Thermal Bridging

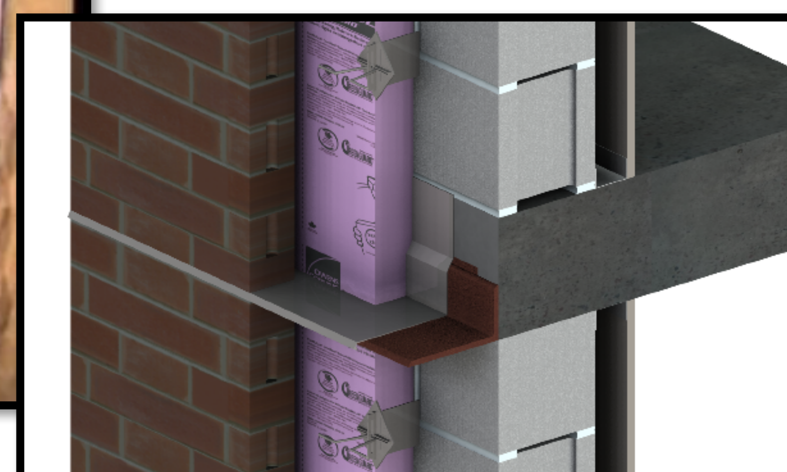
Good Enclosures Require More Than Adding Insulation

Washington DC
Sept 2016

Thermal Bridging

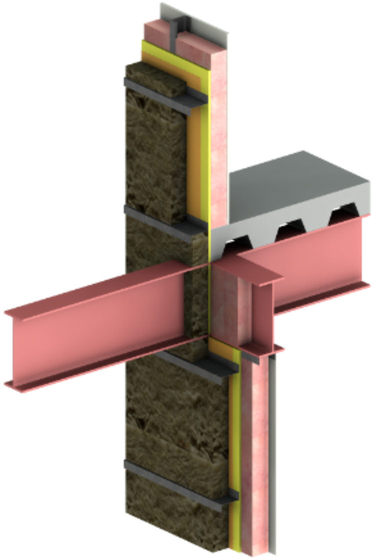
What is a Thermal Bridge?

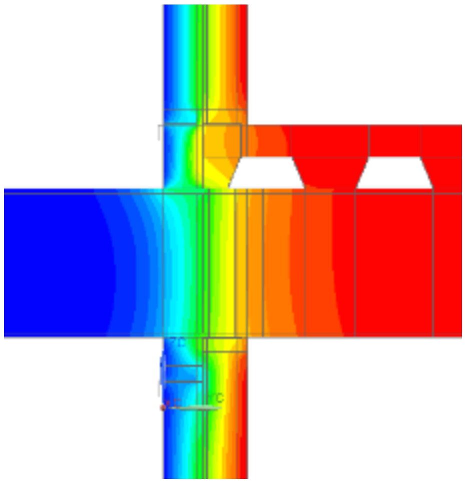
- Highly conductive material that by-passes insulation layer
- Areas of high heat transfer
- Can greatly affect the thermal performance of assemblies



Why Do We care about Envelope Thermal Performance

- Heat flows determine:
  - Heating and cooling system capacity
  - Purchased energy requirements
  - Compliance with energy codes
  - Compliance with voluntary energy programs
- Arrangement of materials determine:
  - Surface temperatures
  - Condensation and moisture collection
  - Durability
  - Mold growth and health issues





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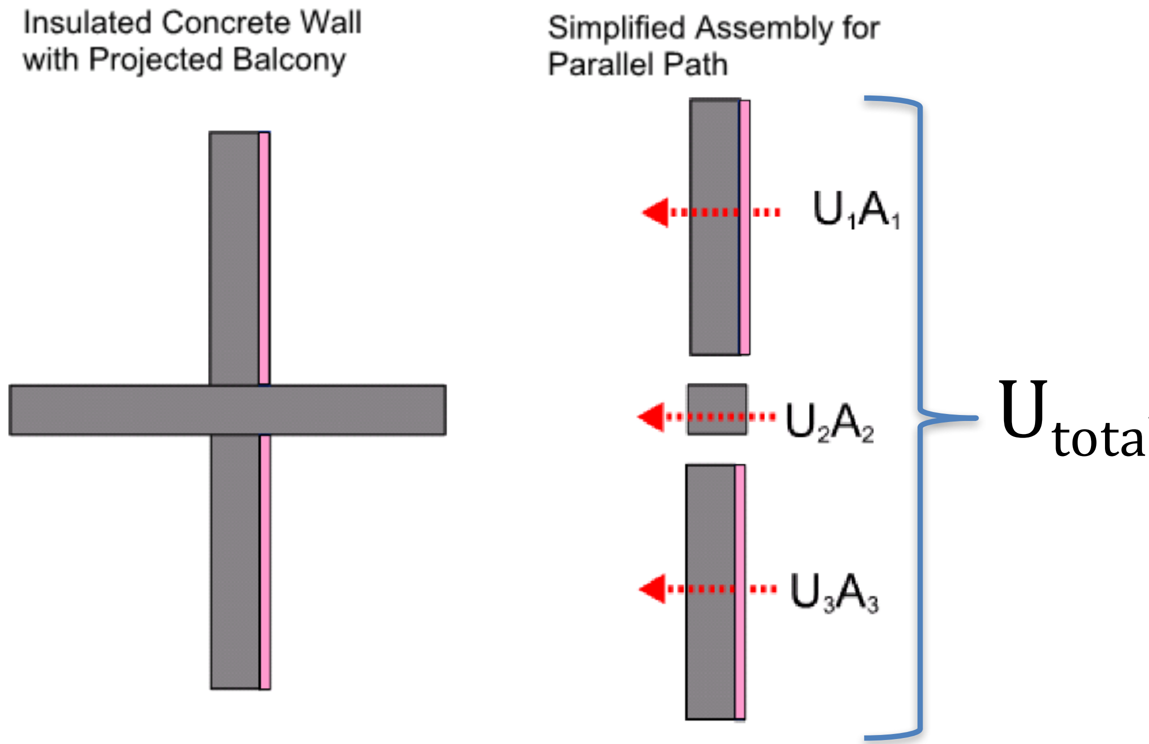
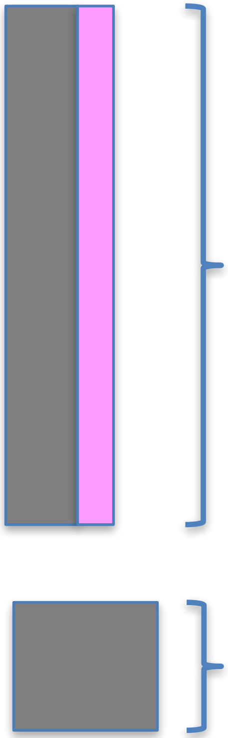
Parallel Path Heat flow

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



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

Parallel Path



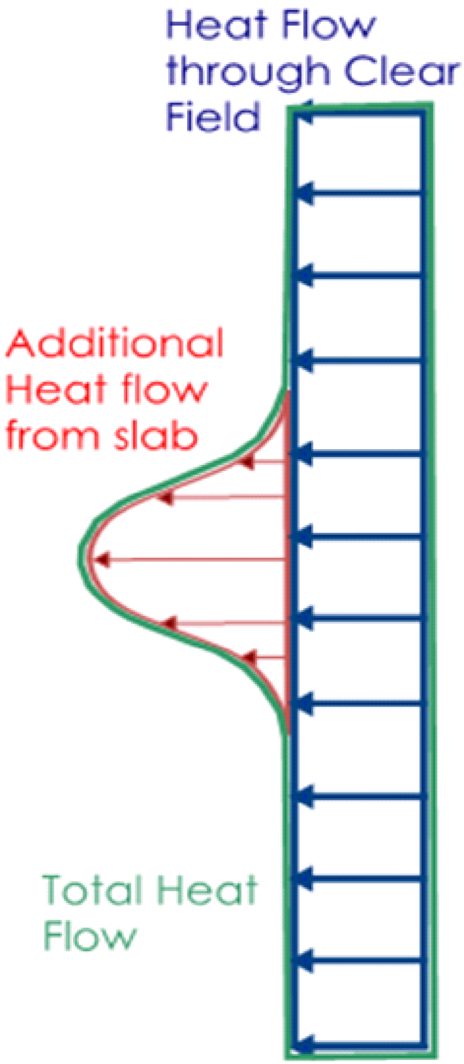
R20 for 8’3” wall

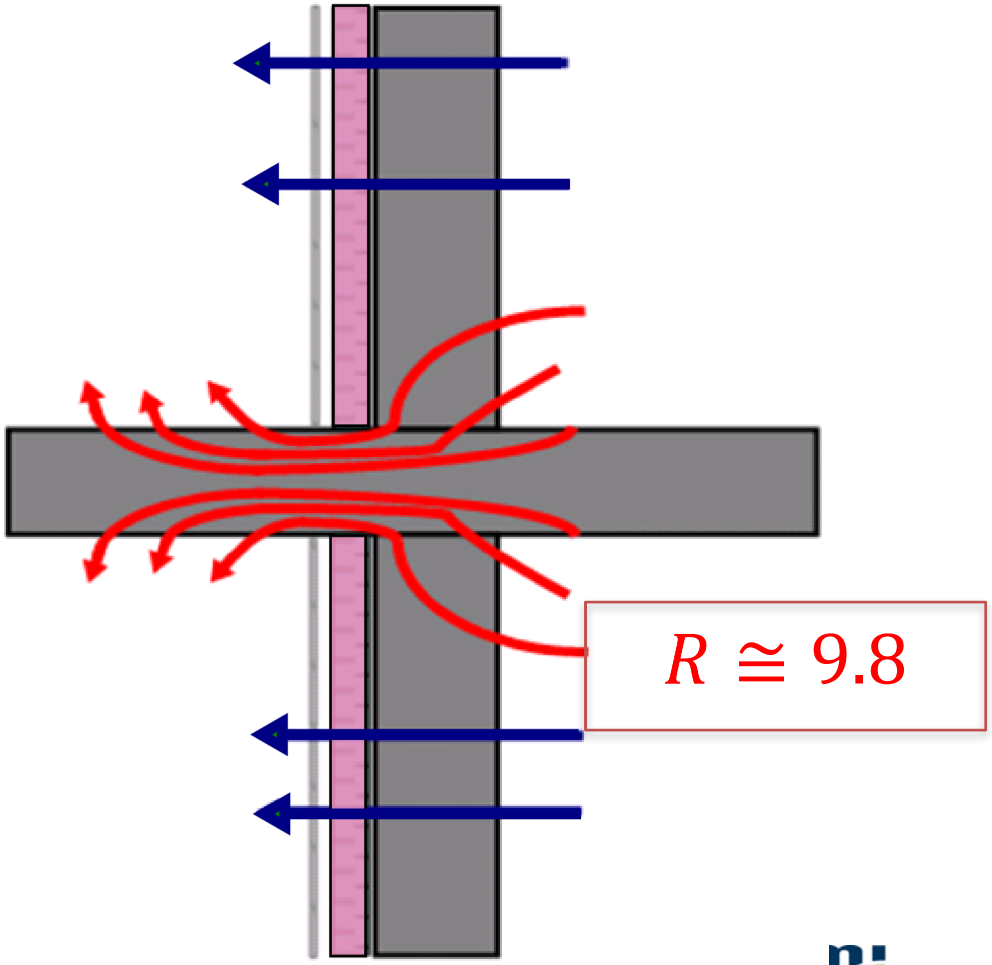
R2 for 9” slab edge

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

$$R \cong 11.5$$

Addressing lateral Heat Flow





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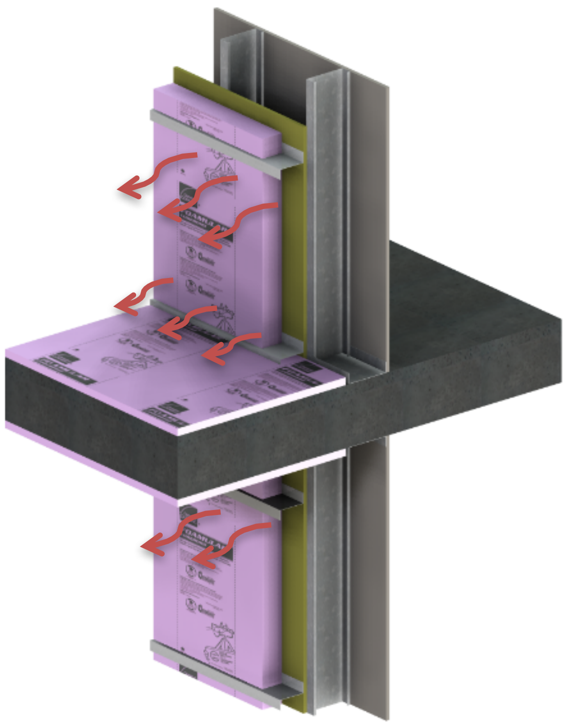
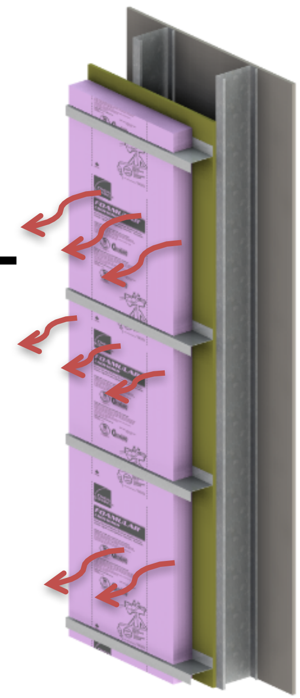
Figuring Out Linear Losses

Q



$-$

Q_o



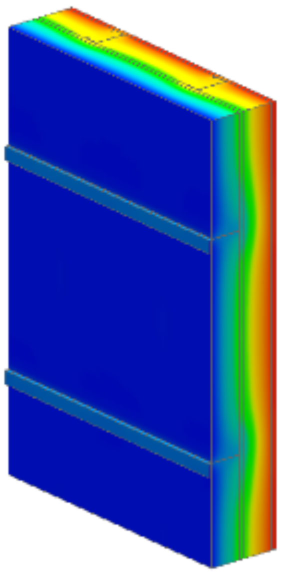
$=$

Q_{slab}

Additional heat loss due to the slab

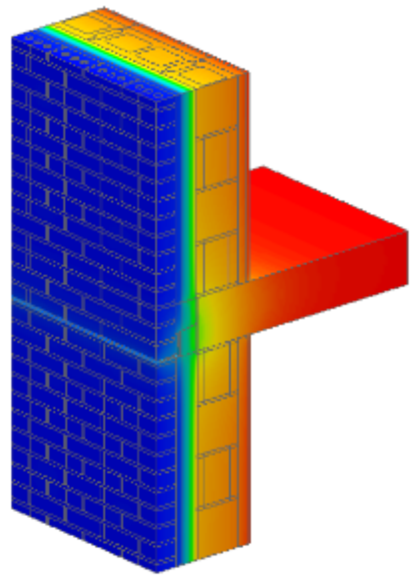
The Conceptual Leap

Types of Transmittances



Clear Field

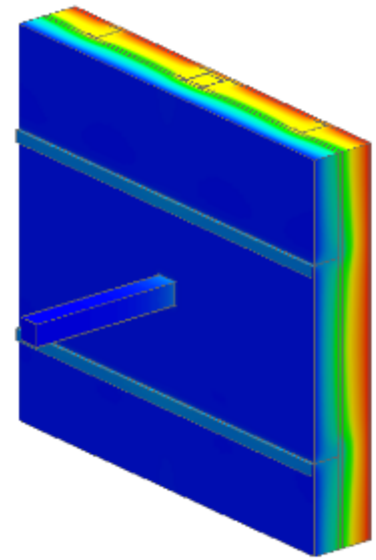
U_o



Linear

Ψ

psi



Point

χ

chi

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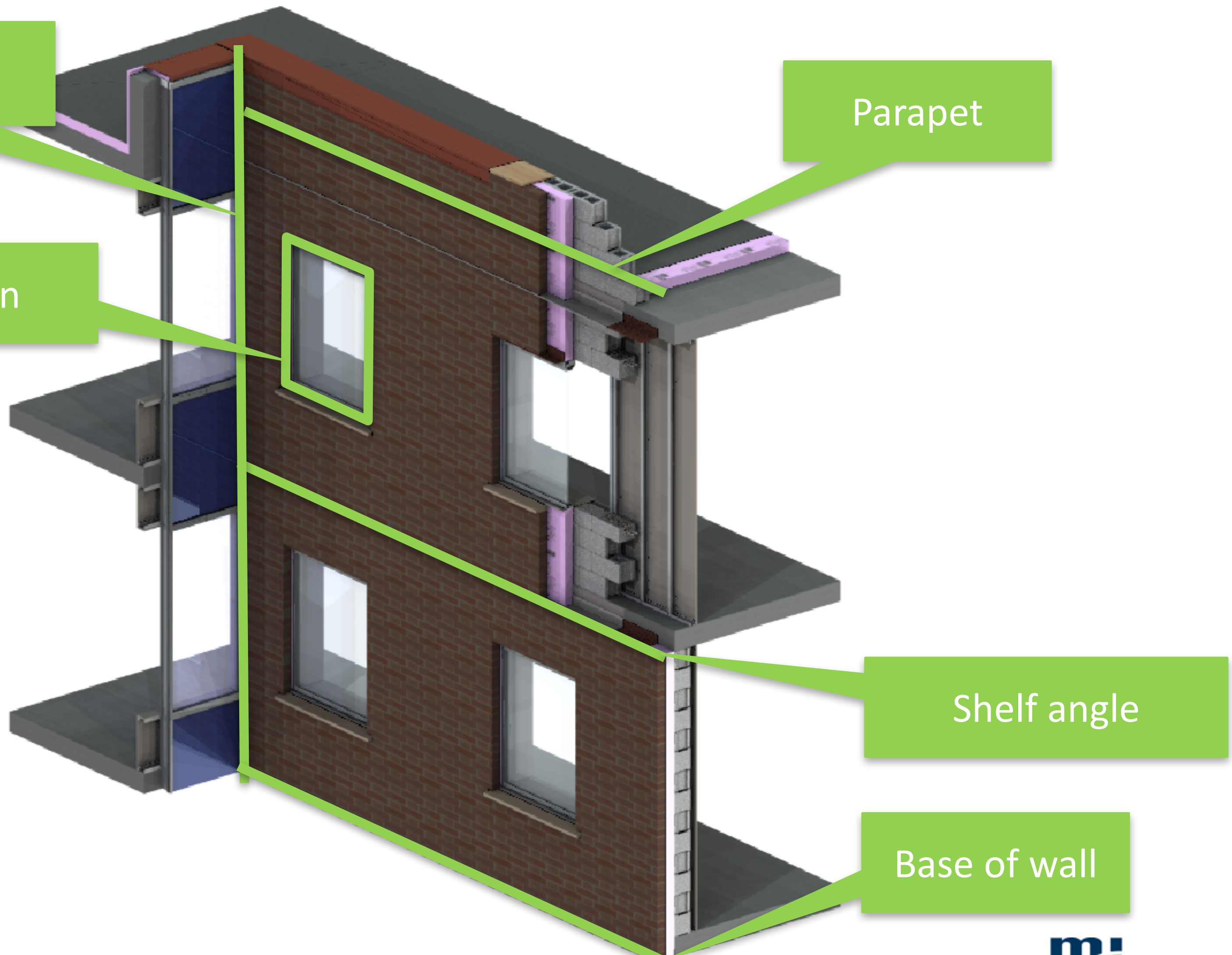
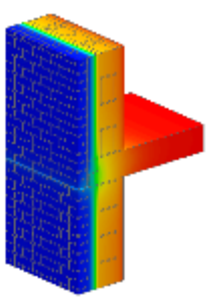
Building Envelope Analysis





Linear

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Overall Heat Loss

Total Heat loss	=	heat loss due to clear field	+	Heat loss due to interface details

OR

$$Q / \Delta T = (U_o \cdot A_{Total}) + \Sigma(\Psi \cdot L) + \Sigma(\chi)$$

OR

$$U_T = \frac{\Sigma(\Psi \cdot L) + \Sigma(\chi)}{A_{Total}} + U_o$$

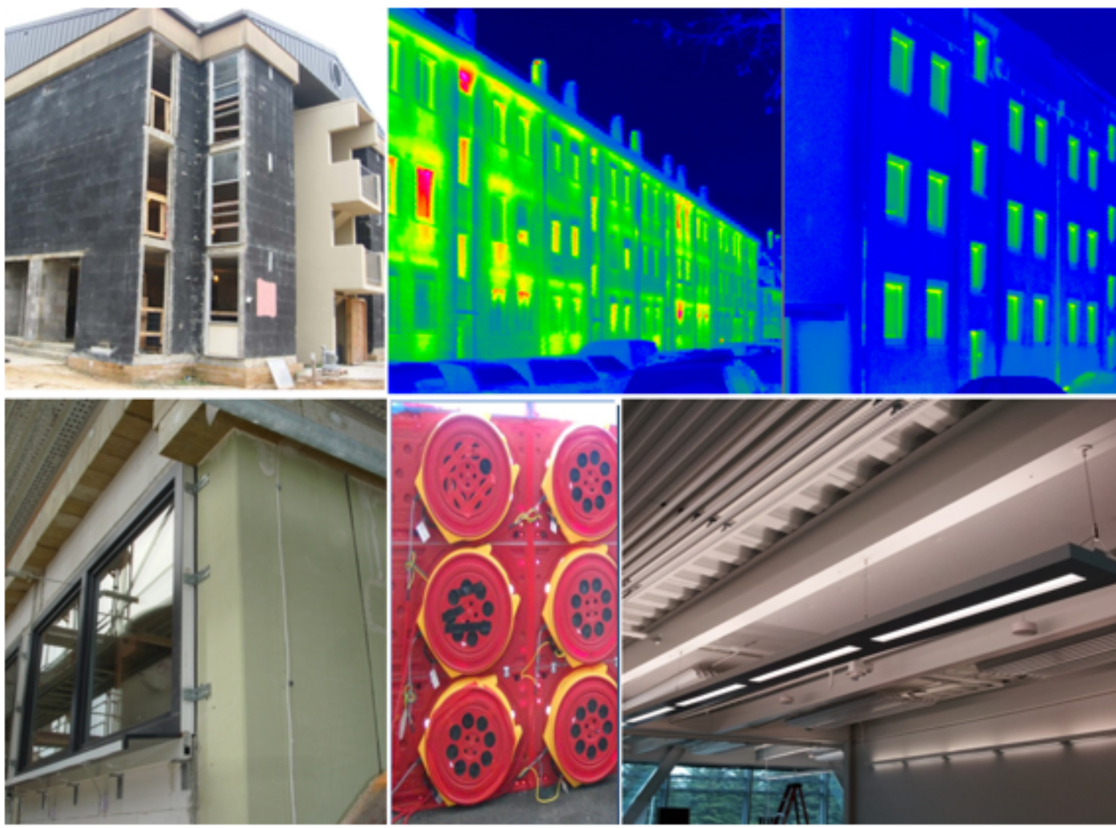
Where to Find Data

International·Energy·Agency¶

Deep·Energy·Retrofit¶

**A·Prescriptive·Guide·to·Achieve·Significant·Energy·Use·
Reduction·with·Major·Renovation·Projects¶**

Annex·61,·Subtask·A¶



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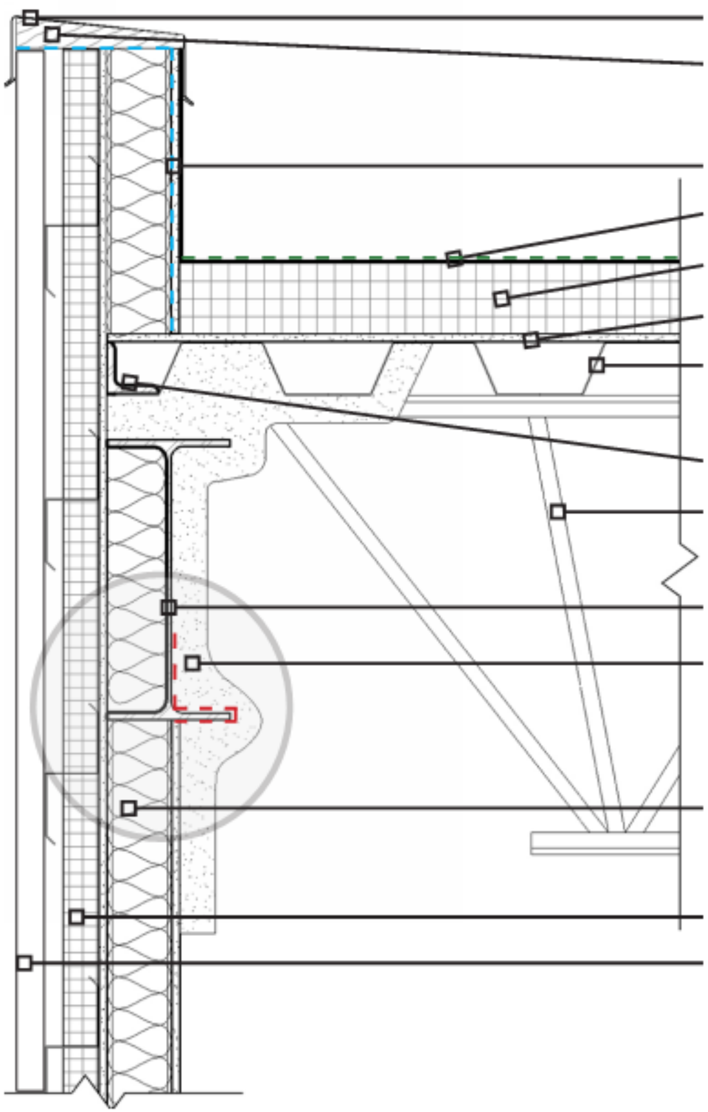
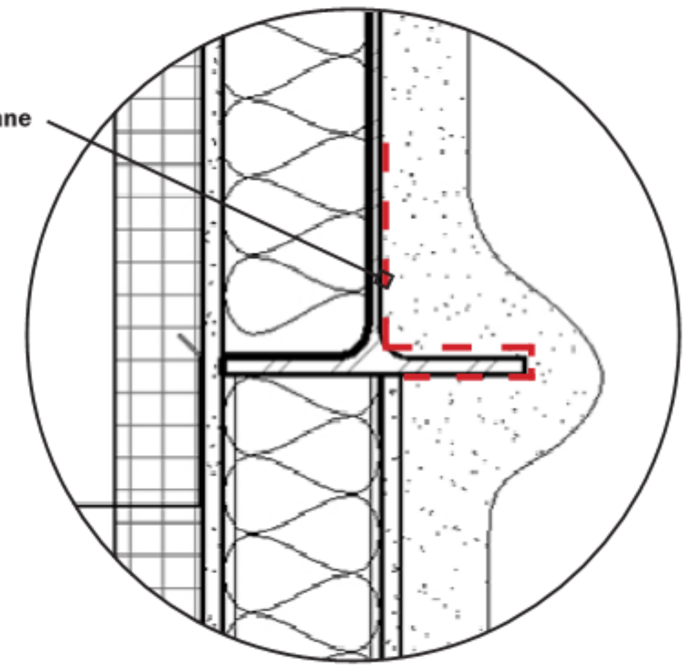
Best-Case Thermal Loss Reduction: 0.529 Btu/h • ft • °F

Proposed retrofit



Detail from inset



Q/C and sequencing

Details

1. Apply a layer of spray foam insulation at the interior roof/wall intersection region.
2. Apply a finish layer of spray-on fire protection over the insulation.

Note

For improved performance, see proposed solution 1d for exterior under

Where to Find Data

CERL US Army
W9132T-10-D-0002

Solutions and Instructional Aids for Prevention of Thermal Bridges

August 21st 2014
Web Based Presentation

- **Project Team**
- Mark Lawton, Morrison-Hershfield
- Bob Ryan, Passive House Academy
- John Straube, Building Science Consulting Inc.

Passive House Academy

Morrison Hershfield

buildingsciencelabs

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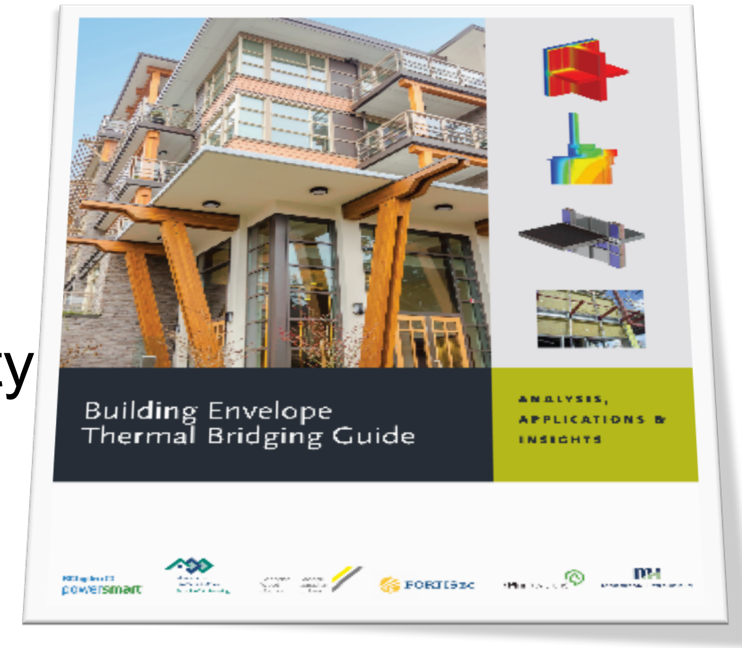
Where to Find Data

- Building Envelope Thermal Bridging Guide
  - Extensive catalogue of assemblies and details (400+)
  - Includes clear field, linear and point transmittances for a variety of constructions and configurations
  - How to section with examples
  - Energy and Cost Benefit Analysis
  - Industry and Policy Implications



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Power smart

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Residential ▾ | **Business** ▾ | Alliance of Energy Professionals ▾ | Local government

Home › Energy Savings › Business › Programs & Incentives › Commercial New Construction

Commercial New Construction

By being a leader in energy management, we can assist with resources, potential funding and technical assistance to building owners, developers and the design industry to create high-performance, energy-efficient buildings.

PROGRAMS & INCENTIVES

- Leaders in energy management
- Business energy-saving incentives
- Commercial energy management assessment
- Energy performance contracts
- Continuous optimization
- Energy studies & audits
- Industrial project incentives

Building envelope thermal bridging guide

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

Version 1.1 – April 2016

Many details and assemblies were added to the thermal performance catalogue (Appendix A and B) of BETB Guide Version 1.1. The sections related to the cost benefit analysis and market transformation have been removed so that the new version focuses only on providing thermal performance data and how to utilize this information in everyday practice.

Refer to the original version of the BETB Guide released in 2014 for sections related to energy savings and cost benefit analysis (Part 2) and market transformation (Part 3: Significance, Insights, and Next Steps). These documents are still relevant to current realities but are not material that need to be referenced in everyday practice and have not been updated since the original version of the BETB Guide.

- Building Envelope Thermal Bridging Guide – Version 1.1 [PDF, 7.0 MB]
- Appendix A – Catalogue Material Data Sheets – Version 1.1 [PDF, 63.1 MB]
- Appendix B – Catalogue Thermal Data Sheets – Version 1.1 [PDF, 56.7 MB]

Version 1.0 – October 2014

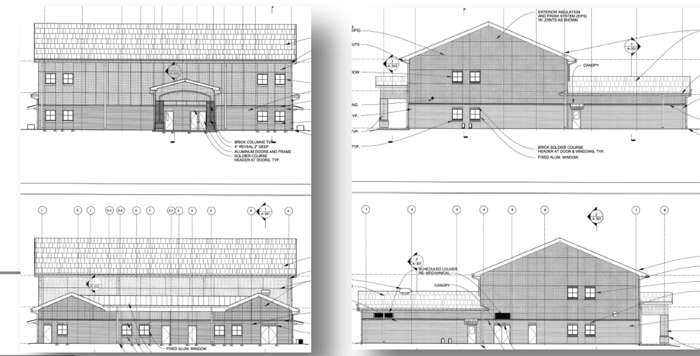
Most practitioners will find PART 1 and Appendices A and B to be most useful. PART 1 outlines how to effectively account for thermal bridging. Appendices A and B provide a catalog of common building envelope assemblies and interface details, and their associated thermal performance data.

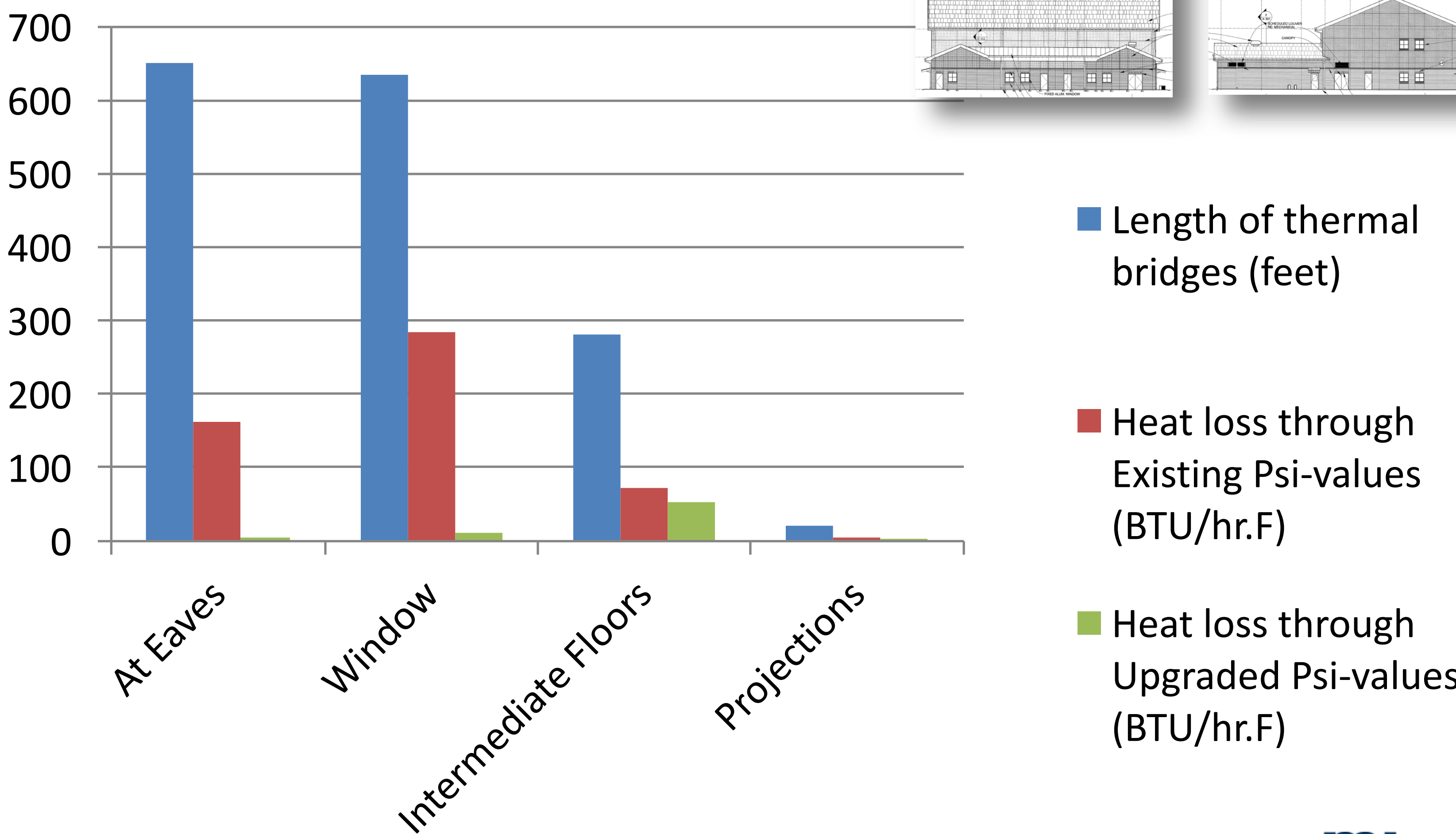
Researchers and regulators will be interested in PART 2 and PART 3, and Appendices C to E. They contain the cost-benefit analysis, and discussion on significance and further insights, of using this guide to mitigate thermal bridging in buildings.

CATALOGUE INDEX

Magnitude of Heat Losses through Thermal Bridges in Combat Team Complex

External Insulation





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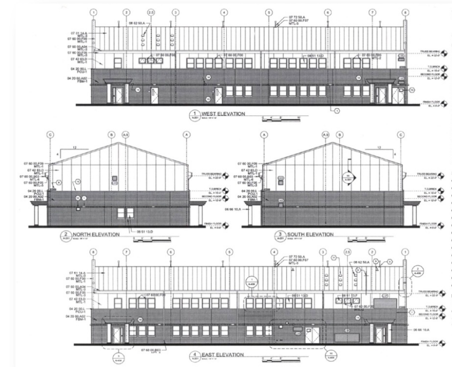
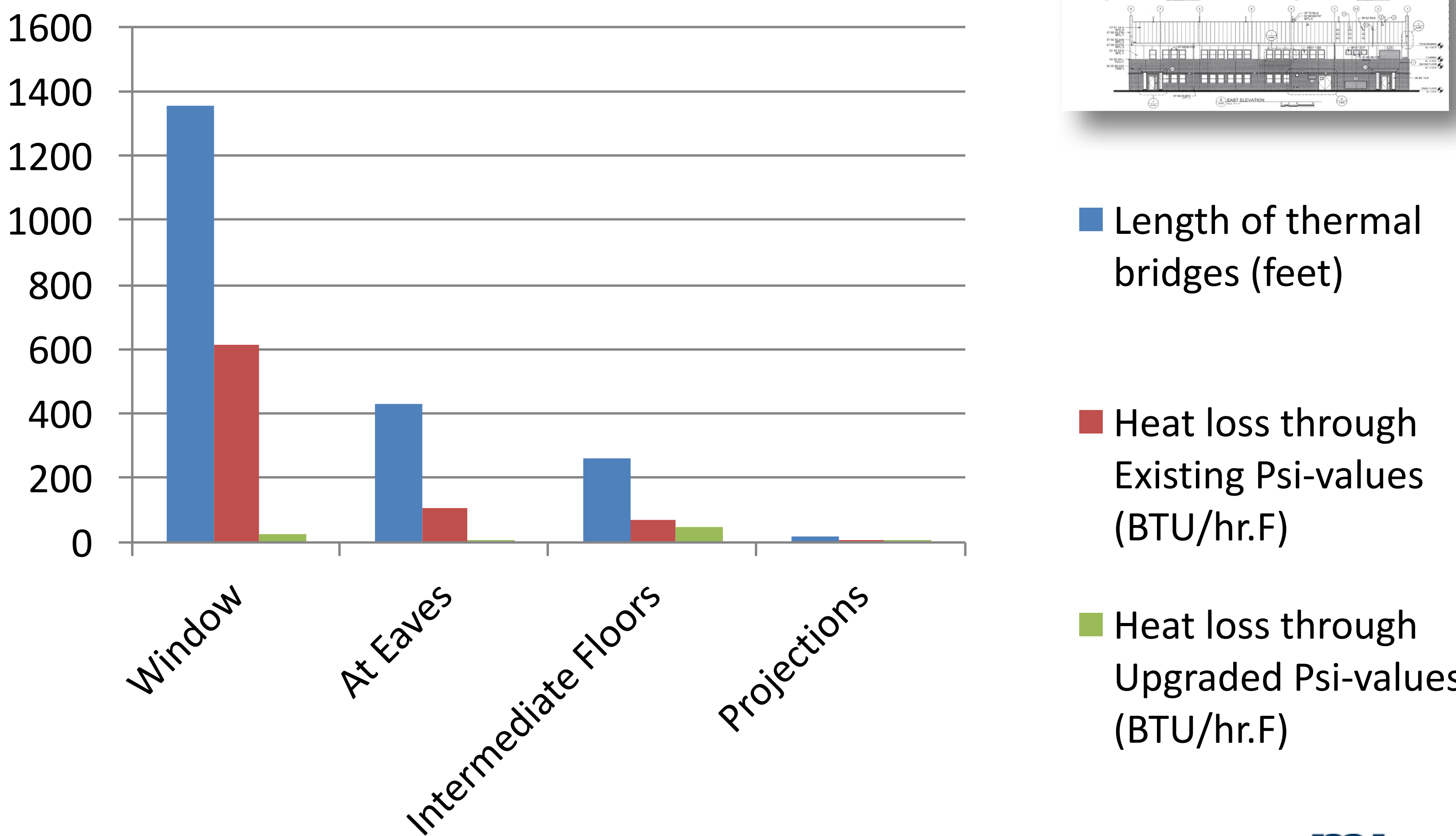
Magnitude of Heat Losses through Thermal Bridges in Administrative Buildings

External Insulation





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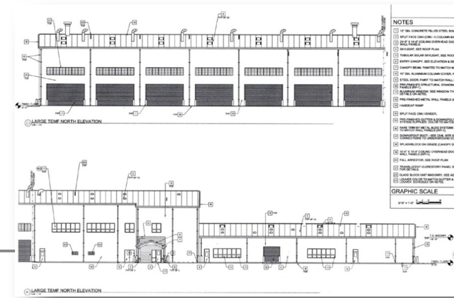
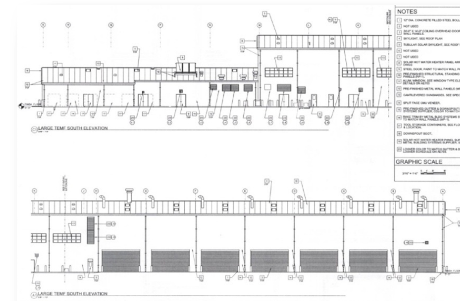
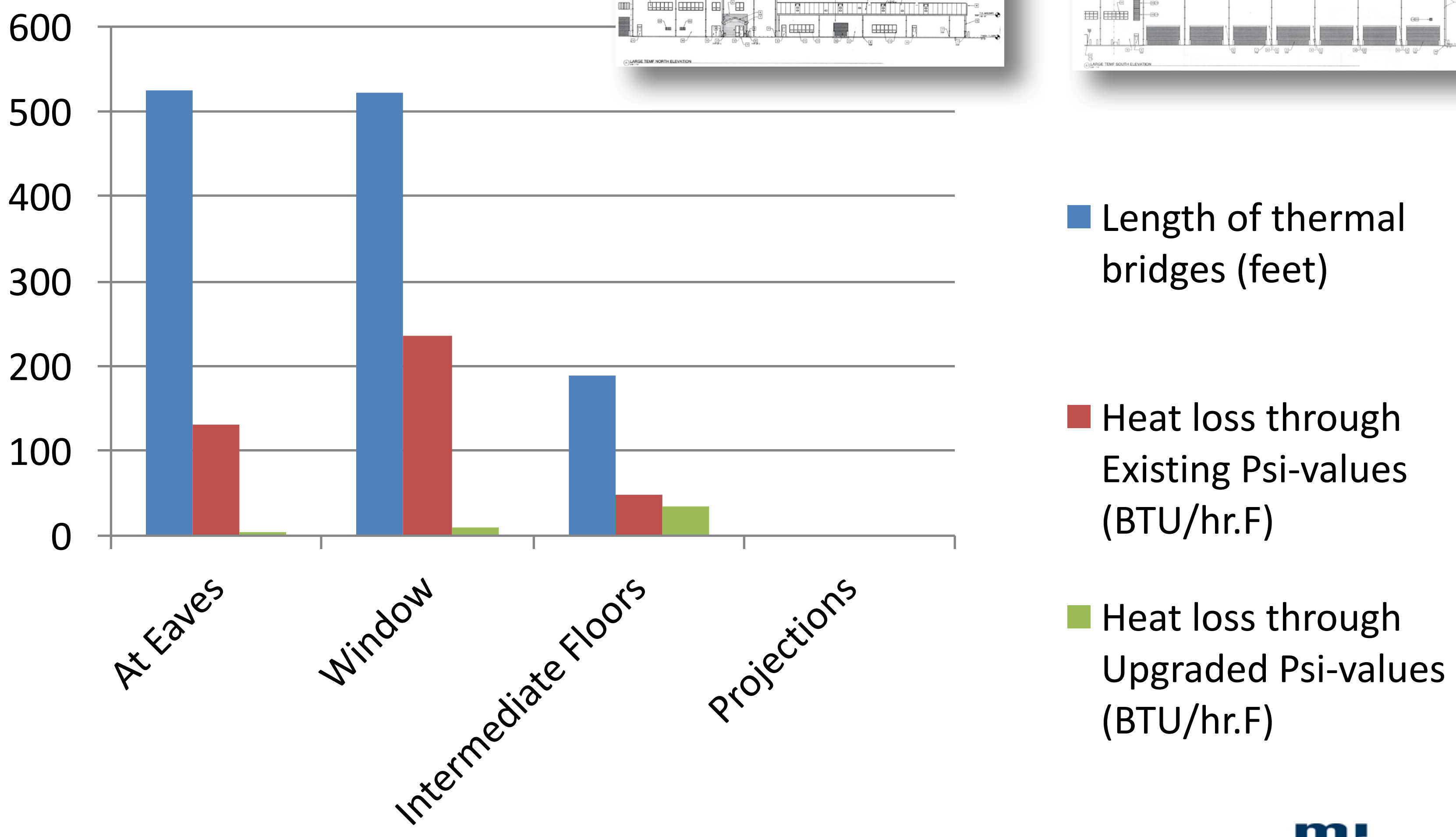
Magnitude of Heat Losses through Thermal Bridges in Large TEMF

External Insulation







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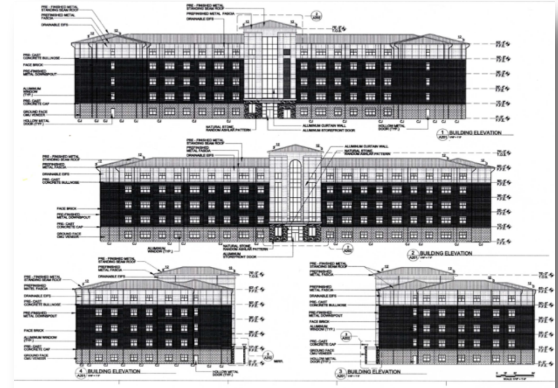
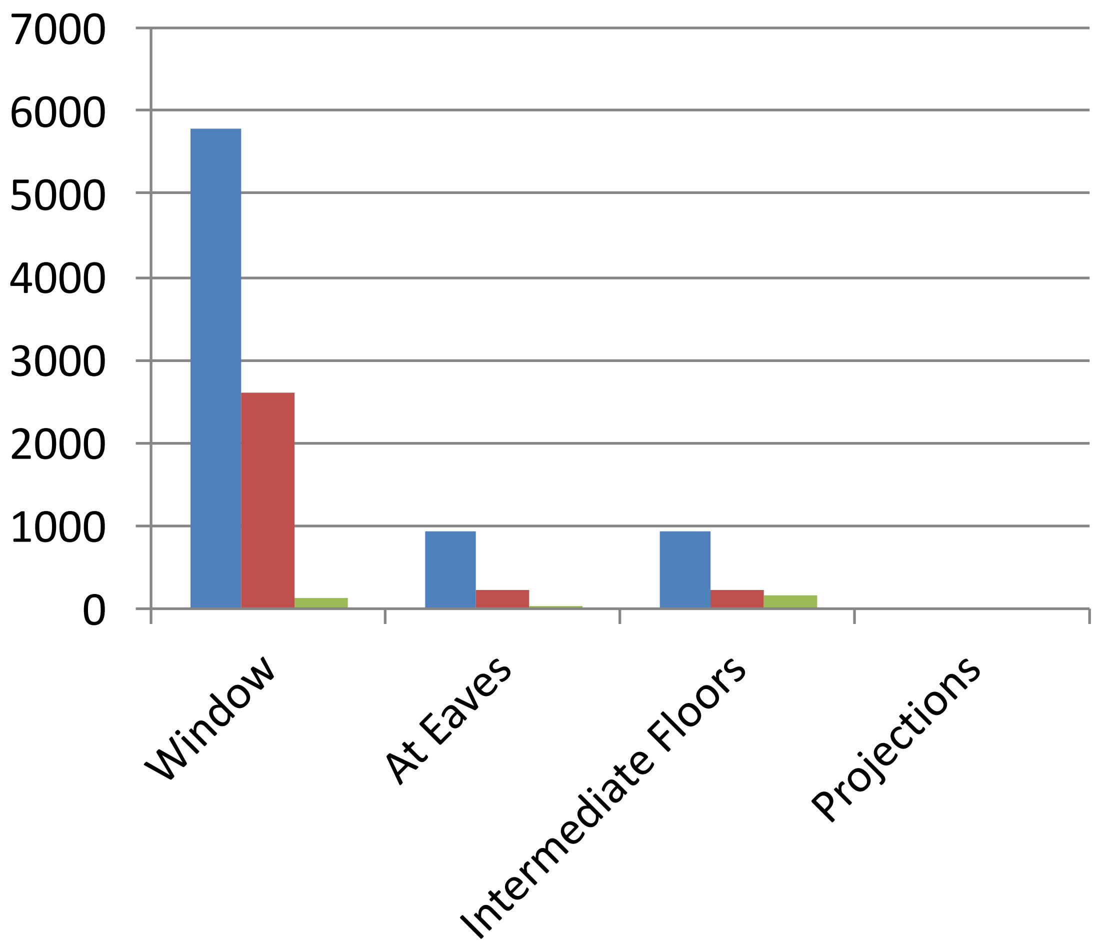
Magnitude of Heat Losses through Thermal Bridges in Administrative Buildings

External Insulation





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BUILDING ENVELOPE ANALYSIS

○ Sum of Active Clear Field Areas (Default)	55508.00	ft^2
○ User Defined Area	Enter User Defined Opaque Area	ft^2

Opaque U-Value (BTU/hr ft^2 °F)	0.139
Effective R-Value (hr ft^2 °F/BTU)	7.2

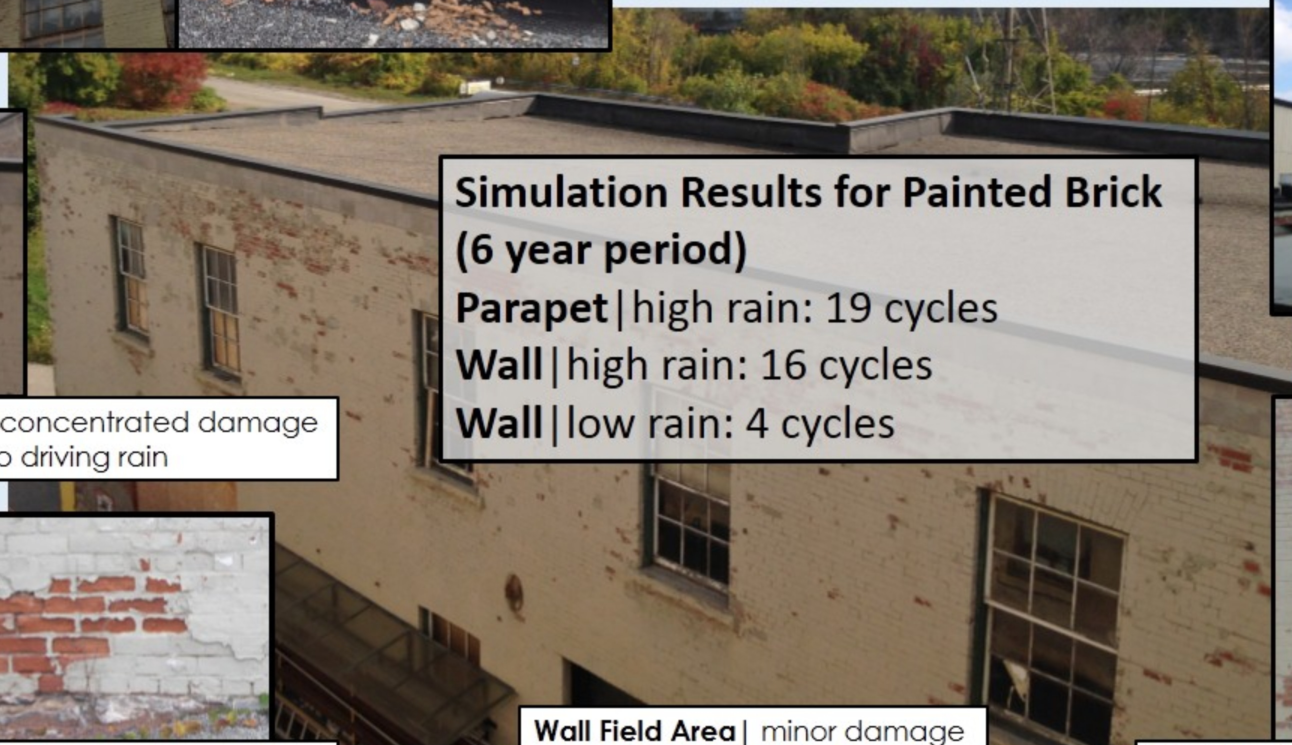
Proposed Building Entries

Add/Remove Detail	Transmittance Type	Include	Transmittance Description	Area, Length or Amount Takeoff	Units	Transmittance Value	Units	Source Reference	Heat Flow (BTU/hr°F)	%Total Heat Flow
								Totals	7707.8	100%
Add Clear Field	Clear Field	☑	Spandrel Panel	9036.00	ft^2	0.130	BTU/ hr ft² °F	Enter Source Here	1174.7	15%
Remove Clear Field	Clear Field	☑	Concrete Wall	46472.00	ft^2	0.070	BTU/ hr ft² °F	Enter Source Here	3253.0	42%
Add Linear Interface Detail	Linear Interface Detail	☑	Parapet at WW	298.00	ft	0.125	BTU/ hr ft °F	Enter Source Here	37.3	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Parapet at CW	50.00	ft	0.058	BTU/ hr ft °F	Enter Source Here	2.9	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Parapet WW-Deck	89.00	ft	0.470	BTU/ hr ft °F	Enter Source Here	41.8	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Parapet CW-Deck	35.00	ft	0.450	BTU/ hr ft °F	Enter Source Here	15.8	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Glazing Trans Vert	19938.00	ft	0.050	BTU/ hr ft °F	Enter Source Here	996.9	13%
Remove Linear Interface Detail	Linear Interface Detail	☑	Glazing Trans Horiz	2072.00	ft	0.050	BTU/ hr ft °F	Enter Source Here	103.6	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Balcony at WW	4477.00	ft	0.177	BTU/ hr ft °F	Enter Source Here	792.4	10%
Remove Linear Interface Detail	Linear Interface Detail	☑	Balcony at CW	1776.00	ft	0.140	BTU/ hr ft °F	Enter Source Here	248.6	3%
Remove Linear Interface Detail	Linear Interface Detail	☑	Spandrel Bypass	3589.00	ft	0.290	BTU/ hr ft °F	Enter Source Here	1040.8	14%
Remove Linear Interface Detail	Linear Interface Detail	☐	Eyebrow	888.00	ft	0.500	BTU/ hr ft °F	Enter Source Here	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☐	Shear Wall	1295.00	ft	0.660	BTU/ hr ft °F	Enter Source Here	0.0	0%

Example – Ottawa Industrial Buildings

Parapet | extenstive severe damage
- Un-heated, high exposure to snow Melt, driving rain, solar

Un-heated Wall | localized severe damage
- high exposure to rain and run-off



Simulation Results for Painted Brick (6 year period)

Parapet | high rain: 19 cycles

Wall | high rain: 16 cycles

Wall | low rain: 4 cycles

Corner | moderate concentrated damage
- high exposure to driving rain

Base of Wall | localized severe damage
- high exposure to snow melt

Wall Field Area | minor damage
- medium to low Exposure to driving rain

Window Sill | locatized damage
- water/snow run-off

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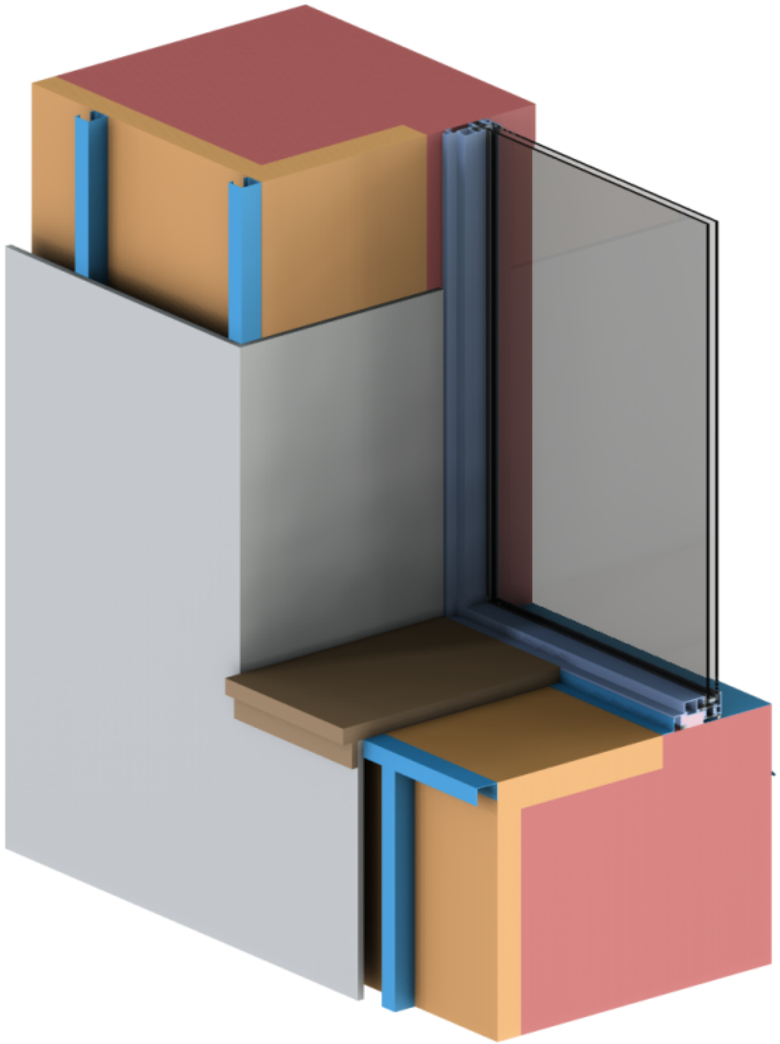
EXAMPLE – WALL AND WINDOW INSULATION OPTIONS



[Link to spreadsheet]

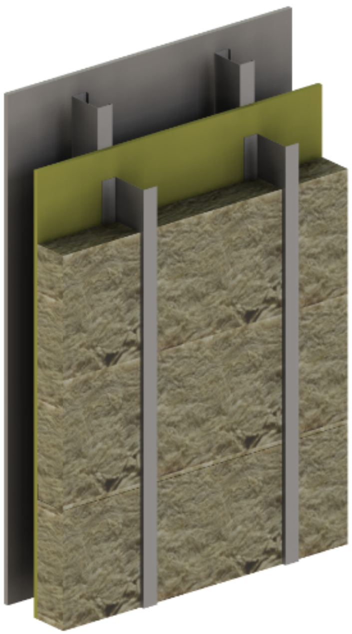
Building Envelope Priorities

Priority 1
- Vision Area / Glazing Ratio
- Clear Field Assemblies

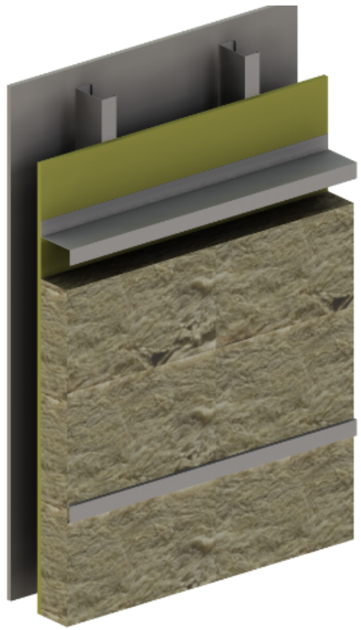
Priority 2
- Slab Edge
- Window Transitions
- Parapet

Priority 3
- Other details (corners)
- Isolated features (entrance canopy, etc.)

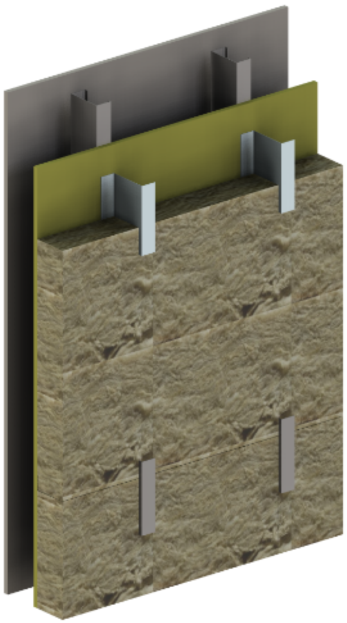
CLEAR FIELD ASSEMBLIES



Vertical Z-Girts



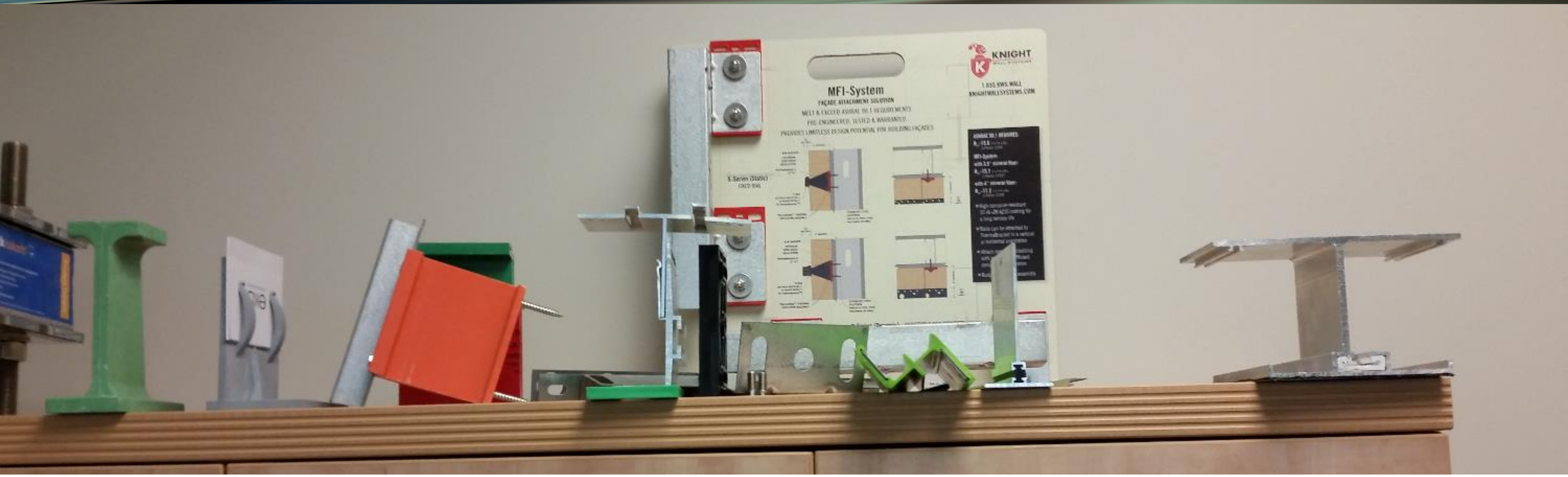
Horizontal Z-Girts



Intermittent

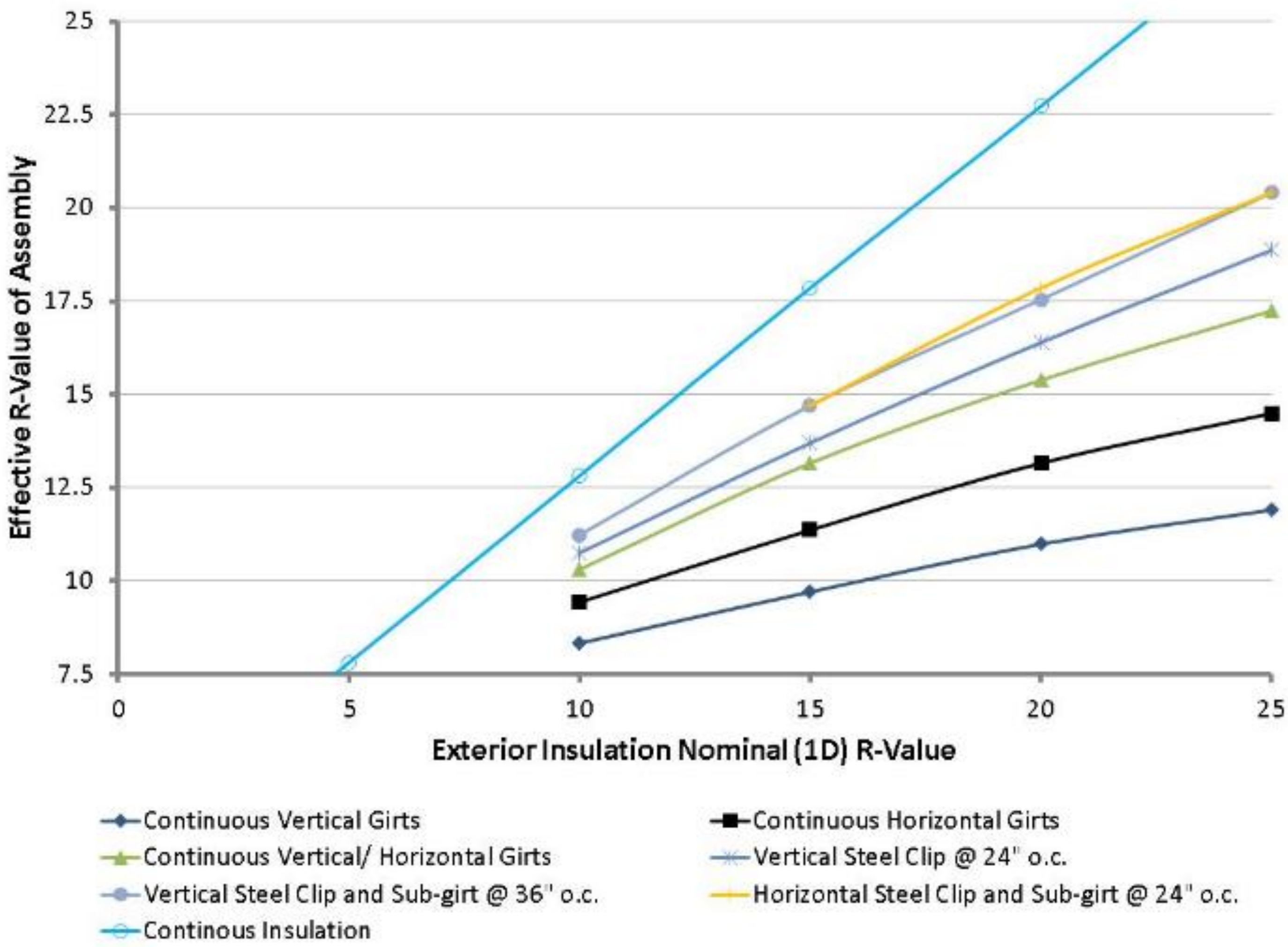
Proprietary Systems

NEW TECHNOLOGY



Many clip and rail systems are now available on the market

Effect of Thermal bridging in 3D



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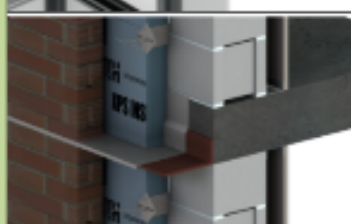
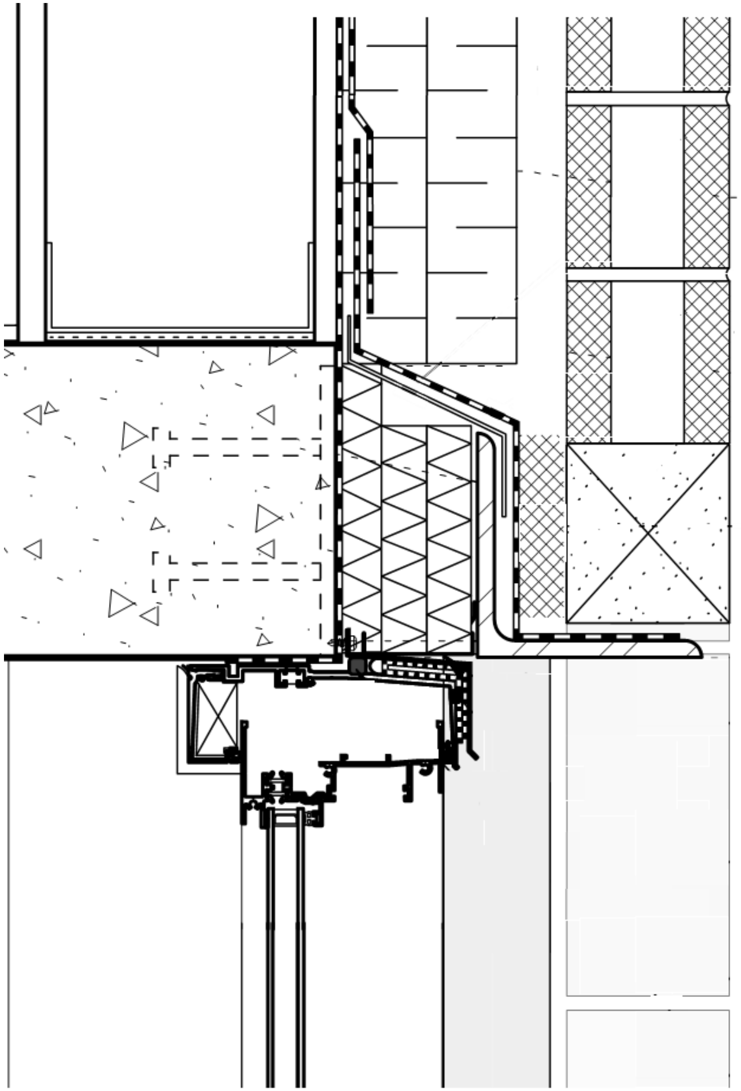
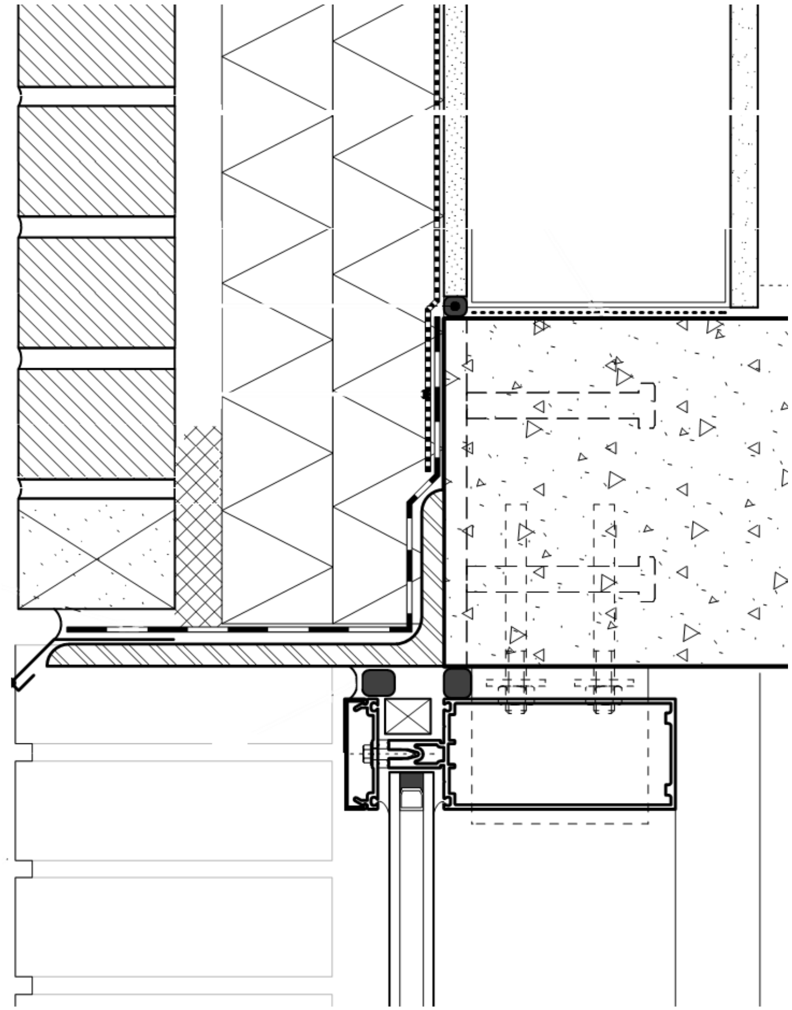
PRIORITY 2 – SLAB EDGES

Table 1.3: Performance Categories and Default Transmittances for Floor and Balcony Slabs

	Performance Category		Description and Examples	Linear Transmittance	
				Btu / hr ft F	W / m K
FLOOR AND BALCONY SLABS		Efficient	**Fully insulated with only small conductive bypasses** Examples: exterior insulated wall and floor slab.	0.12	0.2
		Improved	**Thermally broken and intermittent structural connections** Examples: structural thermal breaks, stand-off shelf angles.	0.20	0.35
		Regular	**Under-insulated and continuous structural connections** Examples: partial insulated floor (i.e. firestop), shelf angles attached directly to the floor slab.	0.29	0.5
		Poor	**Un-insulated and major conductive bypasses** Examples: un-insulated balconies and exposed floor slabs.	0.58	1.0

Masonry Shelf Angles





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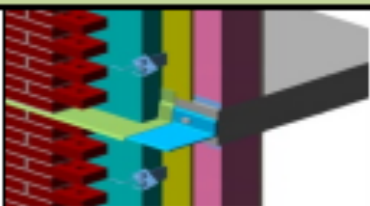
Masonry Shelf Angles

Floor Slab Linear Transmittance

Description of Detail (Thermal Anomaly)		Construction Type	Wall Assembly Description	Detailed Description	Reference	Linear Transmittance Btu / hr ft F	Linear Transmittance W/ m K	Category
Shelf Angle		Steel Framed	Interior and Exterior Insulated Steel Stud with Brick Veneer	**Standard Shelf Angle with Metal Flashing** at Concrete Floor Slab with Exterior and Interior Insulated Steel Stud with Brick Ties Supporting Brick Veneer	5.2.9	0.314	0.544	Poor
Shelf Angle		Steel Framed	Interior and Exterior Insulated Steel Stud with Brick Veneer	**Stand-off Shelf Angle** with Metal Flashing at Concrete Floor Slab with Exterior and Interior Insulated Steel Stud with Brick Ties Supporting Brick Veneer	5.2.10	0.217	0.376	Regular
Shelf Angle		Concrete	Exterior Insulated Concrete block with brick veneer	**Shelf Angle** with Metal Flashing at Concrete Floor with Exterior Insulated Concrete Block Wall Assembly with Masonry Ties Supporting Brick Veneer	6.2.14	0.270	0.467	Regular
Shelf Angle		Concrete	Exterior Insulated Concrete block with brick veneer	**Stand-off Shelf Angle with Metal Flashing** at Concrete Floor with Exterior Insulated Concrete Block Wall Assembly with Masonry Ties Supporting Brick Veneer	6.2.15	0.186	0.322	Improved

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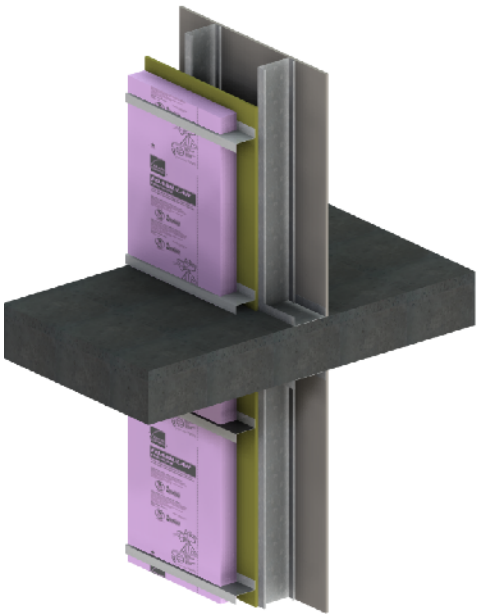
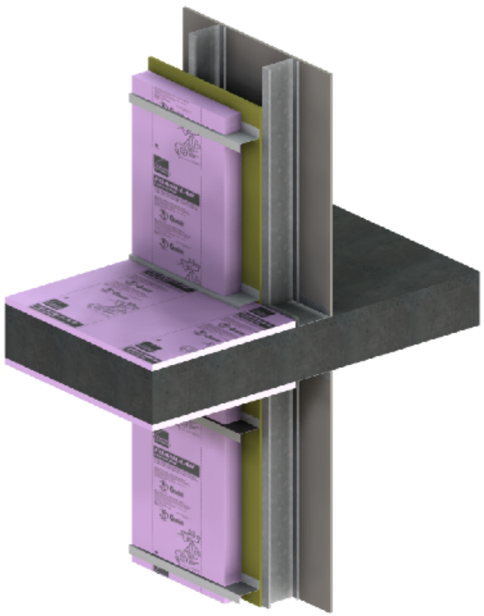
Concrete Slab Edges

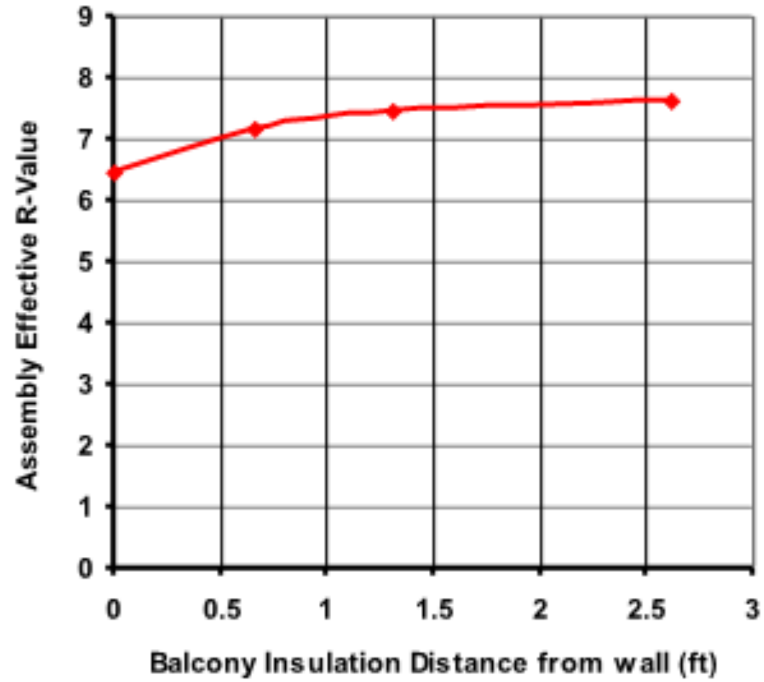
What about wrapping insulation around the balcony?

Slab Linear Transmittance

Balcony Insulation Distance from wall (ft)	R ft²·hr·°F / Btu (m² K / W)	U Btu/ft² ·hr ·°F (W/m² K)	ψ Btu/ft hr °F (W/m K)
0.00 (0.0)	R-6.5 (1.14)	0.155 (0.88)	0.445 (0.770)
0.66 (0.2)	R-7.2 (1.26)	0.140 (0.79)	0.342 (0.592)
1.31 (0.4)	R-7.5 (1.32)	0.134 (0.76)	0.306 (0.529)
2.62 (0.8)	R-7.6 (1.34)	0.131 (0.75)	0.287 (0.496)



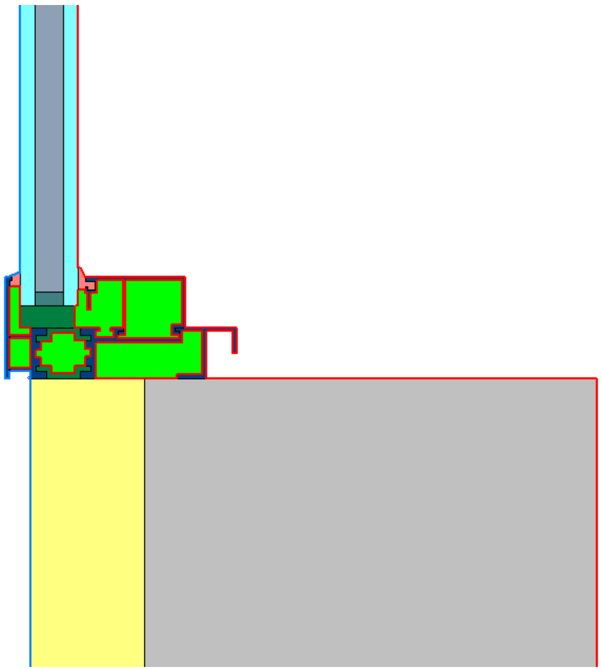


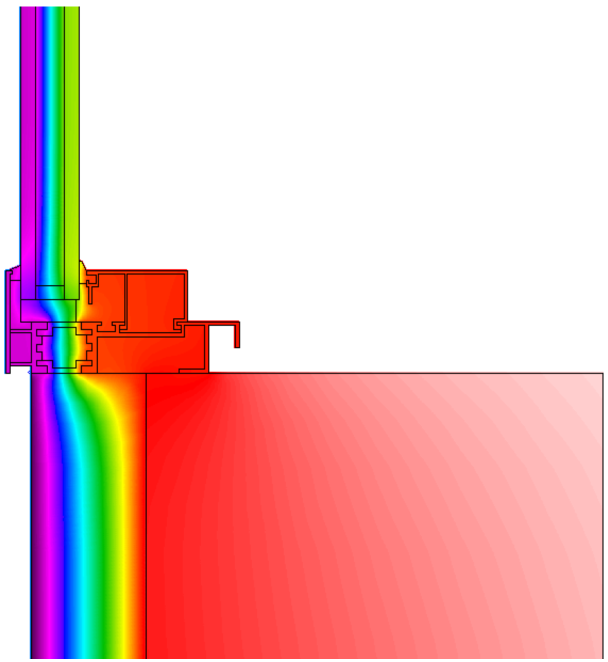


Priority 2 – Window Transitions

Window Fitting Details

Aligned with insulation layer

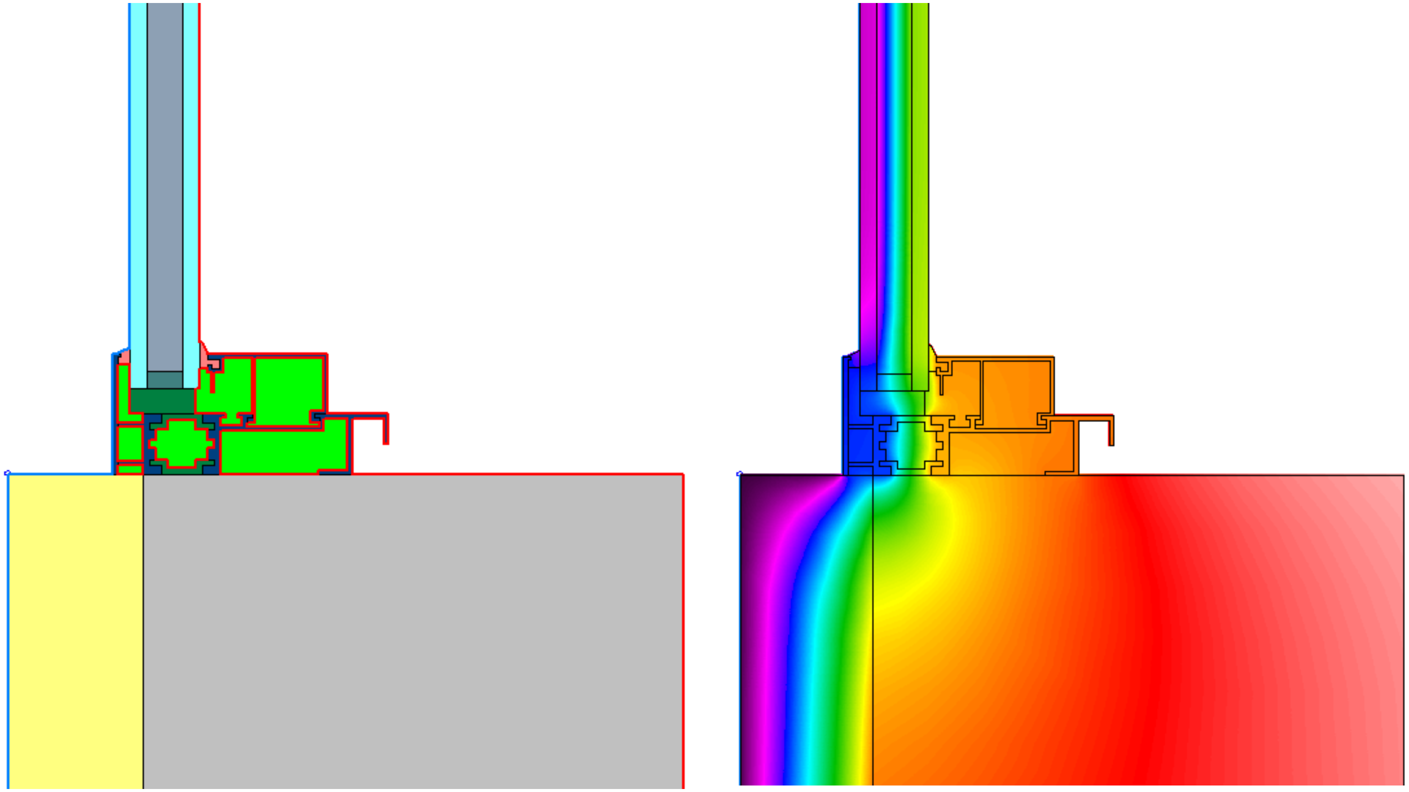




0.013 BTU/hr.ft.F

Window Fitting Details

Adjacent to insulation layer



0.103 BTU/hr.ft.F

Increased by 800%

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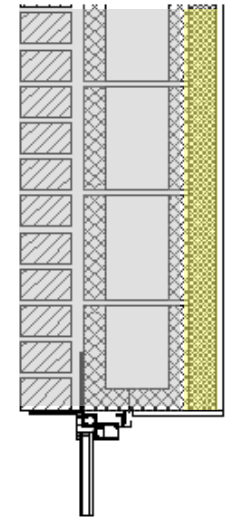
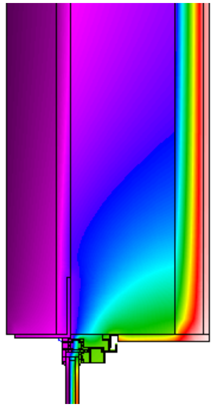
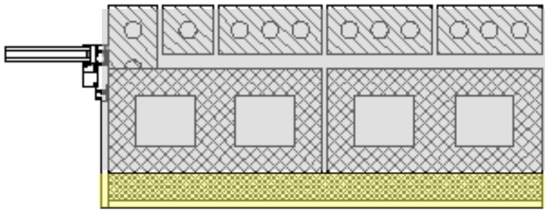
Current US Army Detail

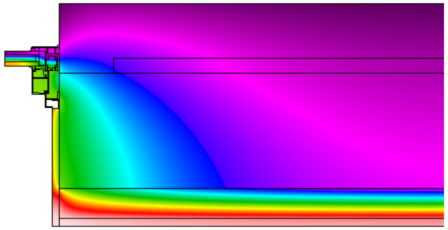


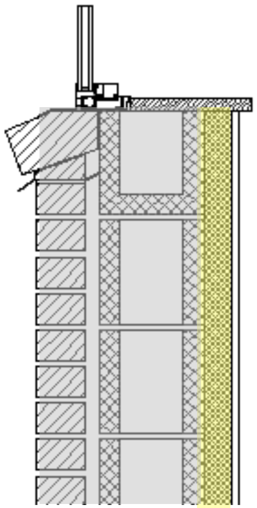
0.315 BTU/hr.ft.F



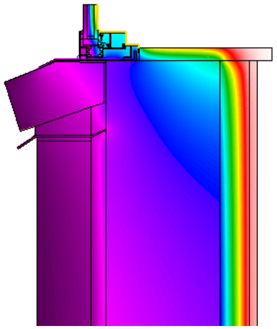


0.308 BTU/hr





0.322 BTU/hr.ft.F



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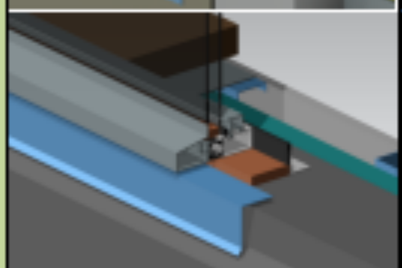
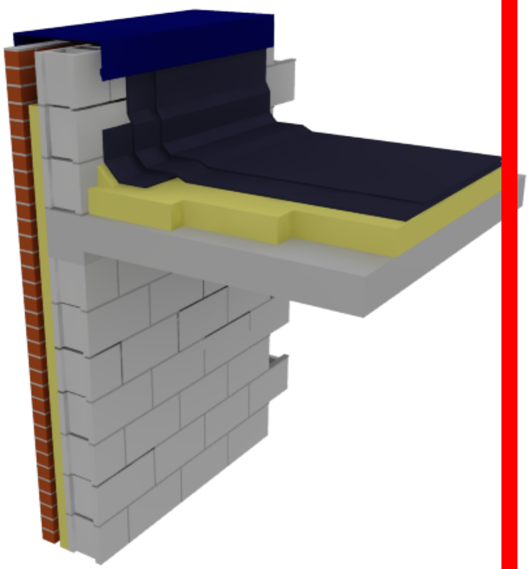
Windows in Rough Openings

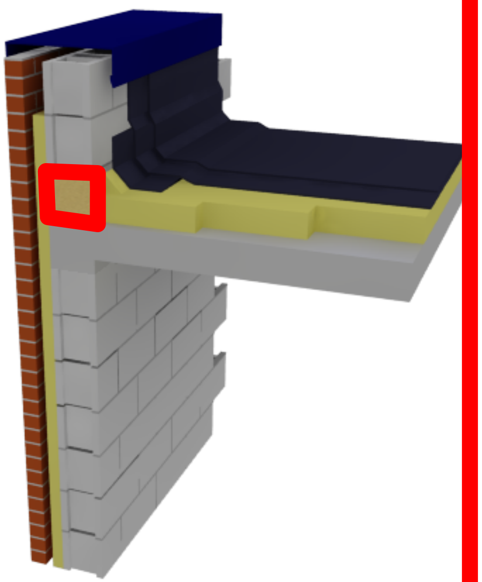
		Performance Category	Description and Examples	Linear Transmittance Btu / hr ft F	Linear Transmittance W / m K
GLAZING TRANSITIONS		**Efficient**	**Well aligned glazing without conductive bypasses** Examples: wall insulation is aligned with the glazing thermal break. Flashing does not bypass the thermal break.	0.12	0.2
		Regular	**Misaligned glazing and minor conductive bypasses** Examples: wall insulation is not continuous to thermal break and framing bypasses the thermal insulation at glazing interface.	0.20	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).	0.29	0.5

Typical detail – poor thermal bridge



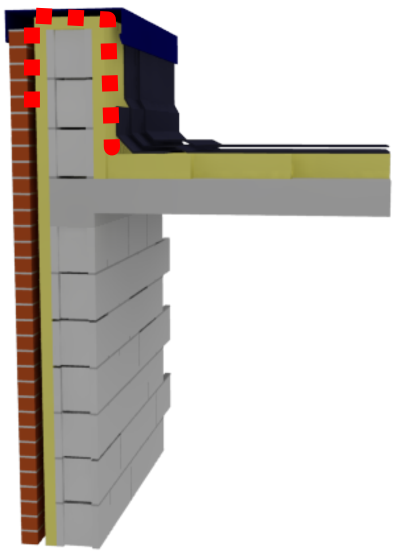
0.247 BTU/hr.ft.F

Option 1: Insert thermal break



0.010 BTU/hr.ft.F

Option 2:Wrap the parapet



0.039 BTU/hr.ft.F

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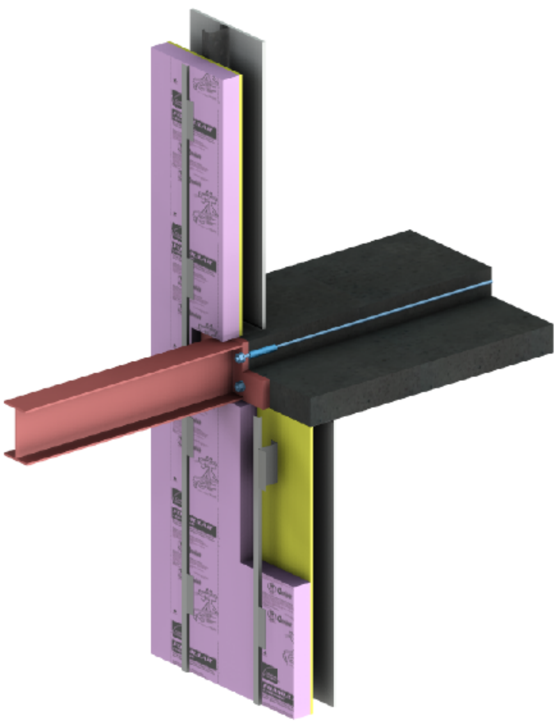
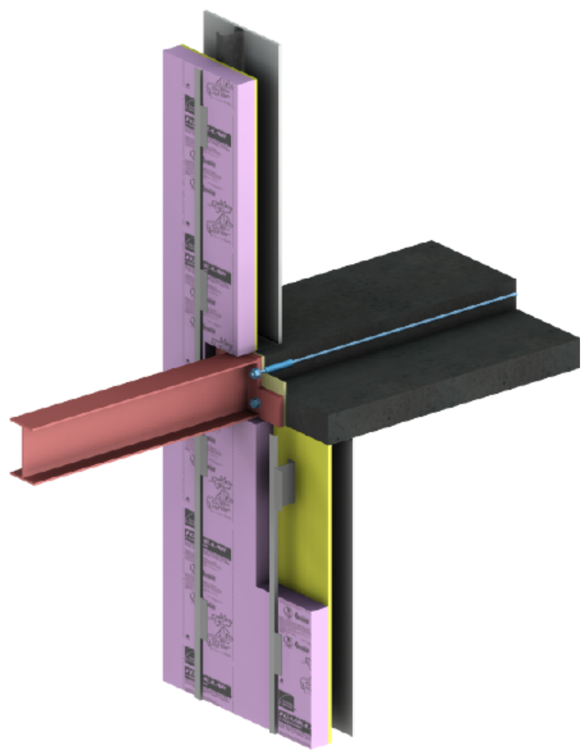
Priority 3 – Other Details

Base Assembly – Clear Wall R13.8 ft²·hr·°F/Btu (U-0.072)

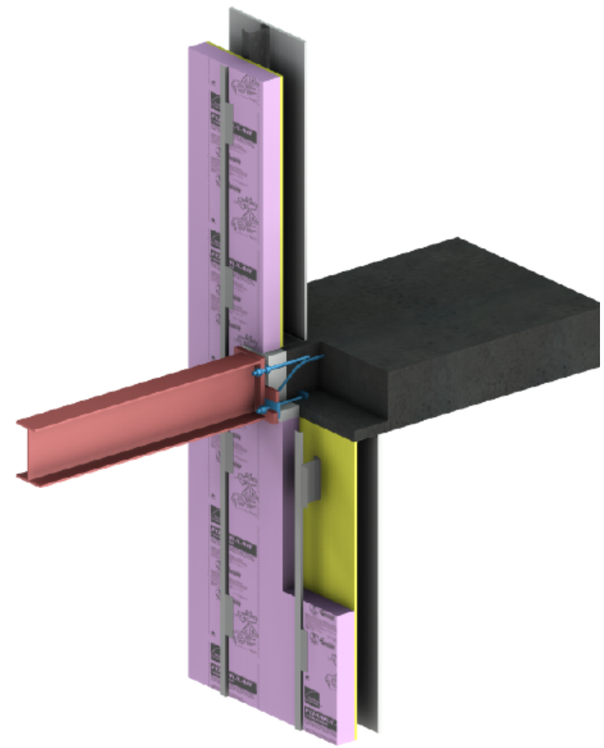
χ = 1.24 Btu/hr·°F
R-7.3 = 53% effective



χ = 0.91 Btu/hr·°F
R-8.2 = 59% effective



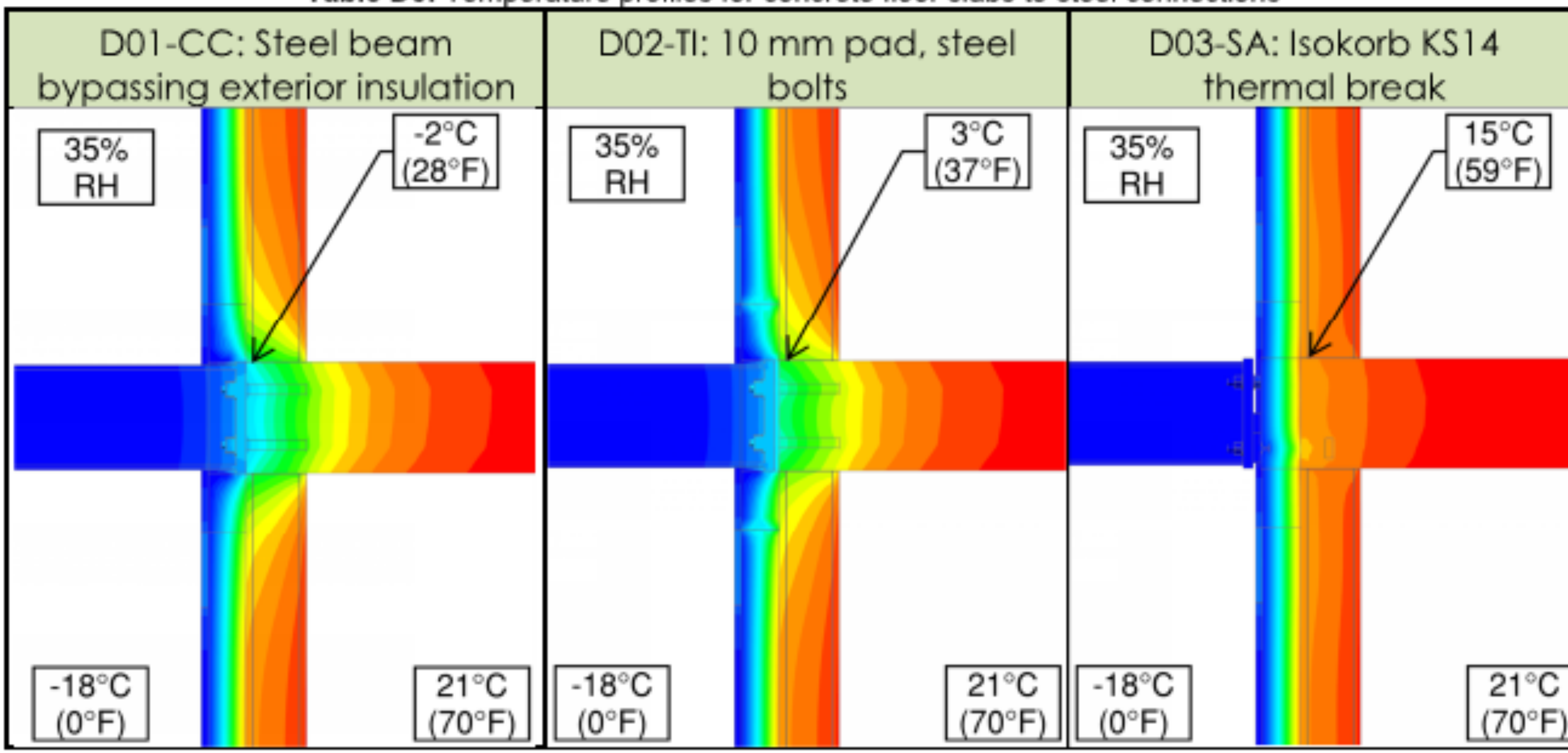
χ = 0.07 Btu/hr·°F
R-12.2 = 88% effective



Steel Canopy Outriggers

Dewpoint is ~ 5°C

Table D5: Temperature profiles for concrete floor slabs to steel connections



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QUESTIONS?

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