
The Building Envelope Thermal Bridging Guide

October 16, 2014

Morrison Hershfield

Presentation Overview

1. Overview of the Thermal Bridging Guide
2. Significance and Insights
3. Where Next?



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Acknowledgments

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Funding Partners

BC hydro
powersmart

FORTIS BC™

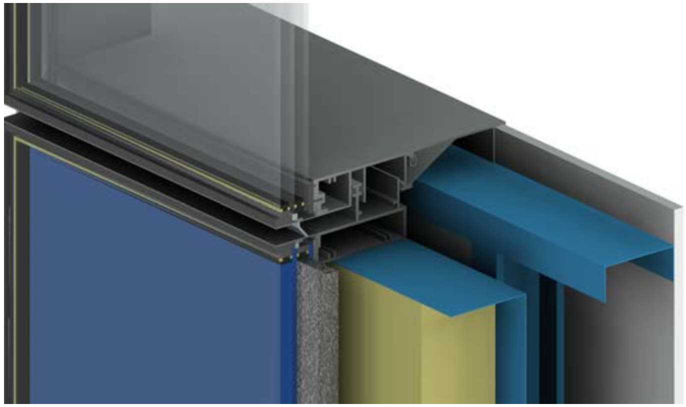
FPInnovations

Canadian Wood Council
Conseil canadien du bois

Homeowner Protection Office
Branch of BC Housing

Private Clients

- EIFS
- Insulated Metal Panel
- Cladding attachments
- Vacuum insulated panels (VIP) in insulated glazed units for glazing spandrel sections
- Structural thermal breaks manufacturer



Use of Energy Codes

- Code Compliance in all of BC
  - References either ASHRAE 90.1 2010 or NECB 2011
- LEED
  - References either ASHRAE 90.1 2007 or MNECB 1997
  - Requires "better than" minimum performance
  - Modeling procedures and assumptions differ from Code compliance – see LEED documents!
- Incentive Programs
  i.e. BC Hydro New Construction Program
  - References ASHRAE and NECB, with modifications
  - Modeling procedures and rules published by BC Hydro

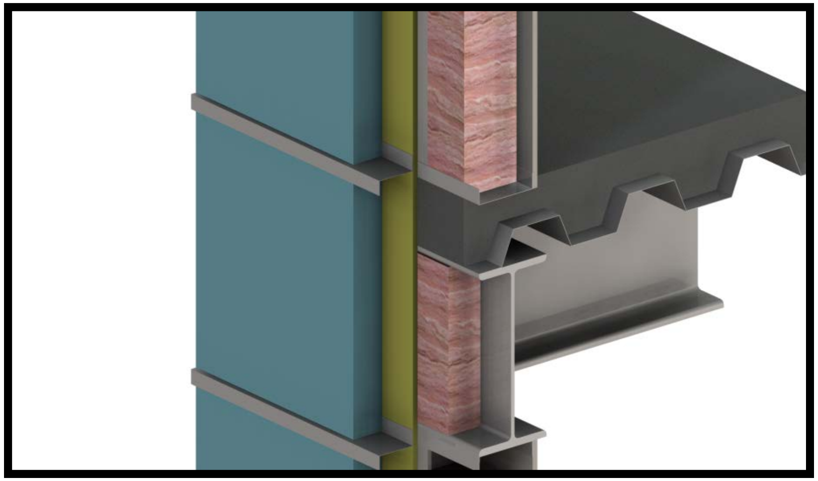
ASHRAE 90.1 Prescriptive Opaque areas

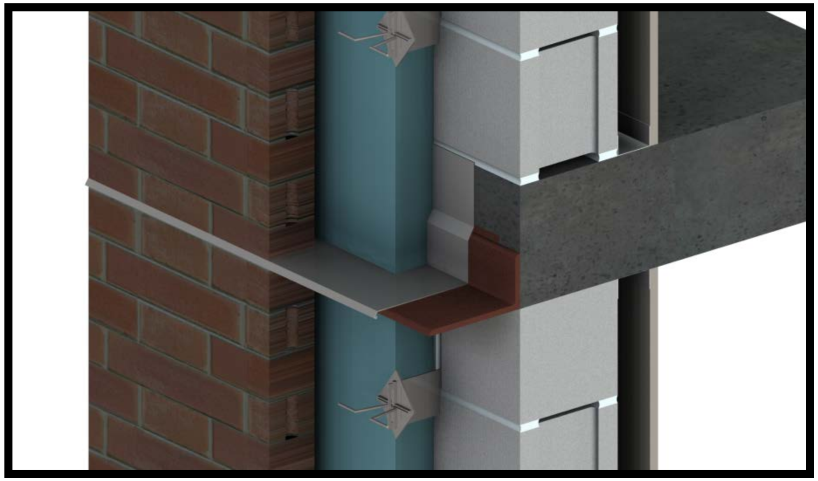
Components	Zone 7					
	Non-Residential		Residential		Semi-Heated	
	U factor	R value	U factor	R value	U factor	R value
Roof - insulation above deck	0.048 (R20.8)	20.0c.i.	0.048 (R20.8)	20.0c.i.	.093 (R8.4)	10c.i.
Roof - Attic	0.027 (R37.0)	38.0	0.027 (R37.0)	38.0	.034 (R29.4)	30.0
Walls - Mass	0.071 (R14.1)	15.2c.i.	0.071 (R14.1)	15.2c.i.	0.123 (R8.1)	7.6c.i.
Walls - Steel framed	0.064 (R15.6)	13.0+7.5c.i.	0.042 (R23.8)	13.0+15.6c.i.	0.124 (R8.1)	13.0
Walls - Wood framed	0.051 (R19.6)	13.0+7.5c.i.	0.051 (R19.6)	13.0+7.5c.i.	0.089 (R11.2)	13.0

Effective Thermal Resistance

What is a Thermal Bridge?

- Highly conductive material that by-passes insulation layer
- Areas of high heat transfer
- Can greatly affect the thermal performance of assemblies

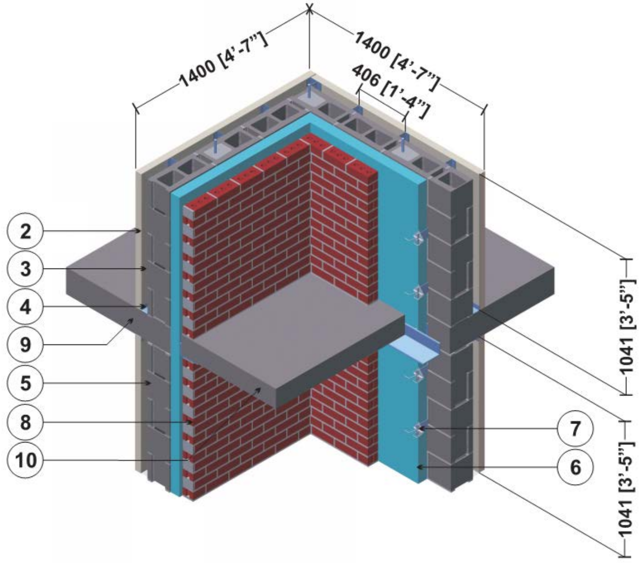




ASHRAE Research Project 1365 2011

Goals and Objectives of the Project

- Calculate **thermal performance data** for common building **envelope details** for **mid- and high-rise construction**
- Develop **procedures** and a **catalogue** that will allow designers quick and straightforward access to information
- Provide information to answer the fundamental questions of how overall geometry and materials affect the overall thermal performance

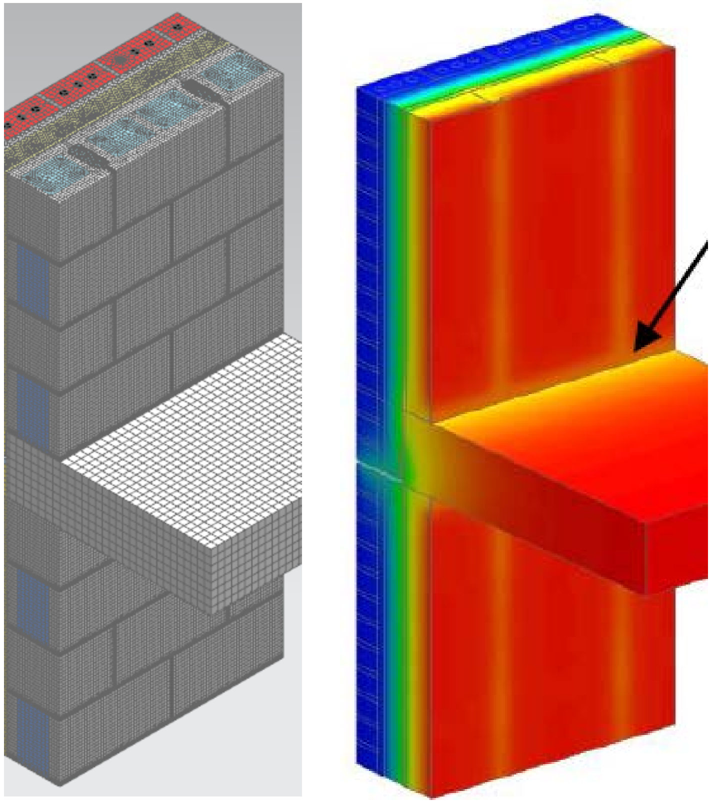


ASHRAE Research Project

Calibrated 3D Modeling Software

- Heat transfer software by Siemens PLM Software, FEMAP & Nx
- Model and techniques calibrated and validated against measured and analytical solutions
- ISO Standards for glazing
- Guarded hot box test measurements, 29 in total

SIEMENS



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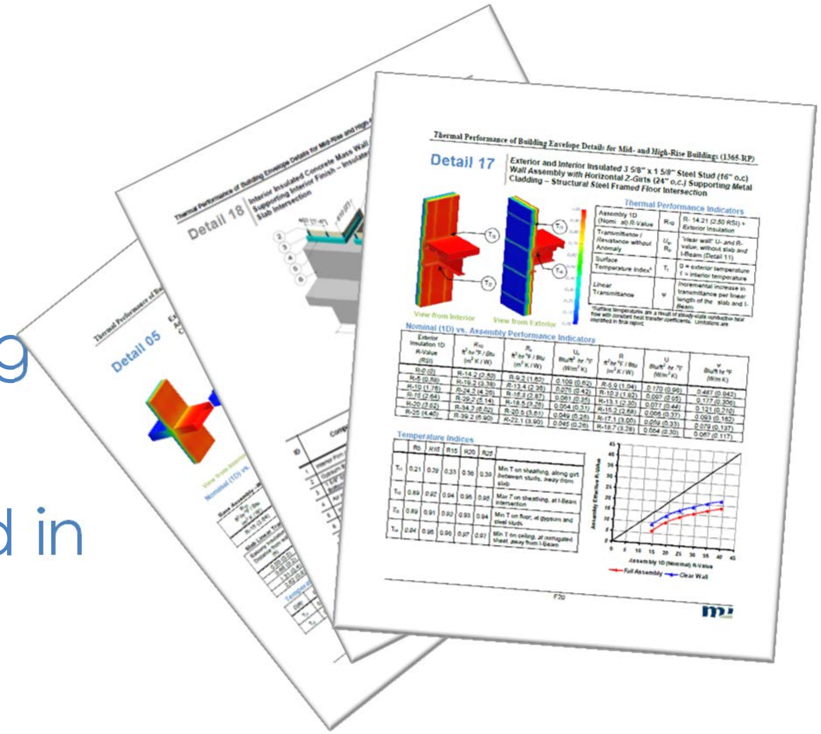
ASHRAE Research Project

Details Catalogue

- **40 building assemblies** and details common to North American construction
- Focus on opaque assemblies, but also includes some glazing transitions
- Details not already addressed in ASHRAE publications
- Highest priority on details with thermal bridges in 3D



What's this BC Study?

Building Envelope Thermal Bridging Guide
Analysis, Applications, & Insights

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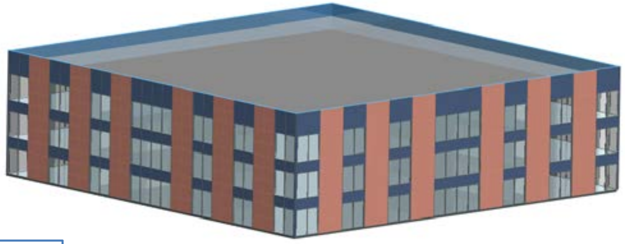
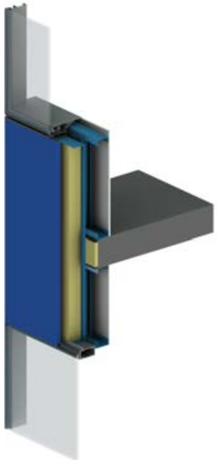
1365-RP and Beyond

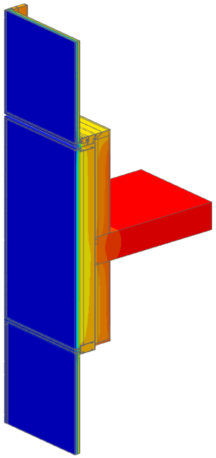
- Connected the dots



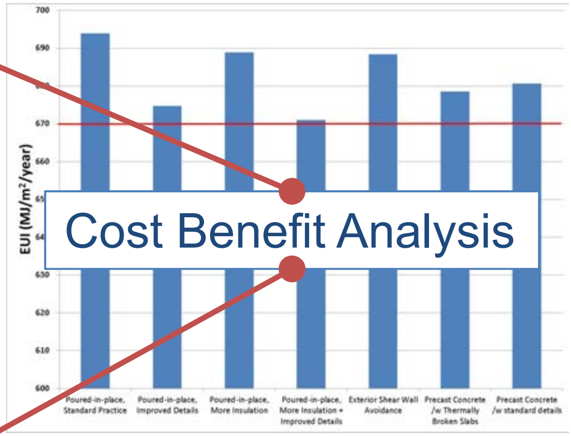
Thermal Performance

Whole Building Energy Analysis





Construction Cost Analysis



Cost Benefit Analysis

BC hydro
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NEW CONSTRUCTION PROGRAM

INCENTIVES, RESOURCES

Power Smart offers financial incentives, resources and technical assistance to building owners, developers and the design industry to create high-performance, energy-efficient buildings.

What it looks like: featured projects

Incentives to study system design

PROGRAMS & INCENTIVES

- Power Smart Partner Program
- Power Smart Express
- Workplace Conservation Awareness
- Energy Management Assessment
- Energy Performance Contracts
- Continuous Optimization

Building Envelope Thermal Bridging Guide

This guide explores how the building industry in British Columbia can meet the challenges of reducing energy use in buildings, in part by effectively accounting for the impact of thermal bridging.

Most practitioners will find PART1 and Appendices A and B to be most useful. PART 1 outlines how to effectively account for thermal bridging. Appendices A and B provide a catalog of common building envelope assemblies and interface details, and their associated thermal performance data.

Researchers and regulators will be interested in PART 2 and PART 3, and Appendices C to E. They contain the cost-benefit analysis, and discussion on significance and further insights, of using this guide to mitigate thermal bridging in buildings.

- Introduction [PDF, 2.2 MB]
- Part 1: Building Envelope Thermal Analysis (BETA) Guide [PDF, 4.5 MB]
- Part 2: Energy Savings and Cost Benefit Analysis [PDF, 1.8 MB]
- Part 3: Significance, Insights and Next Steps [PDF, 2.8 MB]
- Appendix A – Catalogue Material Data Sheets [PDF, 14.3 MB]
- Appendix B – Catalogue Thermal Data Sheets [PDF, 11.7 MB]
- Appendix C – Energy Modeling Analysis and Results [PDF, 1.2 MB]
- Appendix D – Construction Costs [PDF, 1.2 MB]
- Appendix E – Cost Benefit Analysis [PDF, 7.3 MB]

The Beginning of Guides

• **Introduction**	
• **Part 1**	Building Envelope Thermal Analysis (BETA) Guide
• **Part 2**	Energy and Cost Analysis
• **Part 3**	Significance, Insights, and Next Steps
• **Appendix A**	Material Data Catalogue
• **Appendix B**	Thermal Data Catalogue
• **Appendix C**	Energy Modeling Analysis and Results
• **Appendix D**	Construction Costs
• **Appendix E**	Cost Benefit Analysis

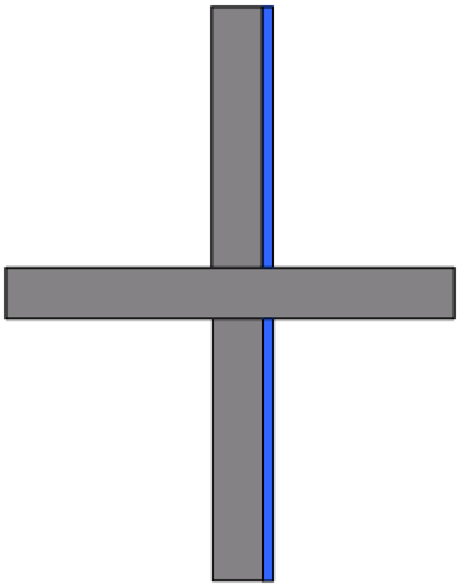
Sorry

And now for a little math

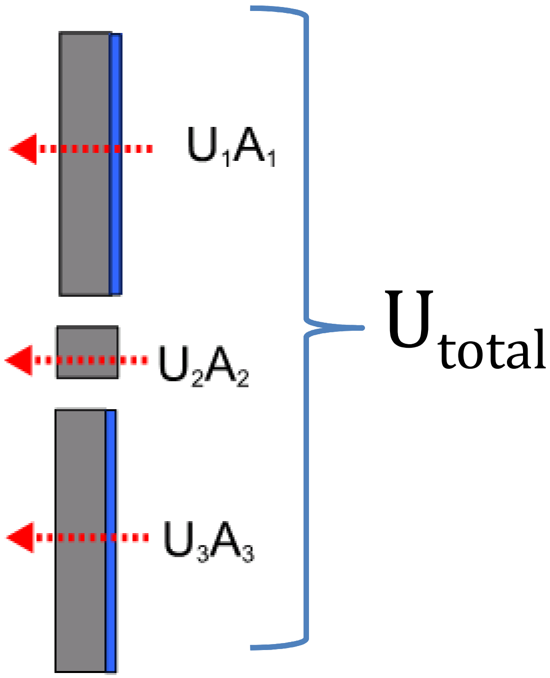
Parallel Path Heat flow

- Assumes heat flows are separate and do not influence each other
- Averages overall heat flow/resistance based on the areas of components

Insulated Concrete Wall with Projected Balcony

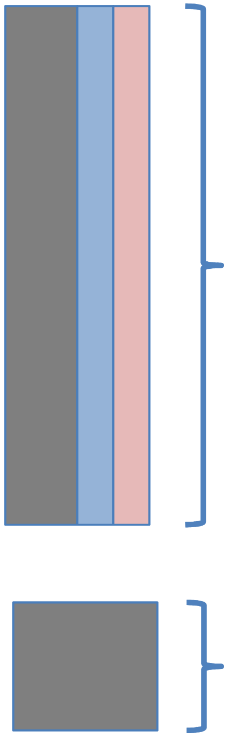


Simplified Assembly for Parallel Path



$$U_{total} = \frac{(U_1A_1 + U_2A_2 + U_3A_3 \ldots)}{(A_1 + A_2 + A_3 \ldots)} \cdot \Delta T$$

Parallel Path Method



R20 for 8’3” wall

R2 for 9” slab edge

$$\frac{1}{R} = \frac{0.75 \times {}^{1}\!/_{2} + 8.25 \times {}^{1}\!/_{20}}{0.75 + 8.25}$$

$$\boxed{R \cong 11.5}$$

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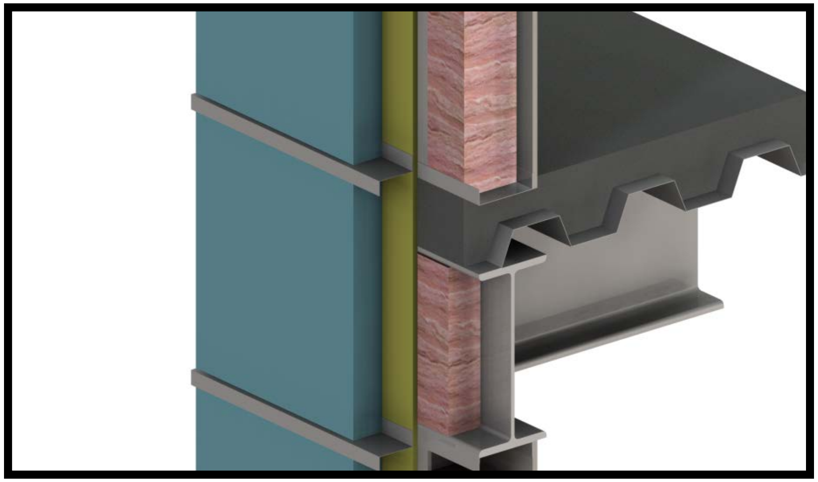
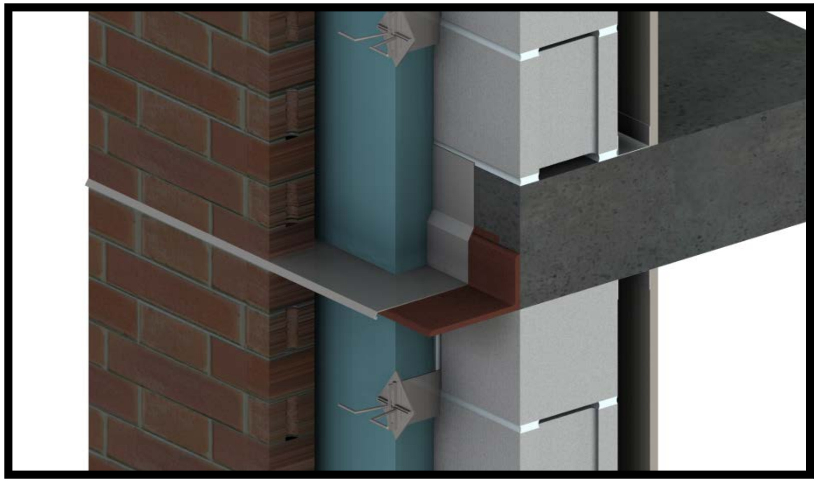
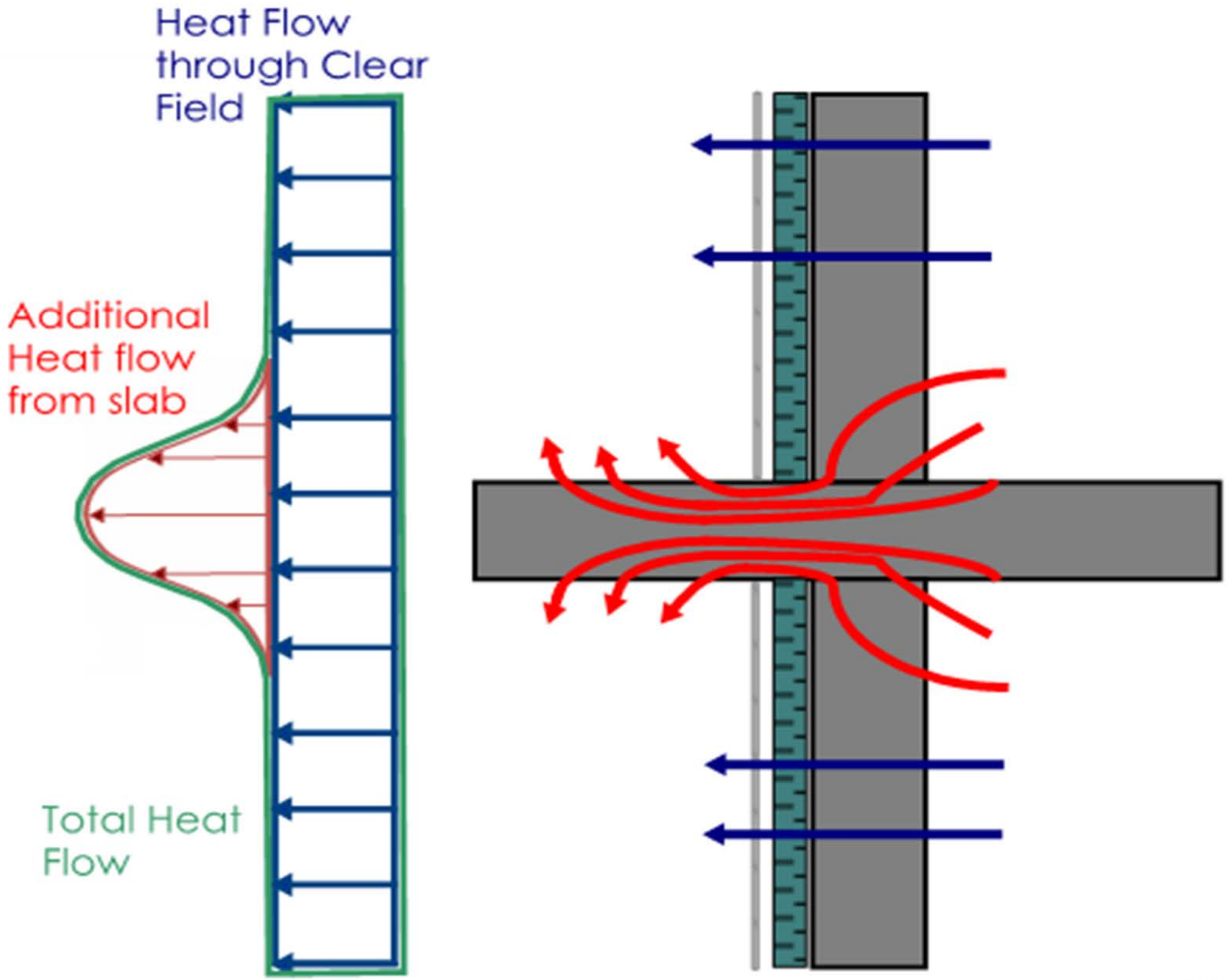
Thermal Bridging

- Parallel path doesn't tell the whole story
- Many thermal bridges don't abide by "areas" ie: shelf angle
- Lateral heat flow can greatly affect the thermal performance of assemblies





Addressing lateral Heat Flow



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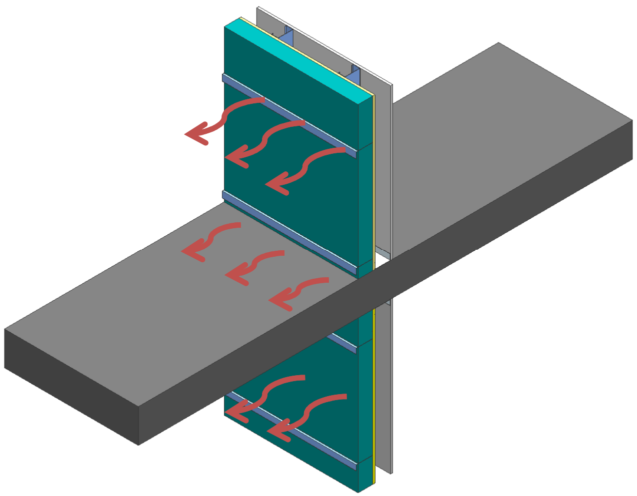
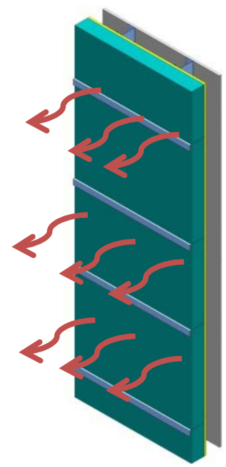
Overall Heat Loss

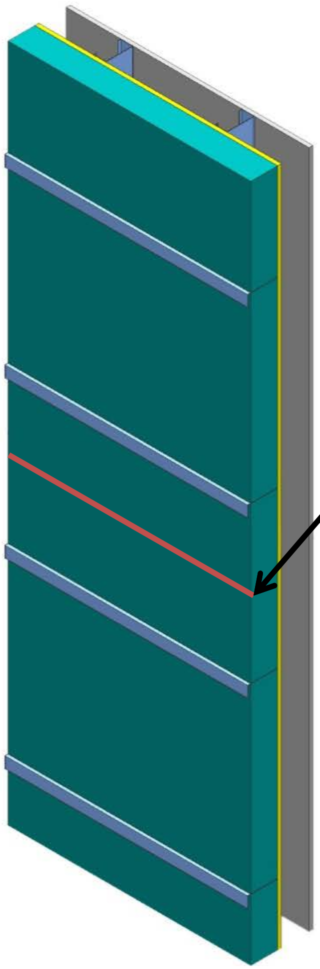
Q — Q_o = Q_{slab}





Additional heat loss due to the slab

Overall Heat Loss

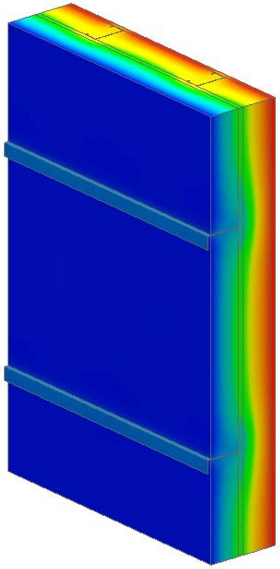


$$\Psi = Q_{slab} / L$$

- The linear transmittance represents the additional heat flow because of the slab, but with area set to zero

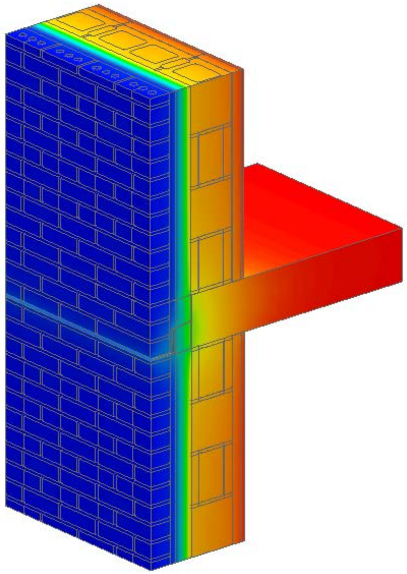
The Conceptual Leap

Types of Transmittances



Clear Field

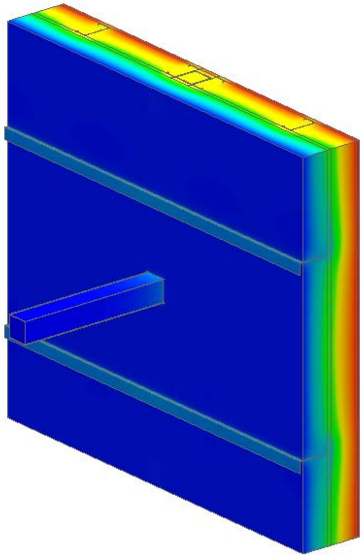
U_o



Linear

Ψ

psi



Point

χ

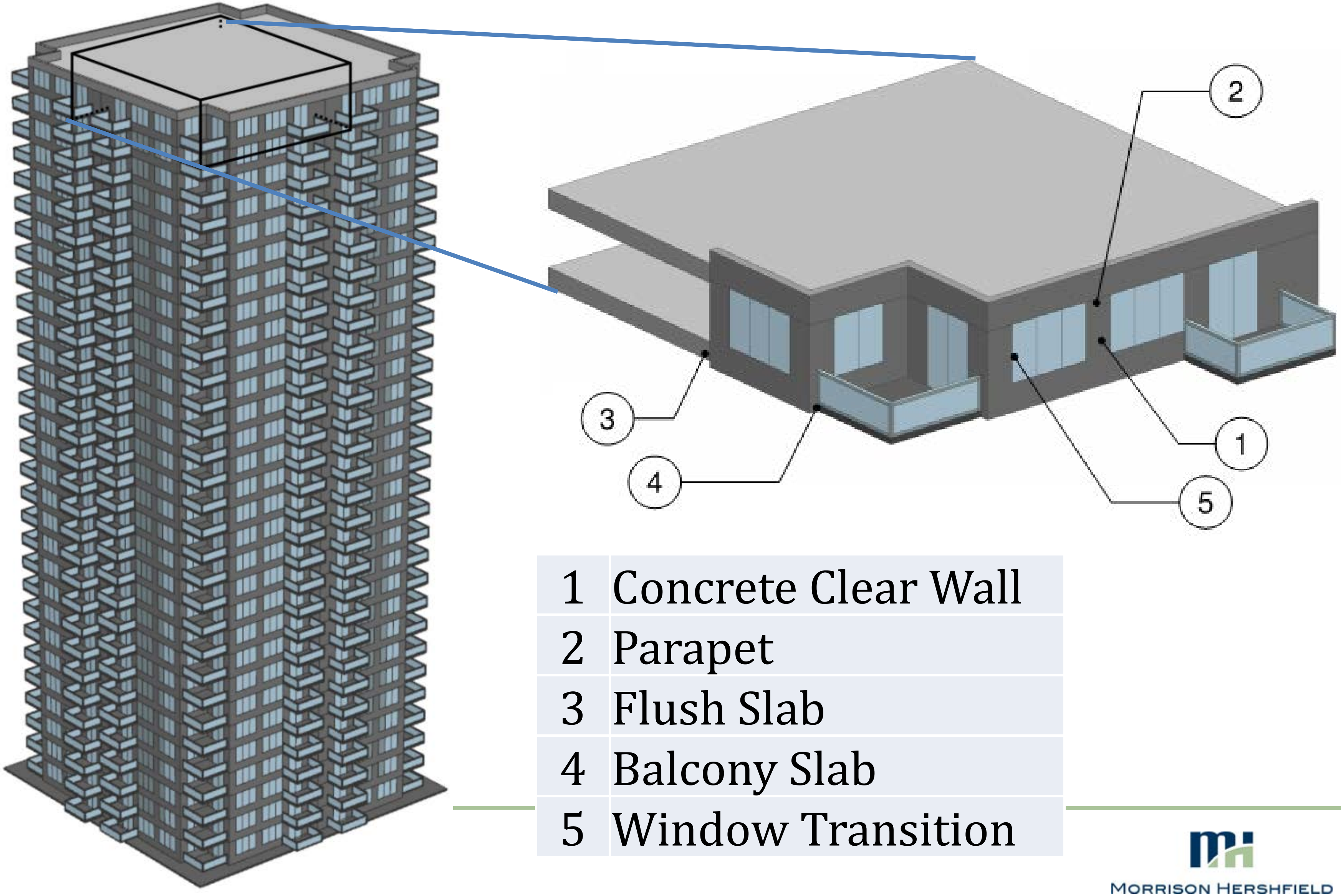
chi

Overall Heat Loss

Total Heat loss = heat loss due to clear field + Heat loss due to anomalies

$$Q / \Delta T = \Sigma(U_o \cdot A) + \Sigma(\Psi \cdot L) + \Sigma(\chi)$$

Identifying assemblies and details



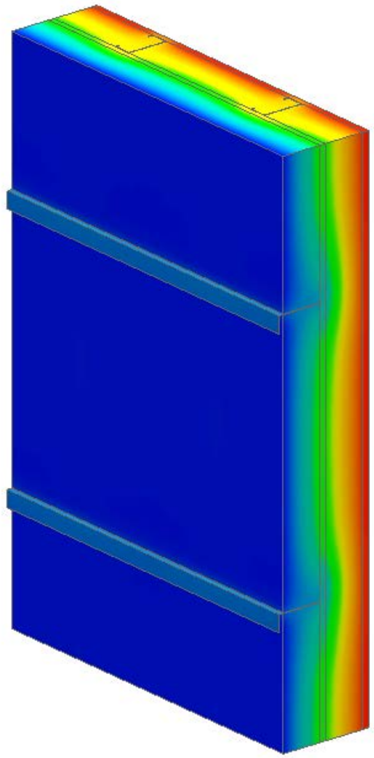
1	Concrete Clear Wall
2	Parapet
3	Flush Slab
4	Balcony Slab
5	Window Transition

Summing Transmittances

Transmittance Description	Area, Length or Amount Takeoff	Units	Transmittance Value	Units	Source Ref	Heat Flow BTU/hr°F
Glazed Spandrel	9036	ft^2	**0.13**	Btu / hr ft² °F	1.1.1	**1,175**
Concrete					1365-18	**3,253**
Parapet at Window Wall					1.1.5	**140**
Parapet at Concrete Wall					1365-20	**23**
Parapet and WW to Deck					1.1.5	**42**
Parapet at Con Wall to De					1365-20	**16**
Glazing Transition, Vert.	19938	ft	**0.29**	Btu / hr ft °F	4.1	**5,782**
Glazing Transition, Horizo					3.2	**704**
Balcony at WW					4.2	**1,254**
Balcony at Conc					1365-18	**835**
Spandrel Bypass					1.1.3	**1,041**
Eyebrow					4.1	**444**
Shear Wall	1295	ft	**0.66**	Btu / hr ft °F	3.4	**855**

Opaque U-Value (BTU/hr ft^2 °F)	**0.080**
Effective R-value (ft^{2}hr °F/BTU)	**12.5**

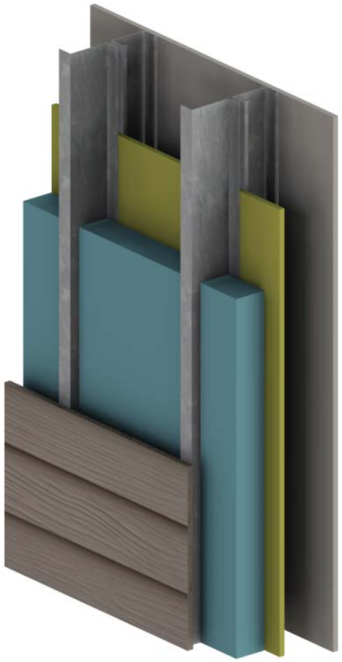
Opaque U-Value (BTU/hr ft^2 °F)	**0.280**
Effective R-value (ft^{2}hr °F/BTU)	**3.6**



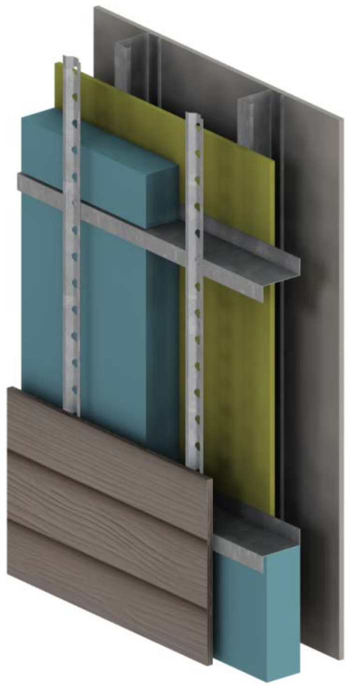
Clear Field

$$U_o$$

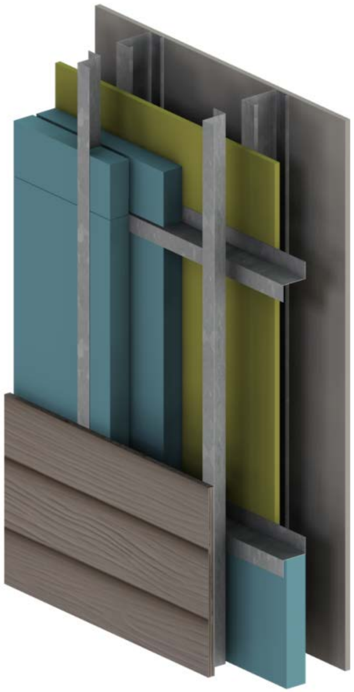
Cladding Attachments



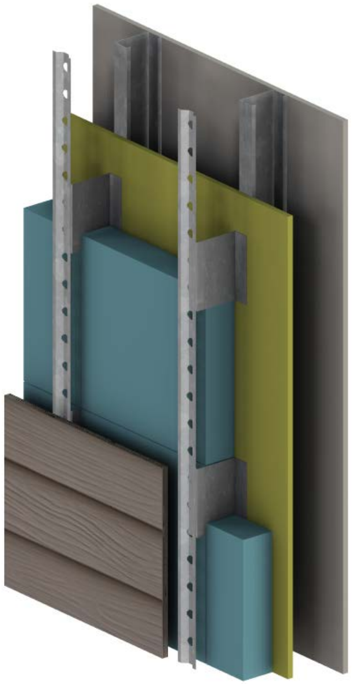
Vertical Z-Girts



Horizontal Z-Girts

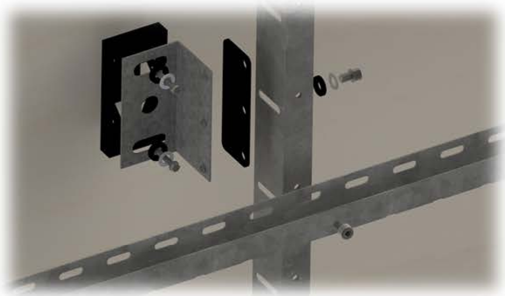


Mixed Z-Girts

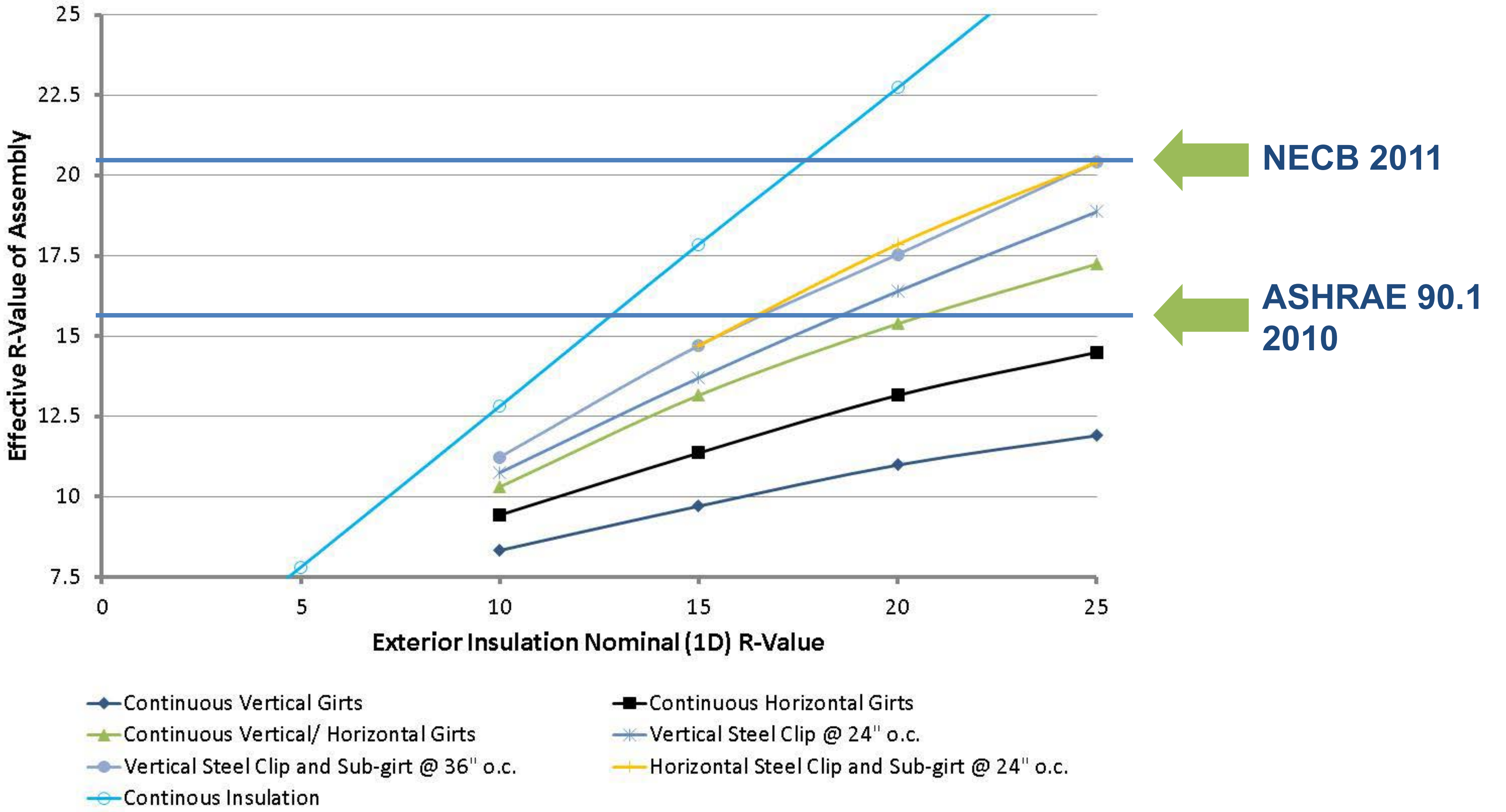


Intermittent Z-Girts

Clip Systems

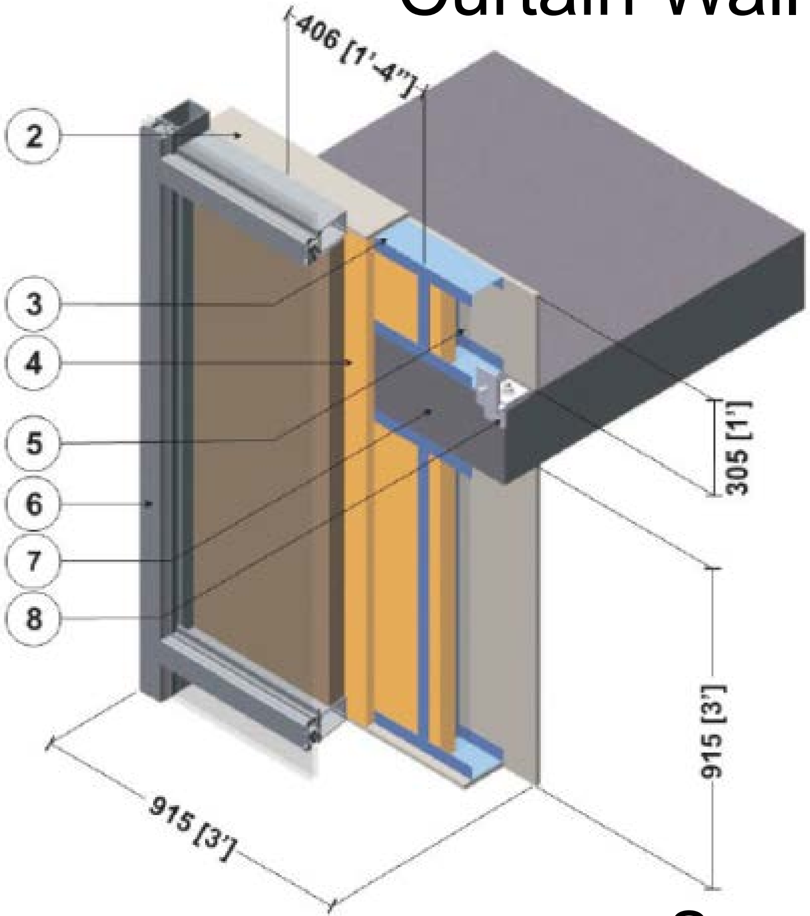


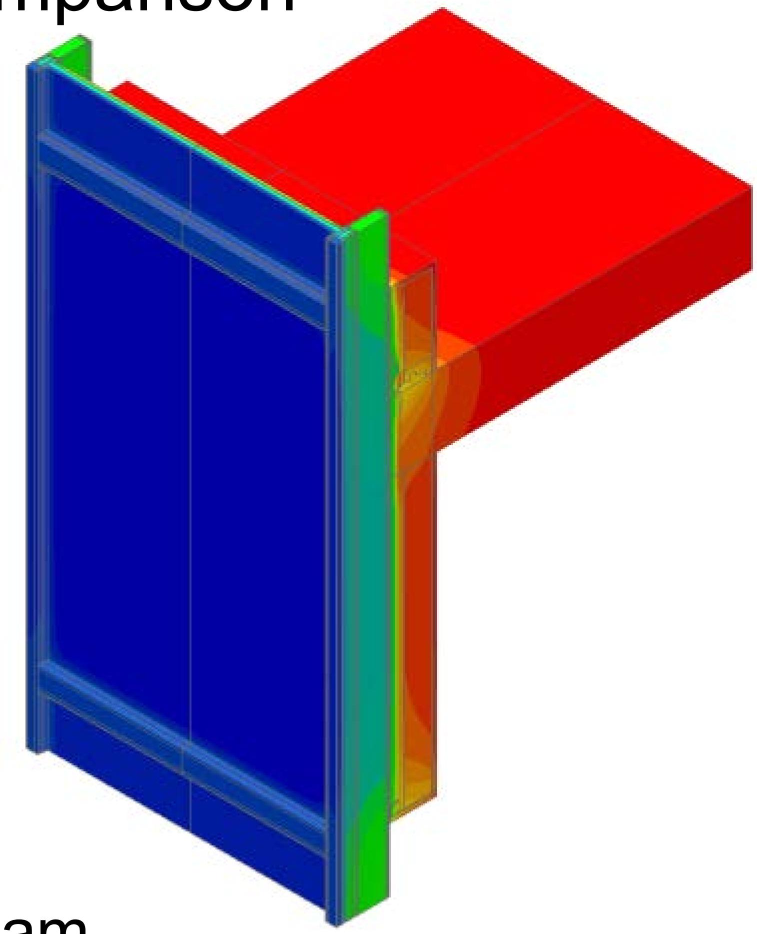
Effect of Thermal bridging in 3D



Glazing Spandrel Areas

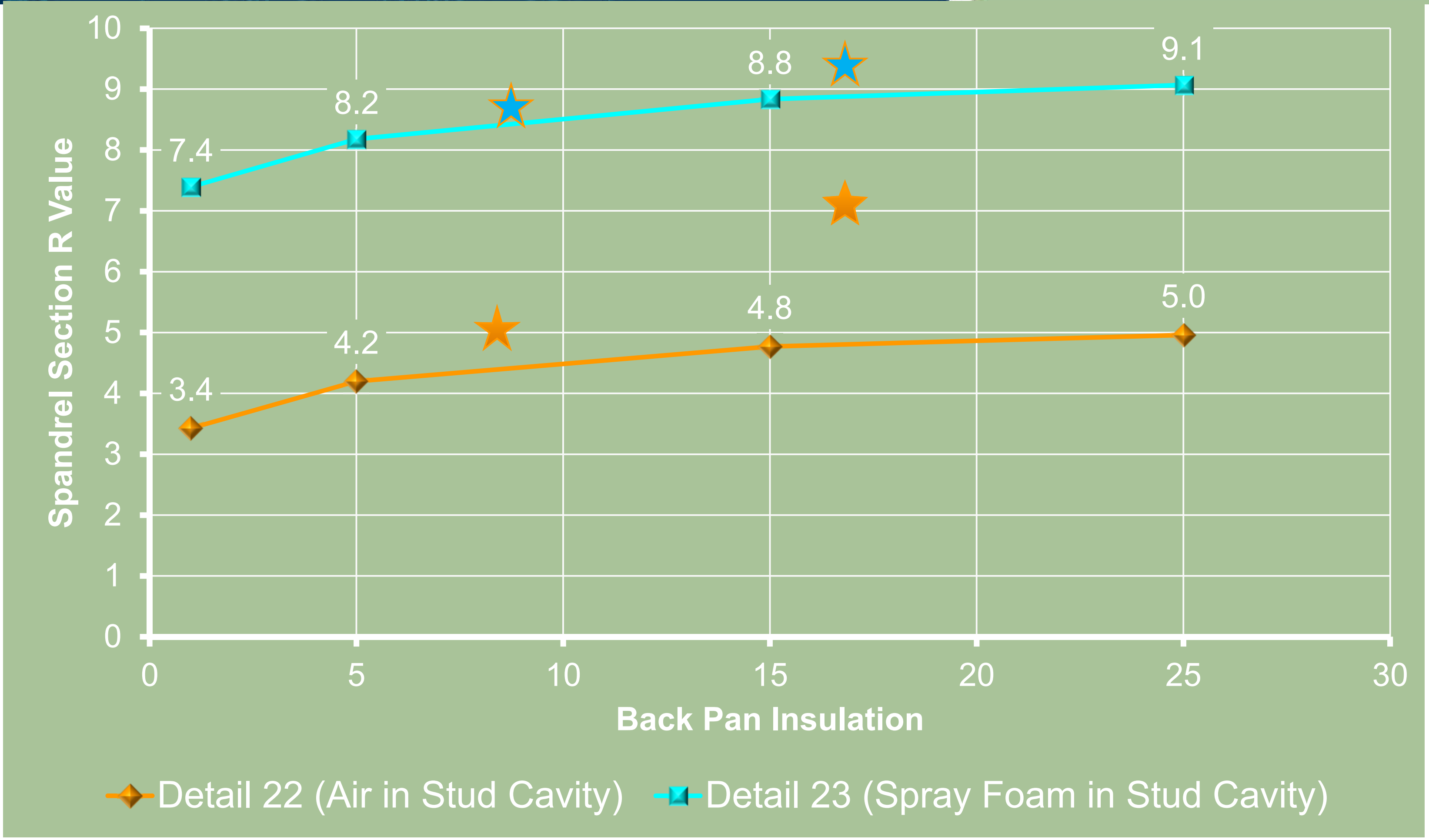
Curtain Wall Comparison





Spray Foam

Glazing Spandrel Areas



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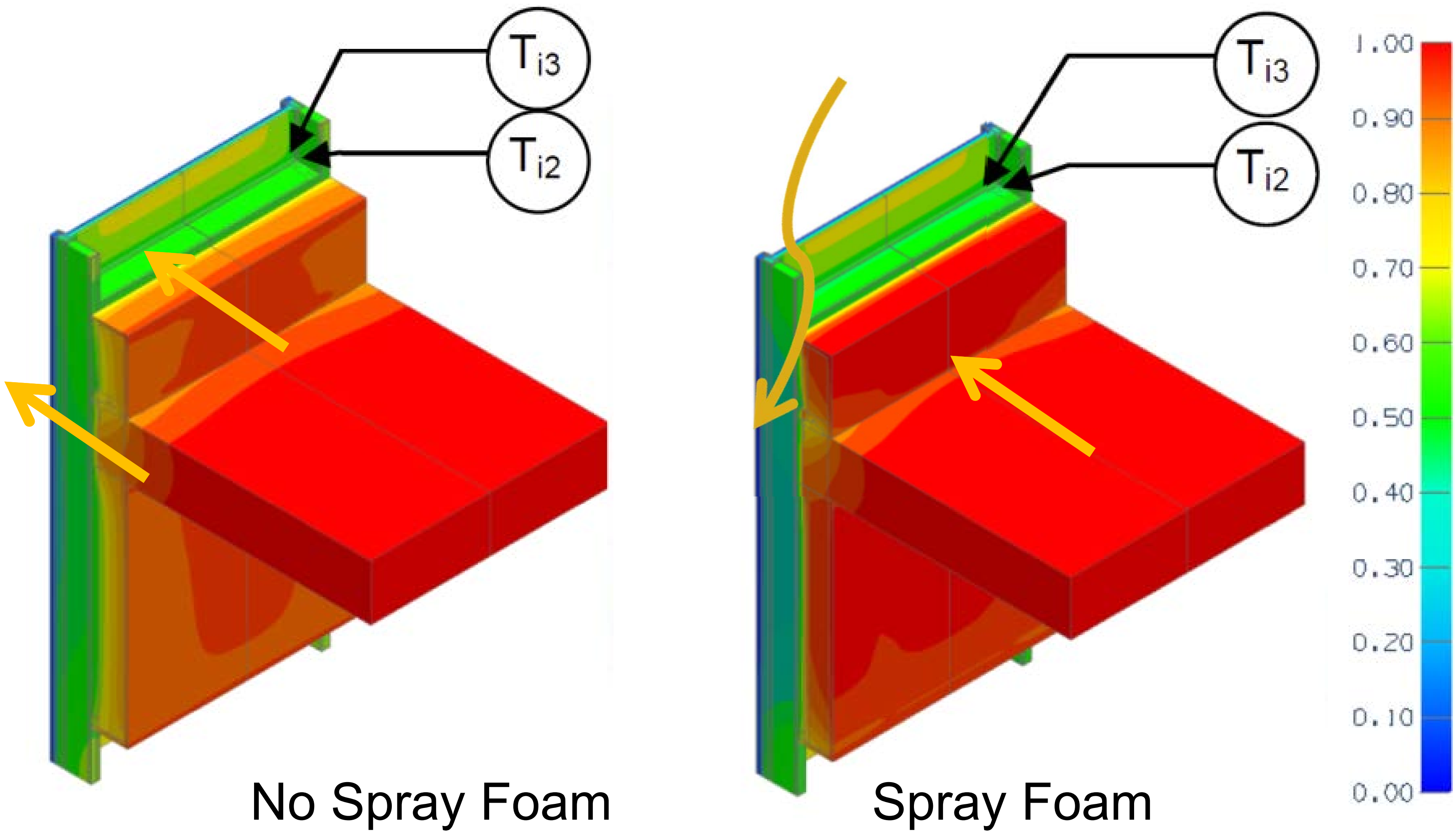
Glazing Spandrel Areas



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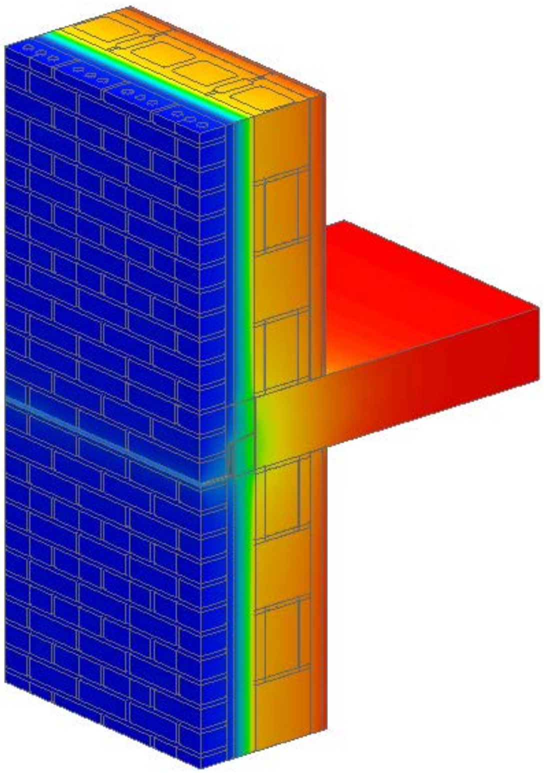


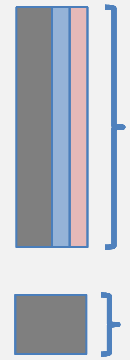
Linear

Ψ

Concrete Walls

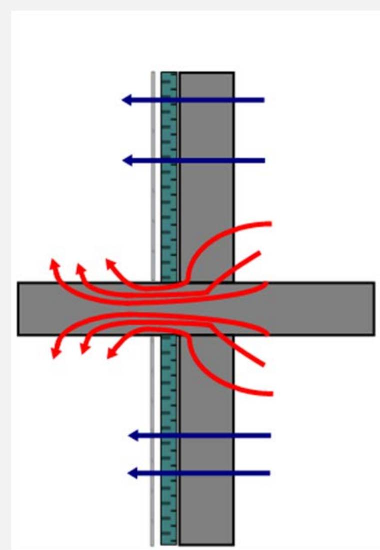
Think ab
An R10
BTU/hr·f
as 4.7 ft

Parallel Path



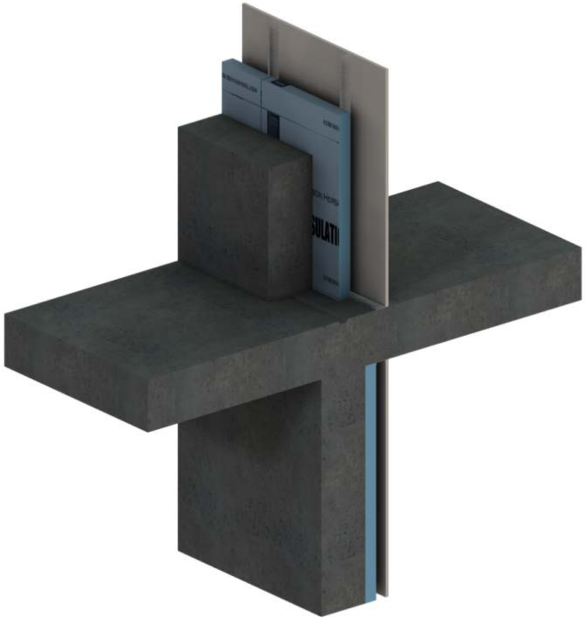
$$R \cong 11.5$$

Linear Transmittance



$$R \cong 9.8$$

Concrete Walls



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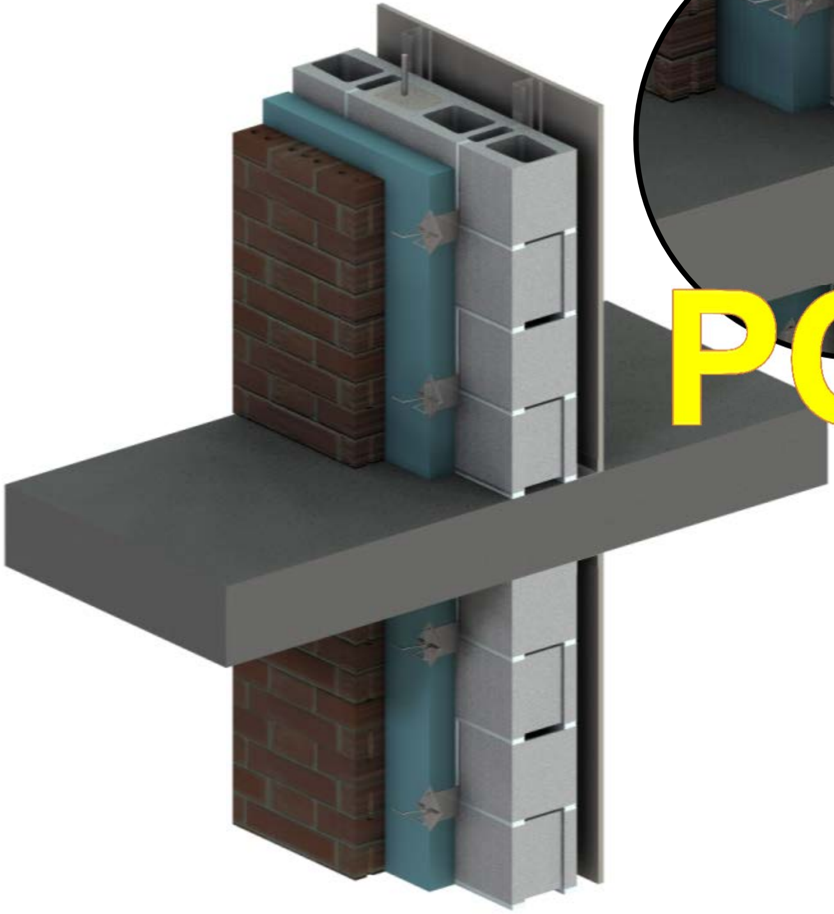
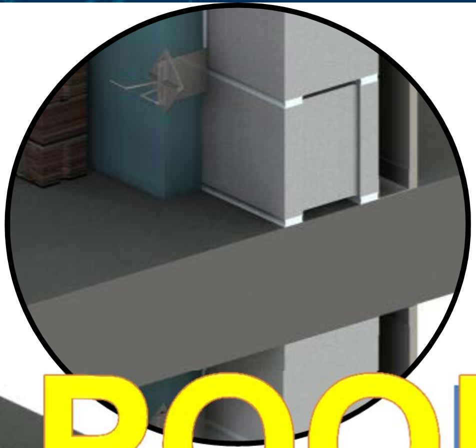
Slab Edges – Balcony





Un-Insulated Balcony Slab		
	SI (W/m·K)	**IP** (BTU/hr·ft°F)
Ψ	0.59	0.34

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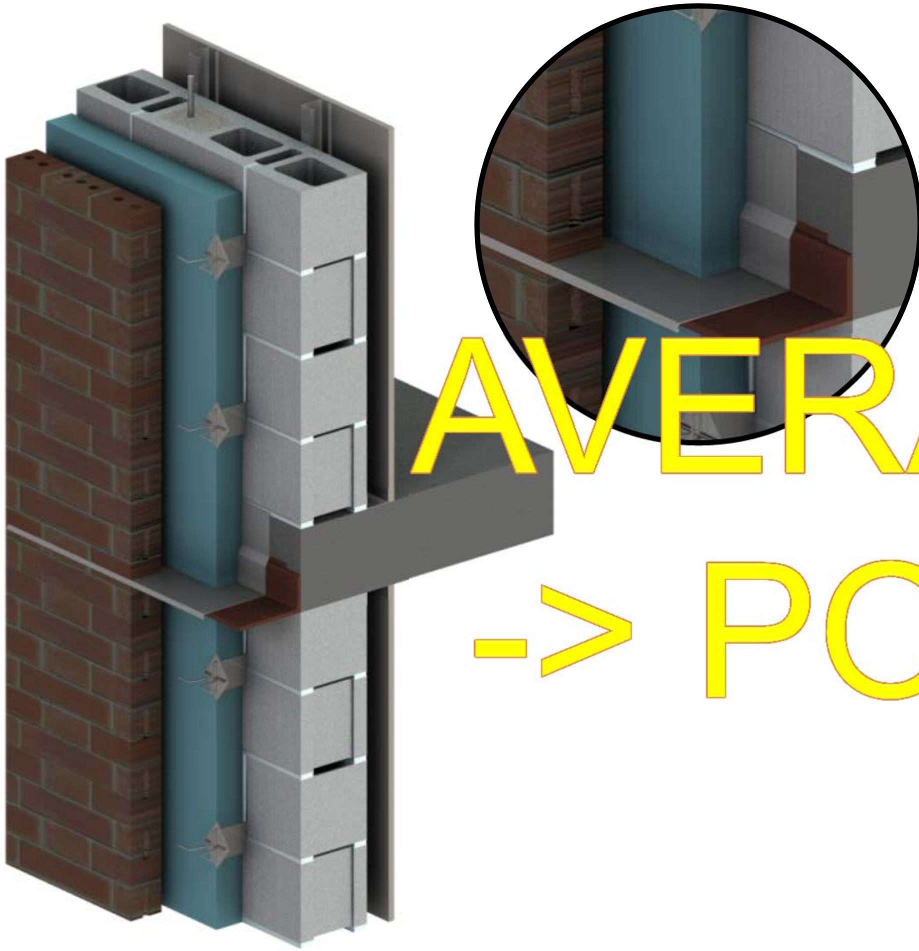
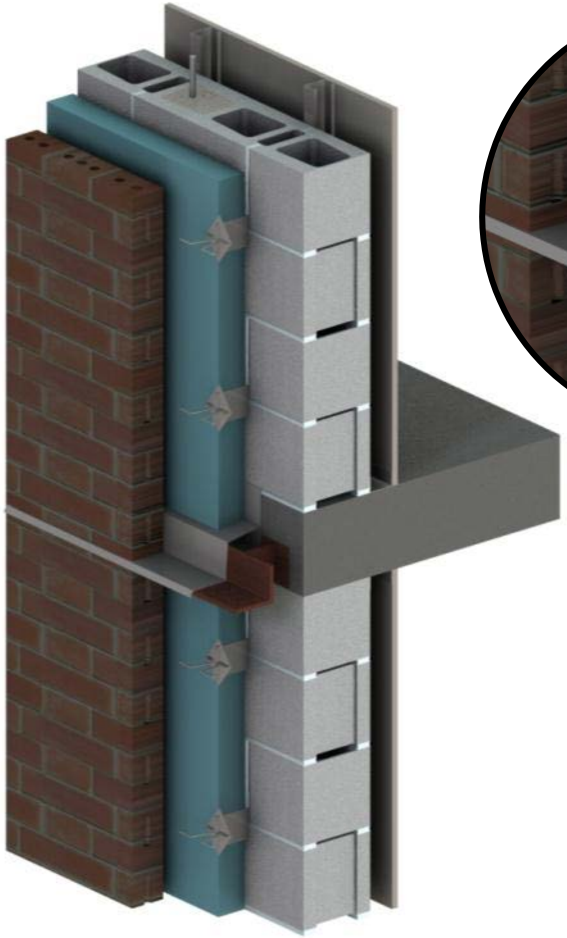
Slab Edges – Shelf Angle

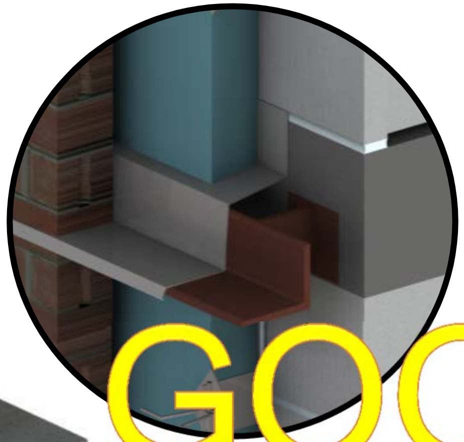


AVERAGE
-> POOR

Shelf Angle		
	SI (W/m·K)	**IP** (BTU/hr·ft°F)
Ψ	0.47	0.27

Slab Edges – Shelf Angle





GOOD

Spaced Shelf Angle		
	SI (W/m·K)	**IP** (BTU/hr·ft°F)
Ψ	0.31	0.18

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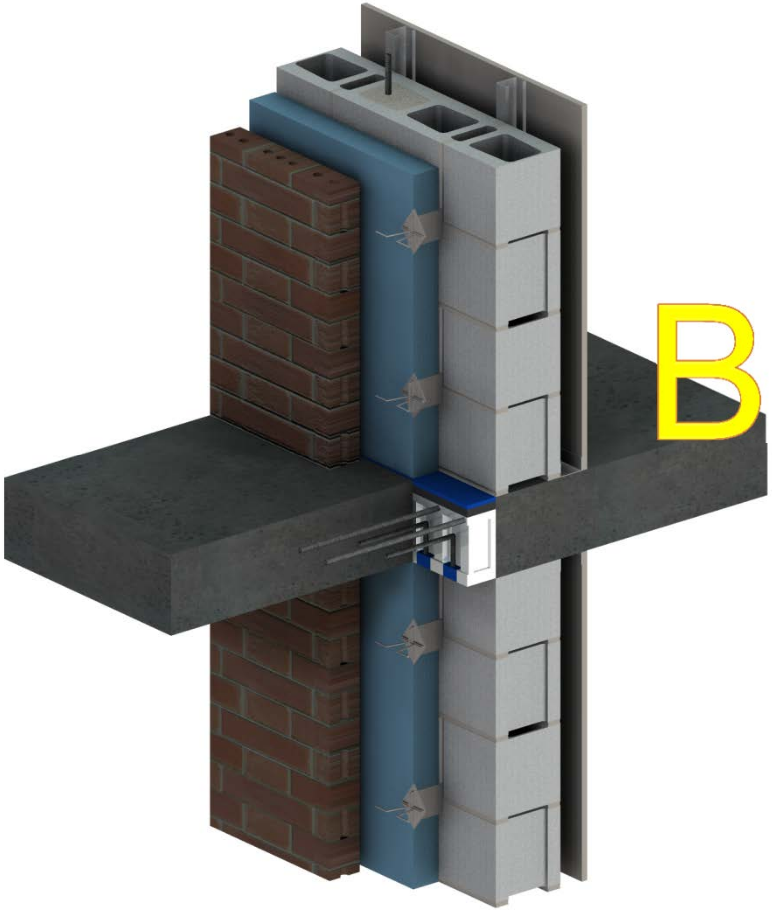
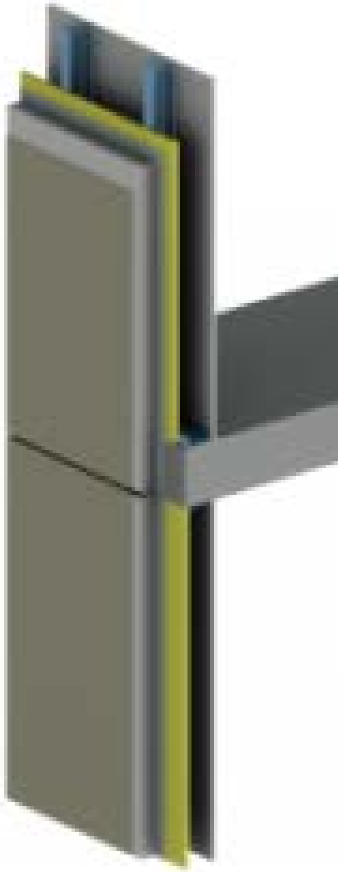
Slab Edges – Balcony



BEST

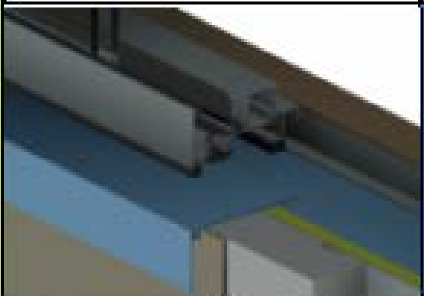
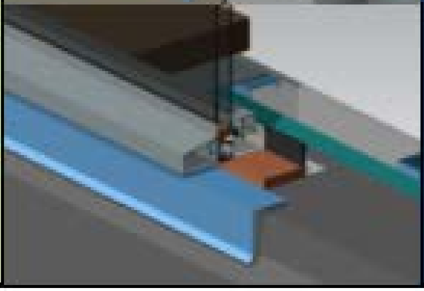
Thermally Broken Balcony Slab		
	SI (W/m·K)	**IP** (BTU/hr·ft°F)
Ψ	0.21	0.12

With EIFS

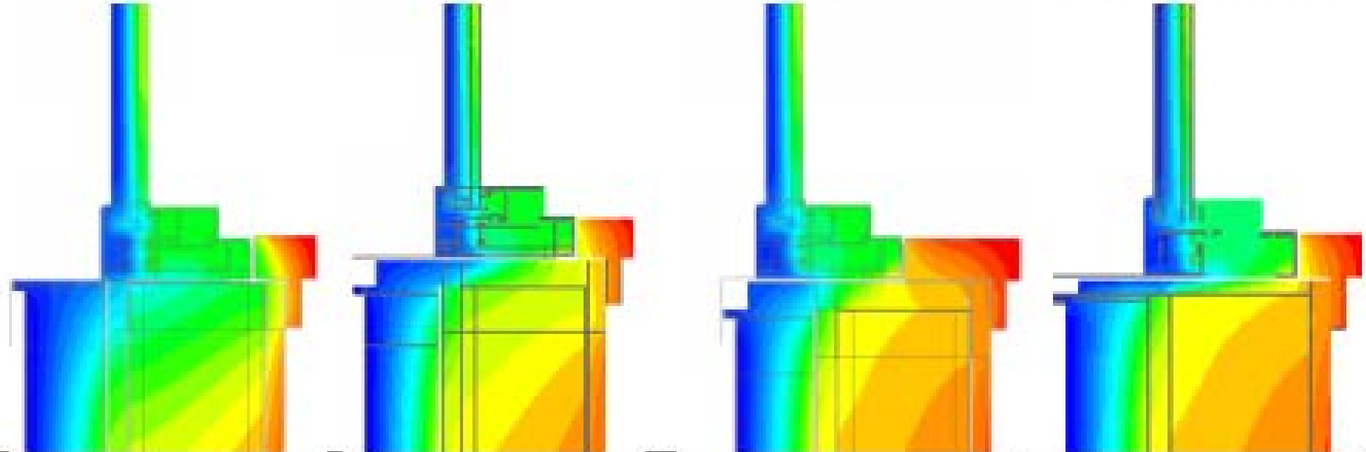


Assembly Type	**Exterior Insulation Nominal R-Value** hr.ft²·°F/BTU (m²K/W)	**Linear Transmittance** BTU/ft.hr.°F (W/mK)
Steel Stud wall with EIFS	R-15 (2.64)	0.012 (0.022)
Steel Stud with EIFS and R-12 batt insulation in stud cavity	R-7.5 (1.32)	0.076 (0.132)
Pour-in-place concrete wall with EIFS	R-15 (2.64)	0.013 (0.023)

Window Interface

GLAZING TRANSITIONS	Performance Category		Description and Examples	Linear Transmittance	
				Btu / hr ft F	W / m K
		Efficient	**Well aligned glazing without conductive bypasses** Example: wall insulation is aligned with the glazing thermal break. Flashing does not bypass the thermal break. **The EIFS interface with the curtain wall was in this category.**	0.1	0.17
		Regular	**Misaligned glazing and minor conductive bypasses** Examples: wall insulation is not continuous to thermal break. **The EIFS punched window details, without improvements, are in this category.**	0.2	0.35
		Poor	**Un-insulated and conductive bypasses** Examples: metal closures connected to structural framing. Un-insulated concrete opening (wall insulation ends at edge of opening).	0.3	0.5

Window in Wall with Ext. Insulation -Empty Cavity



	Base Case	Plywood Liner	Plywood Liner with Window at Exterior	R-4 Insulation Wrapped into Opening
Linear Transmittance (W/m K)	0.41	0.24	0.21	0.21
Glass Temperature Index at Edge (-)	0.465	0.464	0.460	0.456
Frame Temperature Index (-)	0.503	0.505	0.499	0.485

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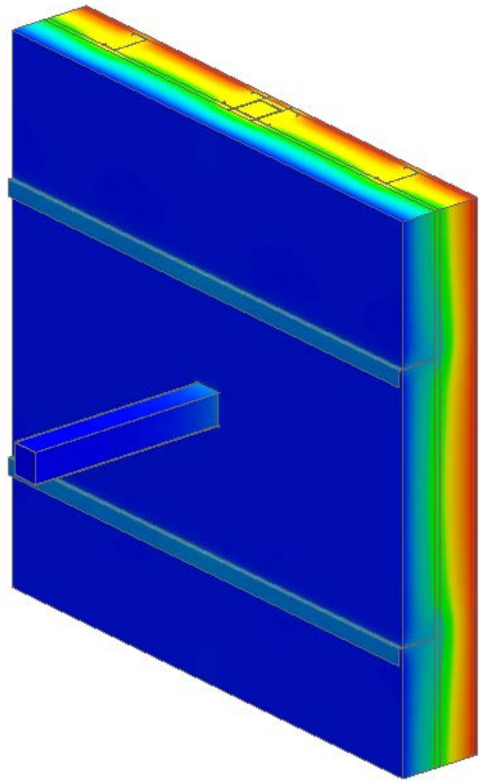

Point

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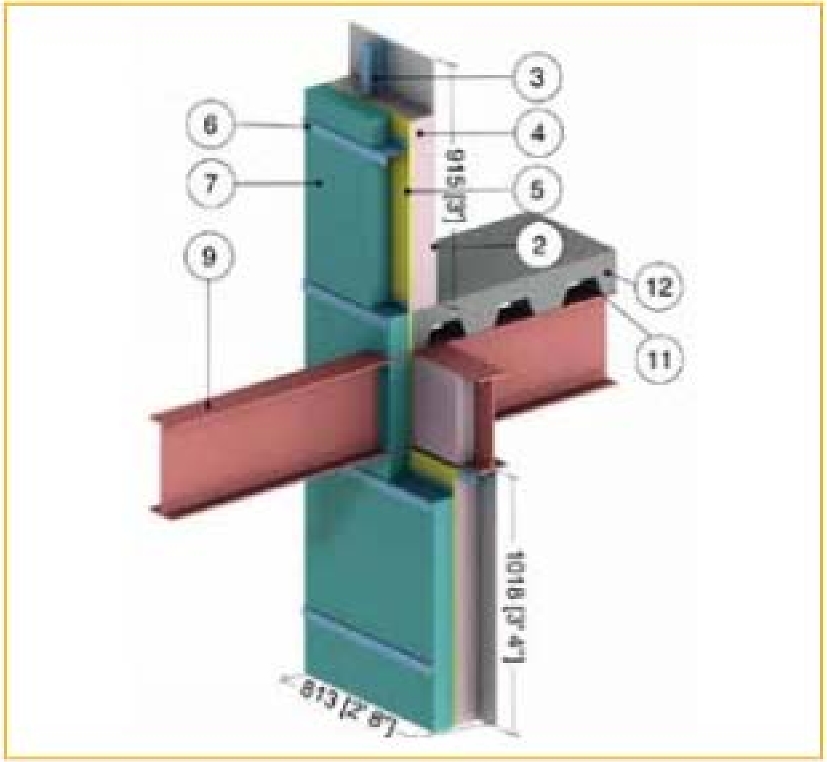
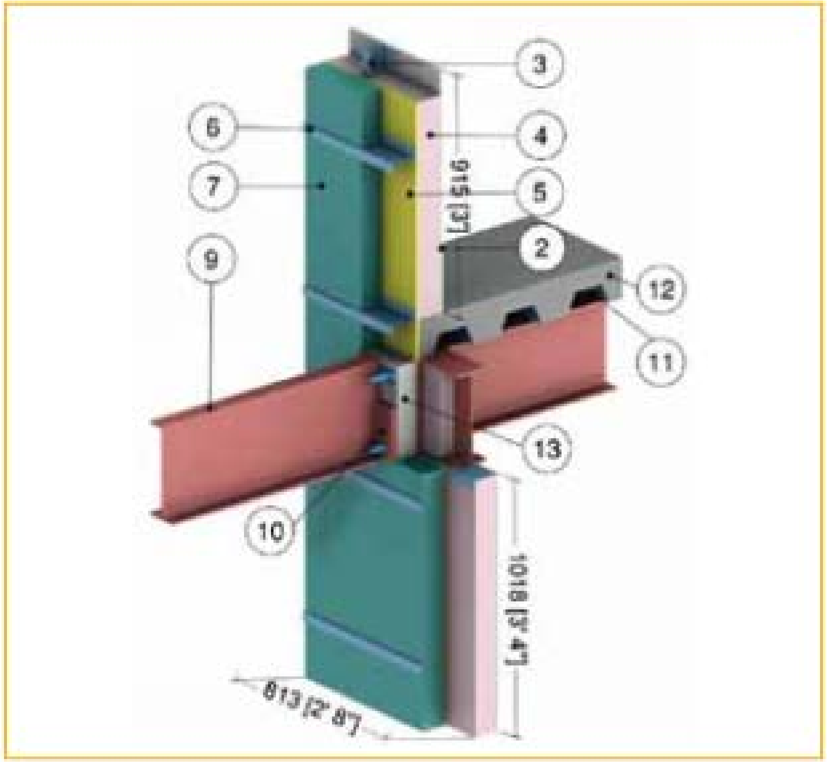
Beam Thermal Breaks

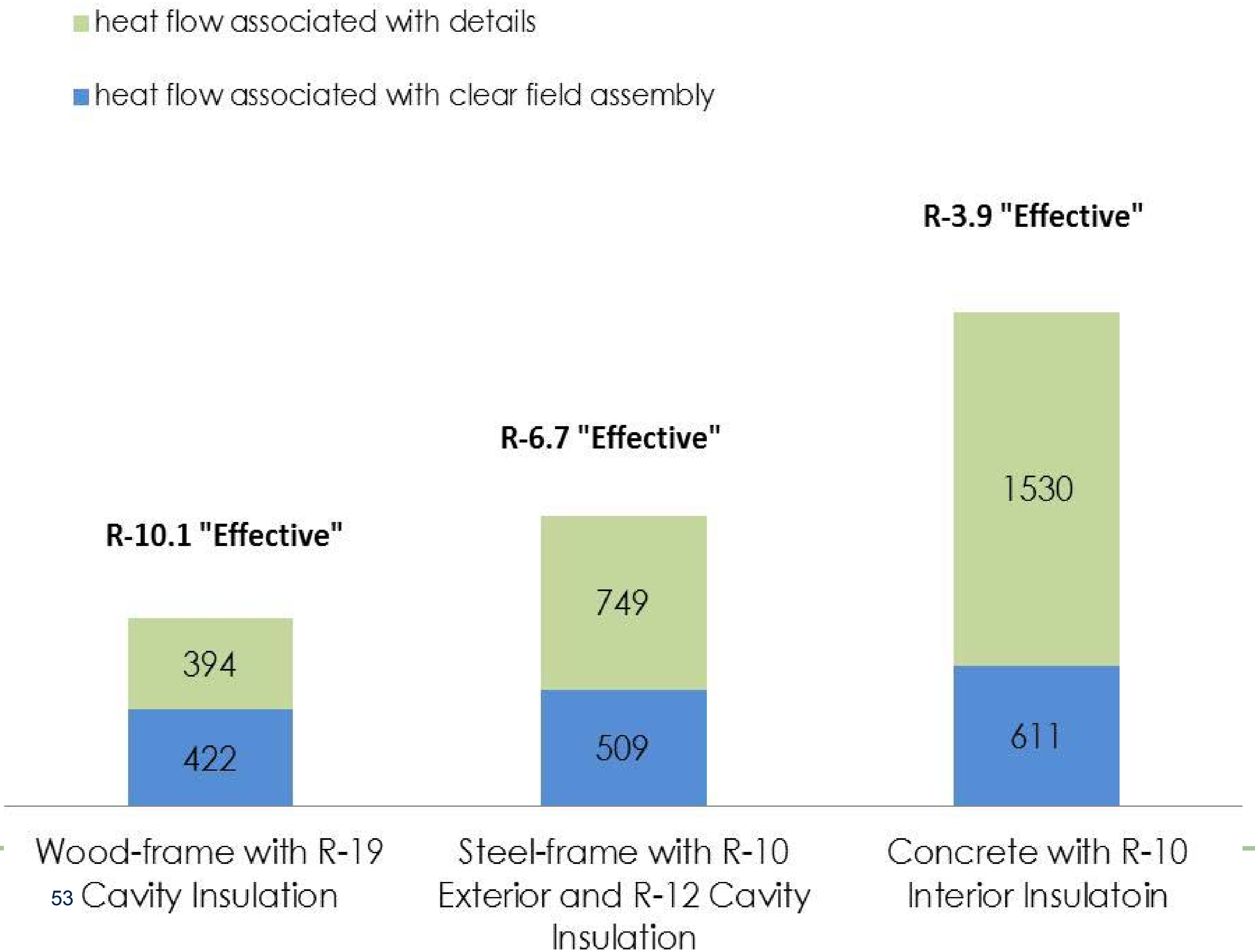




	Exterior Insulation 1D R-Value (RSI)	R_o ft²·hr·°F / Btu (m² K / W)	$R_{effective}$ ft²·hr·°F / Btu (m² K / W)	ψ Btu/ft hr °F (W/m K)	Minimum Temperature Index on slab
Continuous Beam	R-27 (4.79)	R-17 (3.04)	R-7 (1.19)	1.73 (0.92)	0.483
With Isokorb® type S	R-27 (4.79)	R-17 (3.04)	R-9 (1.61)	0.91 (0.48)	0.749

Insights

The impact depends on type of construction.



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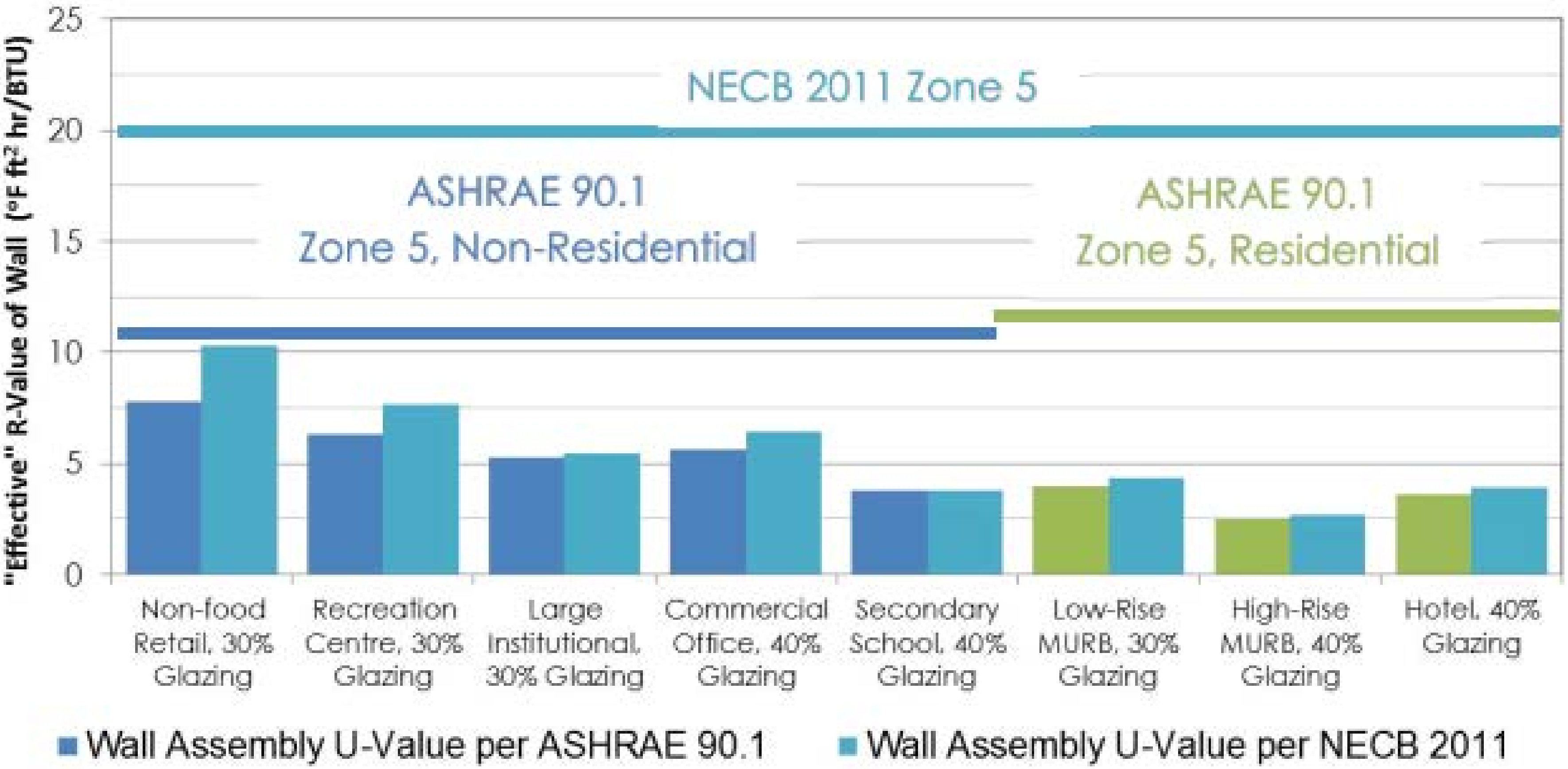
We Ain't Building What We Think We are Building



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Thermal bridges at transitions

not captured by ASHRAE wall assumptions

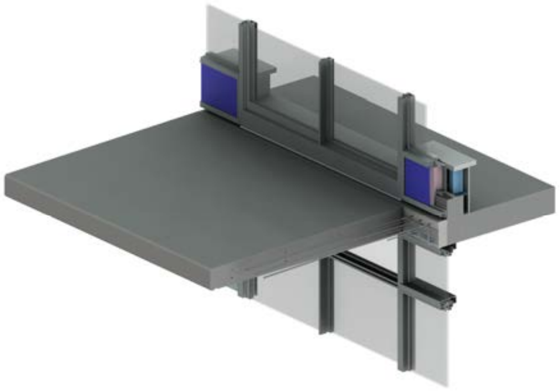
Just Adding Insulation is Seldom Effective

Adding More Insulation to Steel Stud Assemblies to go from an "Effective" R-value of R-15.6 to R-20

Building Type	Incremental Construction Cost	Energy Cost Savings	Payback (years)
Commercial Office	$ 94,825	$ 1,116	85
High-Rise MURB	$ 153,222	$ 2,542	60
Hotel	$ 64,650	$ 543	119
Large Institutional	$ 150,375	$ 1,833	82
Non-Food Retail	$ 24,192	$ 461	53
Recreation Centre	$ 28,400	$ 263	108
Secondary School	$ 36,325	$ 306	119

The Effectiveness of Adding More Insulation

- Even some “expensive” options look attractive when compared to the cost effectiveness of adding insulation
- The cost to upgrade to thermally broken balconies and parapets for the high-rise MURB with 40% glazing may require **two to three times the cost** of increasing effective wall assembly R-value from R-15.6 to R-20, but
- **Seven times more energy savings**
- Better details AND adding insulation translates to the most energy savings and the best payback period



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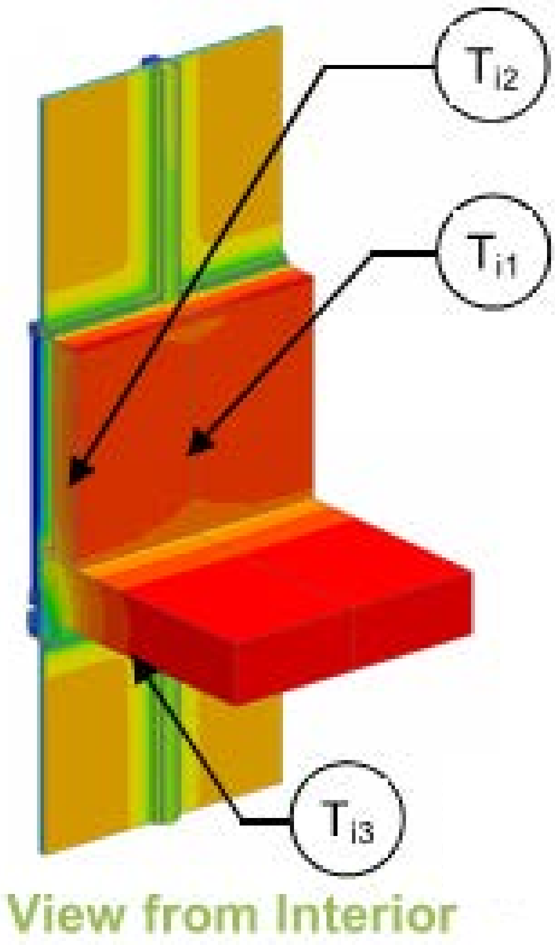
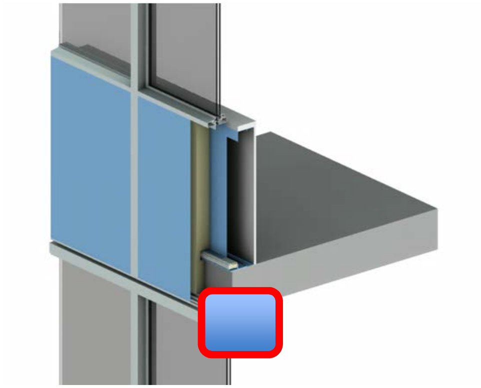
Glazing

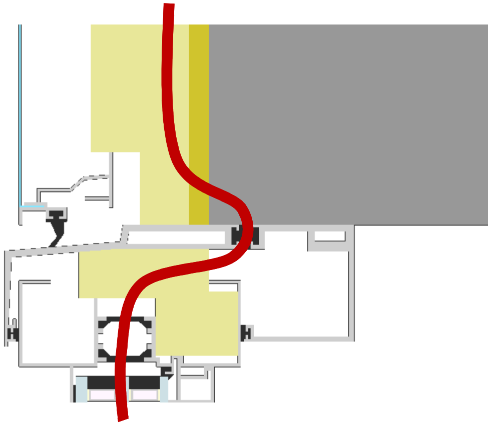


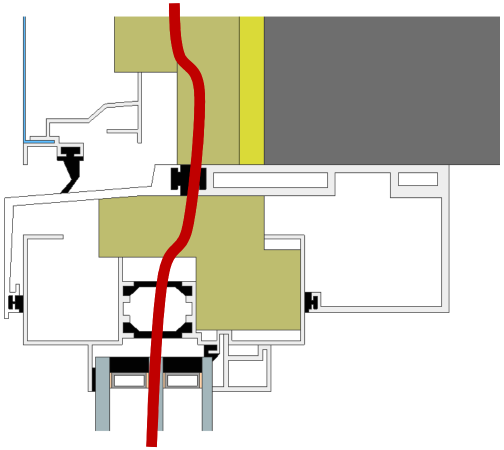
- Glazing area is major determinant of overall U
- U value of opaque spandrel closer to “glazing” values than “wall” values.
- The heat loss through transition elements such as deflection headers is large and usually not included in manufacturer's data
- Improvements can be made and some manufacturers are starting to make them

How to Improve?



Better Deflection Header?





Vision	U-0.21, R-4.7	U-0.21, R-4.7
Opaque	U-0.21, R-4.8	U-0.14, R-7.2

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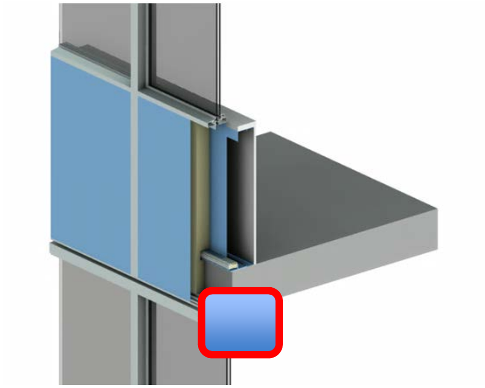
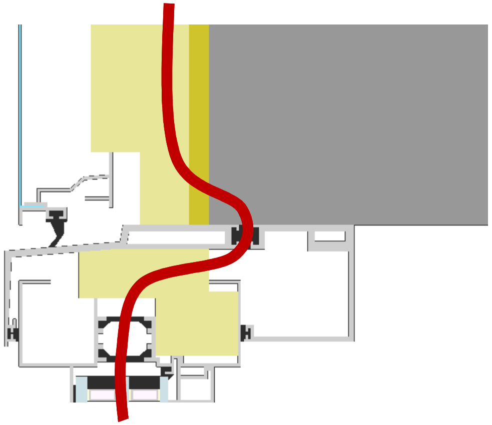
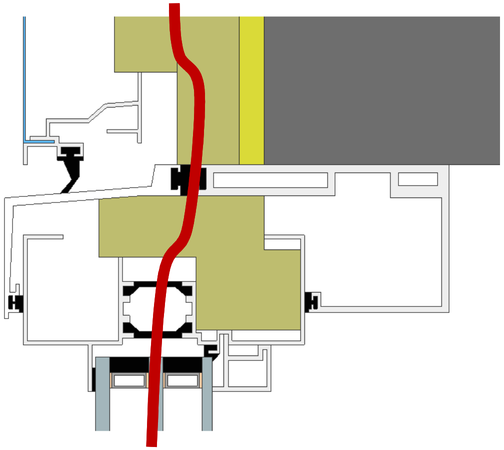
How to Improve?



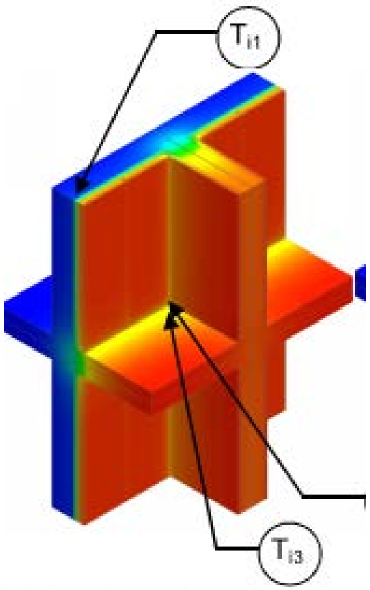
Better Deflection Header?



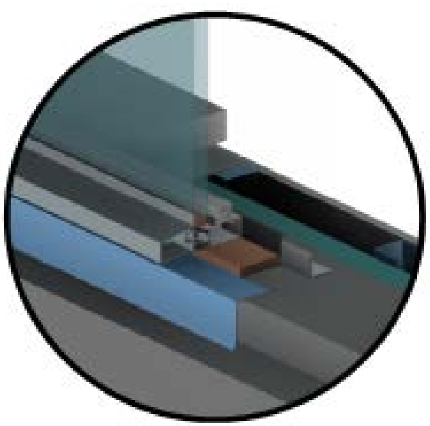


Vision	U-0.21, R-4.7	U-0.21, R-4.7
Opaque	U-0.21, R-4.8	U-0.14, R-7.2

Interior Insulated Concrete Buildings are a Challenge



View from Interior

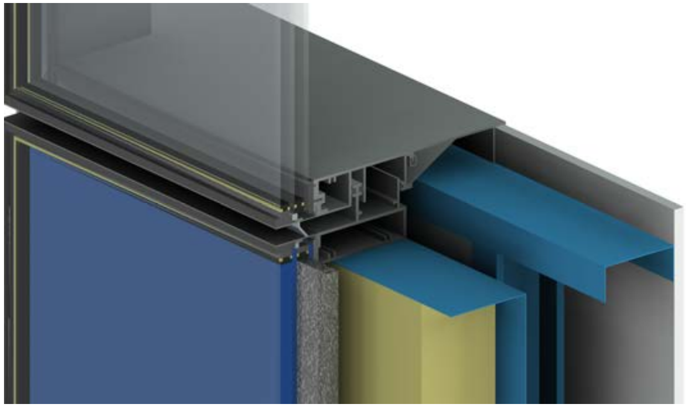


Window Sill Detail

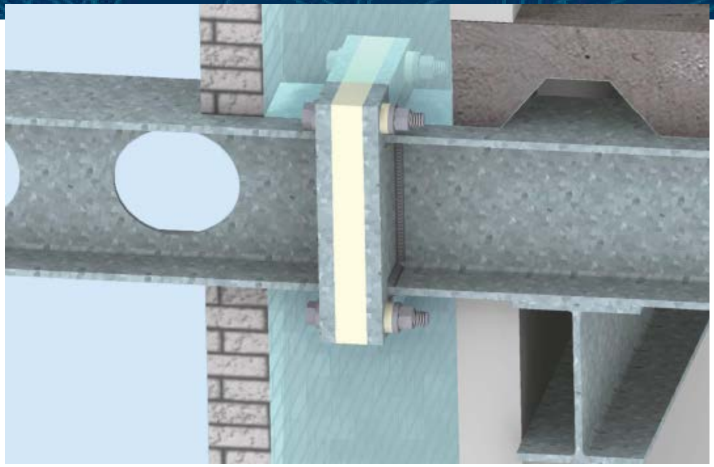
- Insulation interrupted by slabs and shear walls
- Attachment of windows cold concrete problematic

New and Innovative Technologies

- Cladding attachments
- Structural thermal breaks
- Vacuum insulated panels (VIP) in insulated glazed units for glazing spandrel sections

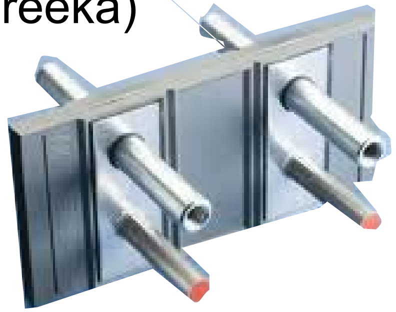


Structural Thermal Breaks

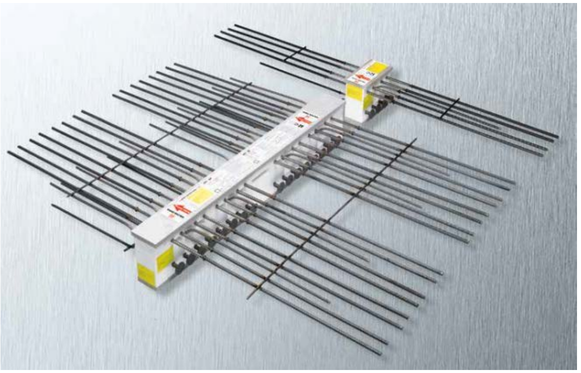


Structural thermal break (image courtesy of Fabreeka)

Structural thermal break (image courtesy of Schock)



Balcony connection (image courtesy of Lenton)



Thermal break (image courtesy of Halfen)

Readily Available Low Conductivity Structural Materials

PU structural thermal break (image courtesy of General Plastics)

Wood – courtesy of the forest ☺

PVC Structural thermal break (image courtesy of Armatherm)

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At Grade Solutions for Structural Thermal Breaks

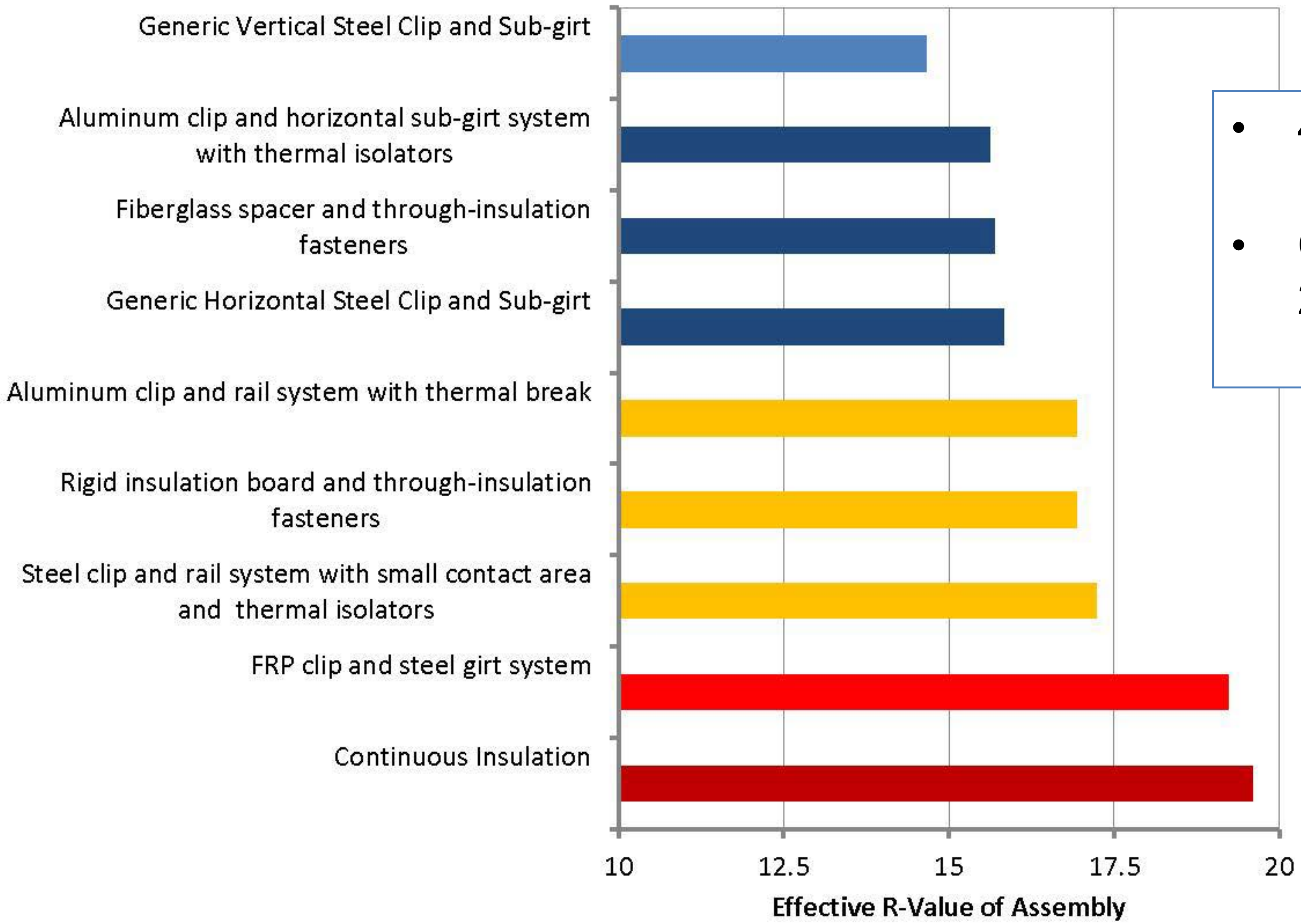
Aerated Concrete
(courtesy of Aercon)

Foam Glass
(courtesy of Perinsul)

EPS Concrete
(courtesy of Bremat)

Foam Glass (courtesy of Perinsul)

Proprietary Systems with Constant Spacing



- 4”, R-16.8 Exterior Insulation
- Clips/sub-girts at 24” o.c.

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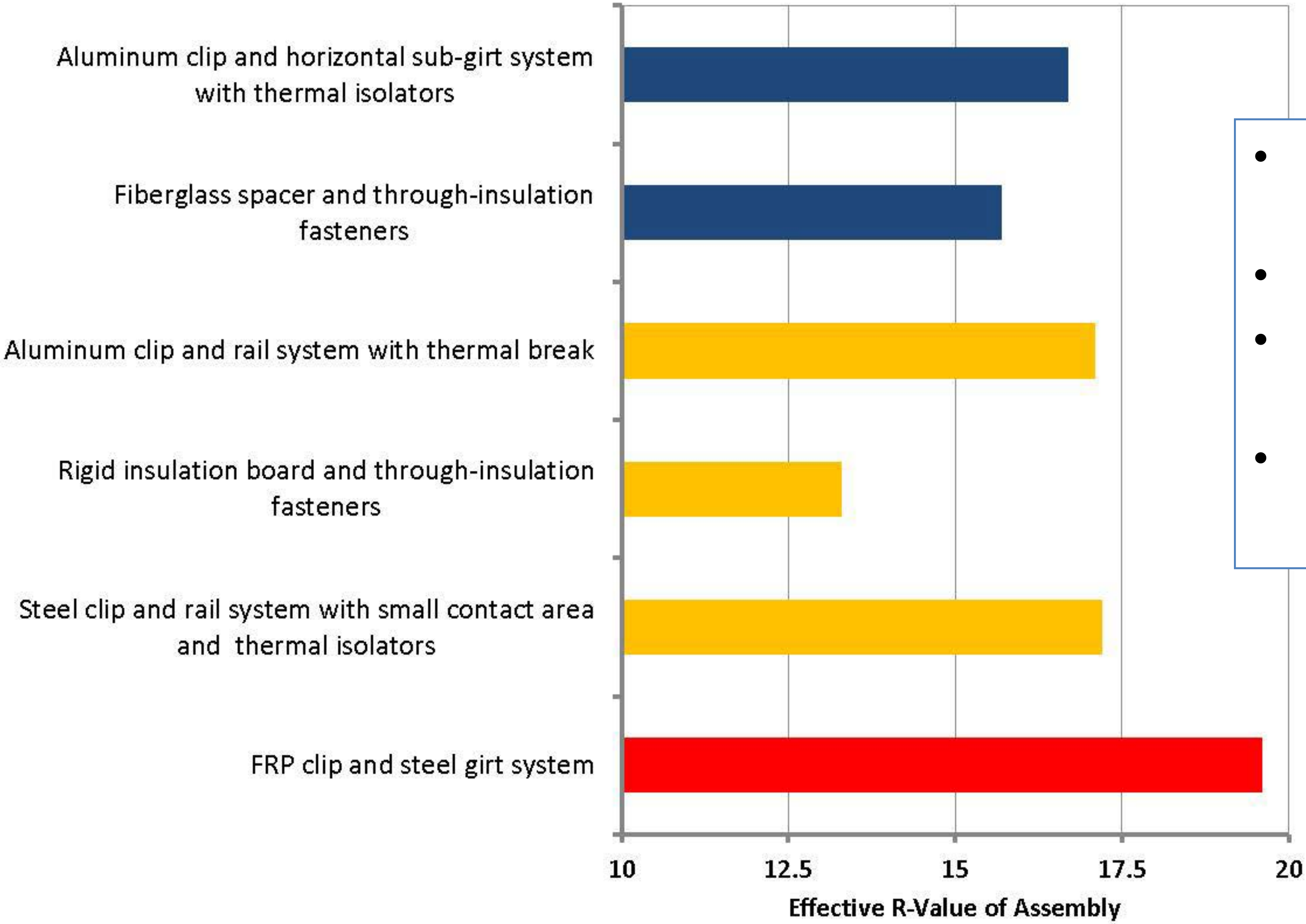
Thermal vs. Structural Performance



- Lightweight cladding (5 psf)
- 40 psf Wind
- 18 gauge steel studs
- 4”, R-16.8 Exterior Insulation

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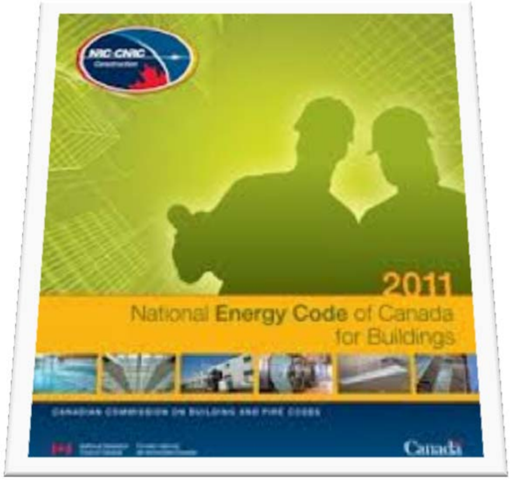
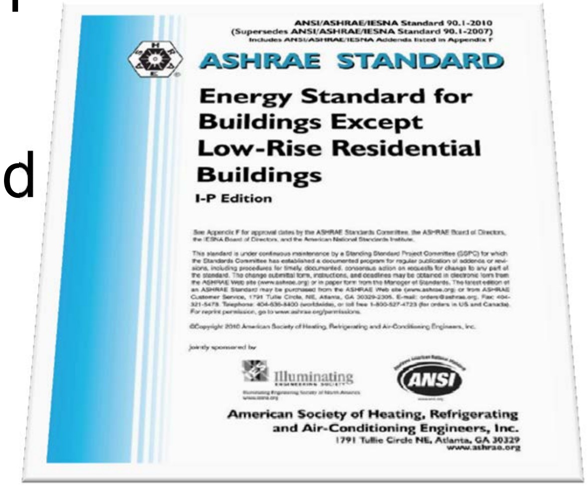
The Role of Energy Codes and Standards

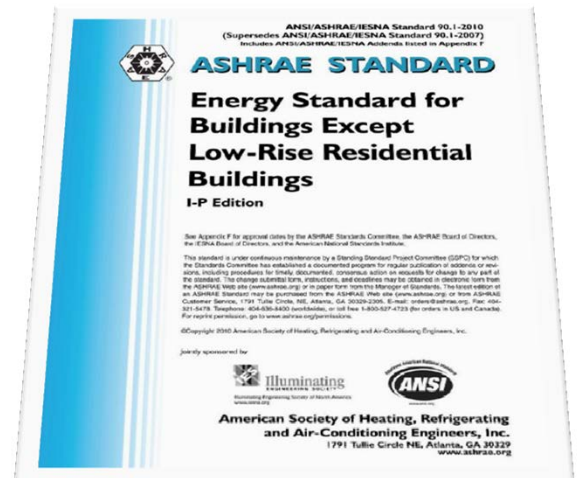
- Requiring that thermal bridging at interface details be considered will be the catalyst for market transformation
- Move past the idea that the only thing a designer or authority having jurisdiction needs to check is how much insulation is provided
- The guide can be leverage to help lead the way to constructive changes





- **Industry needs a level playing field**
- **Designers need options**
- **Incentivize effective solutions**

- **Changes to code are on the way**



Next Steps

- Improve the ability to enforce the code and level the playing field by adding clarity
- Adopt requirements that make sense for our climate and construction practice
- Replace “exceptions” based on wall areas with metrics that represent heat flow like linear transmittance or remove all exceptions
- Create incentives and reward improved details when practical
- Encourage good practice and a holistic design approach
- Use this guide to help policy and authorities implement programs that are more enforceable

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