Early Design Tools for Passive House: Estimating Thermal Bridging

Steven Winter Associates, Inc.
Improving the Built Environment Since 1972

Outline

- Framing the Issue
- A Tool for Design Teams
- Product Overview
- Results
- Unique Thermal Bridges
- Resources

High Performance Walls

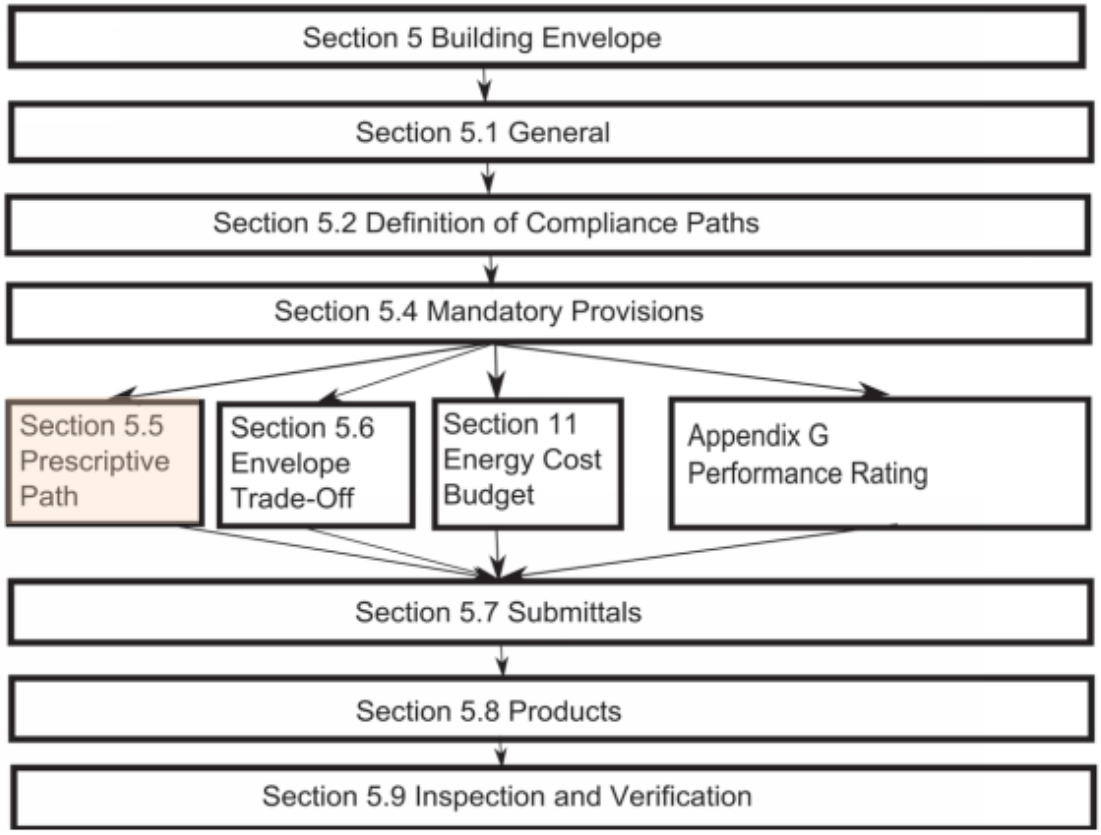
FRAMING THE ISSUE

Thermal Bridging

- Increasingly recognized as a major contributor to energy **loss** in all buildings
- Undermining building performance
- Model vs reality "**performance gap**"
- Critical to Passive House design
- Can have a drastic impact on design and PH compliance
- Becoming standard practice**...**

ASHRAE 90.1 2016 - Addendum AV: Accounting for thermal bridging

Sections 5.5.5.1 to 5.5.5.6 - Proposed Addendum AV: methods for accounting for and mitigating thermal bridging.



Addendum AV: Not Accounted For

- Exterior cladding attachments
- Mechanical penetrations
- Assemblies that are not specifically in the table
  - Allows for interpolation

High Performance Walls

A Tool For Design Teams

Why do we need a design tool

Development

Feasibility, schematic, and design models

Accounting

for de-rate is paramount to meet Passive House space conditioning thresholds

Efficiency

Typical assemblies are variable

Time saver

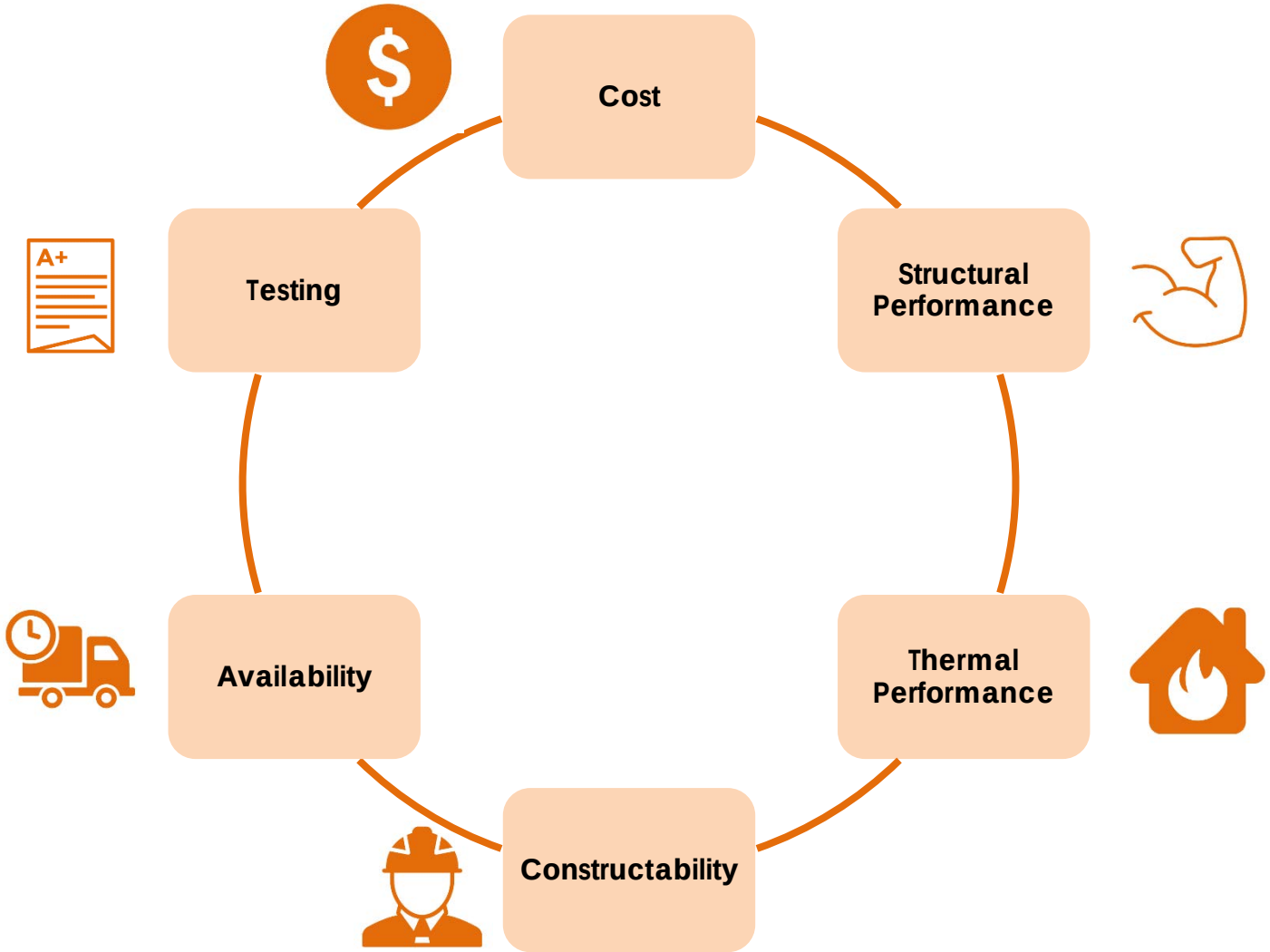
Requires a lot of modeling hours

High Performance Façades

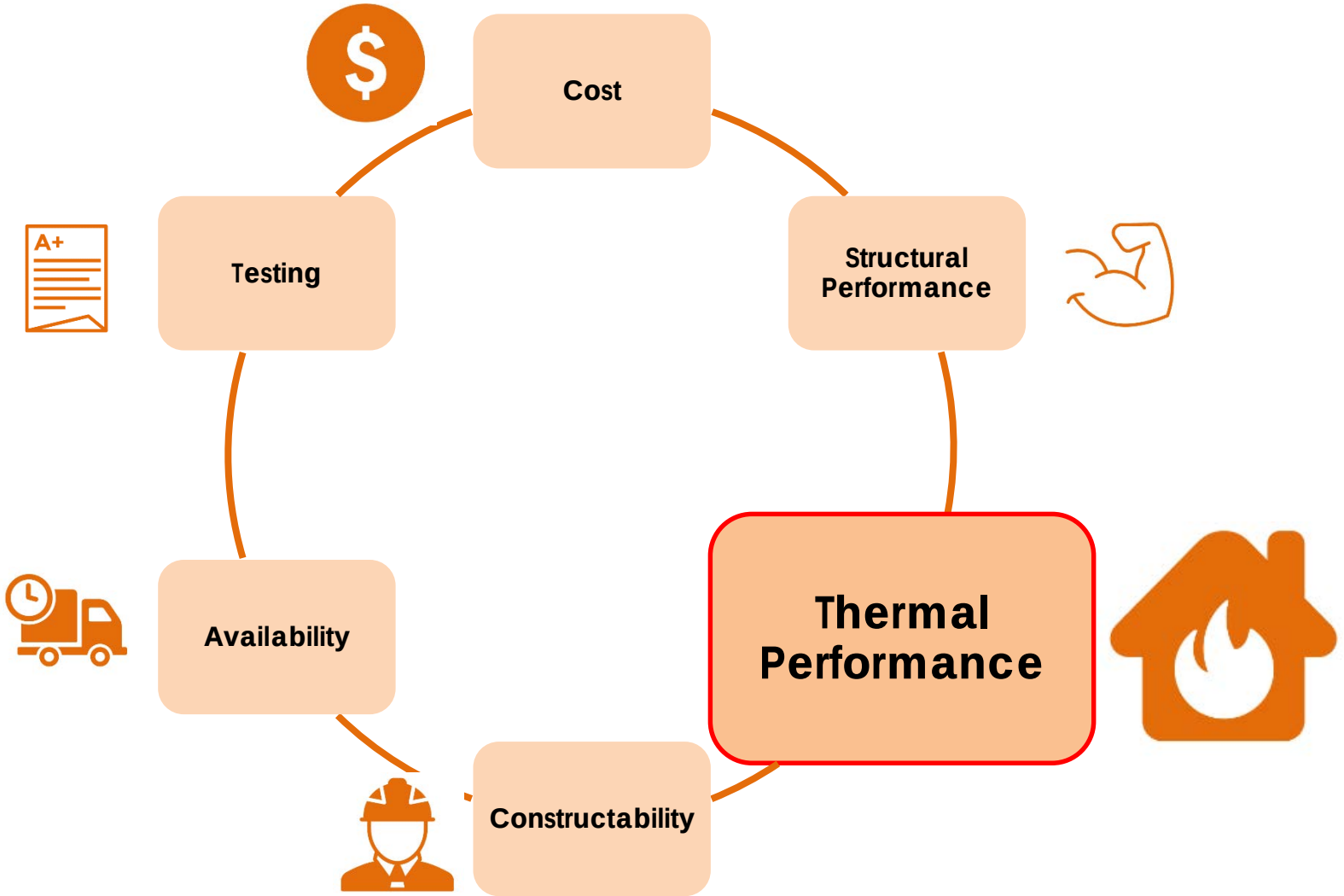
- Wide range of products
- Many factors influence decision
- Thermal performance varies drastically

Cornell Tech Building

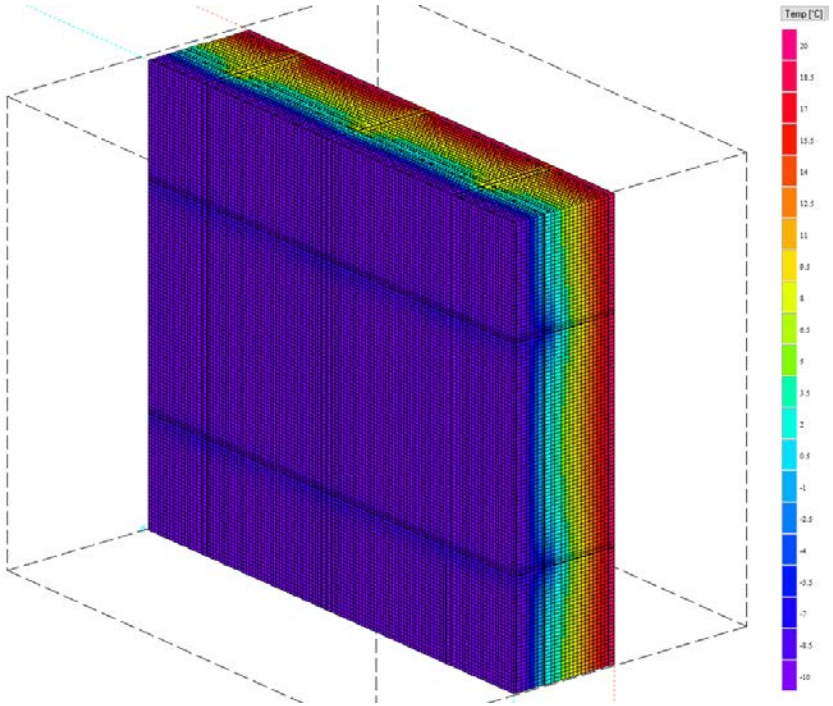
Which System to Use?



Which System to Use?



Thermal Performance



Source: SWA Heat3 Analysis

- Difficult to account for in WUFI/PHPP model
- 3D Modeling required for complex geometry and component array

How do we make conservative & realistic assumptions early in design?

High Performance Walls

PRODUCT OVERVIEW

Product Overview

Brick Façade

- Ties

- Angles

Panel Façade

- Girts

- Clips

High Performance Walls

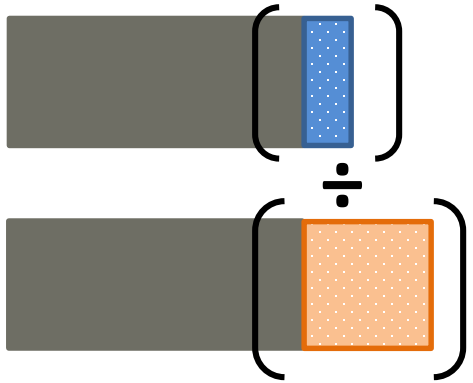
RESULTS

Exterior Insulation Effectiveness

Exterior Insulation Effectiveness = Exterior Insulation Modeled R-Value / Exterior Insulation Nominal R-Value

Exterior Insulation Modeled R-Value

Exterior Insulation Nominal R-Value



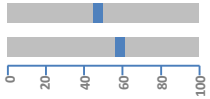
For Cladding Finish Systems: Clips

Galvanized Metal Clips

Description

These clips are usually galvanized steel and are used to support rainscreen and panel cladding systems.

Thermal efficiency per SWA: **46-59%**



46% for Steel backup
59% for CMU backup

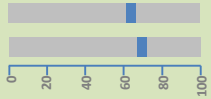
Standard Product

Stainless Steel Clips

Description

Replacing galvanized steel clips with stainless steel ones can greatly reduce the thermal conductivity.

Thermal efficiency per SWA: **63-74%**



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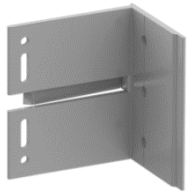
Example Products:
A-Clip. MFSSCHAN

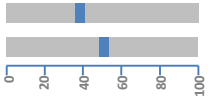
Aluminum Clips



Description

Aluminum clips are light weight and strong. They are a more elastic and non corrosive alternative to traditional metal clips.

Thermal efficiency per SWA: **38-52%**



38% for Steel backup
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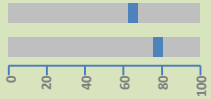
Example Products:
Alpha Brackets

Fiberglass Clips

Description

Fiberglass clips have a much lower thermal transmittance coefficient than any metal equivalent.

Thermal efficiency per SWA: **64-79%**



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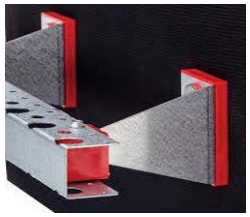
Example Products:
Cascada Clip

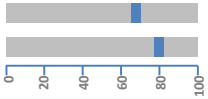
Thermal Stop Clips



Description

This clip has a plastic thermal stop at the base and head to help mitigate thermal bridging.

Thermal efficiency per SWA: **67-80%**



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Pos-I-Tie Thermal Clip, Nvelope NV1 Thermal Clip

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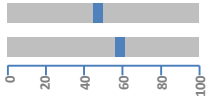

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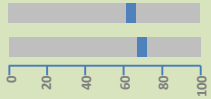

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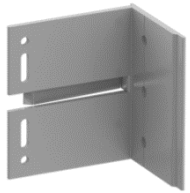

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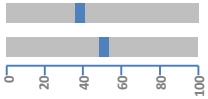

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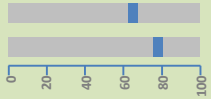

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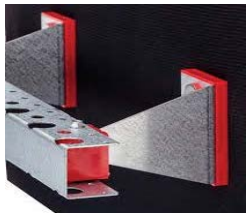

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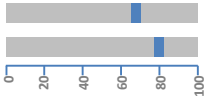

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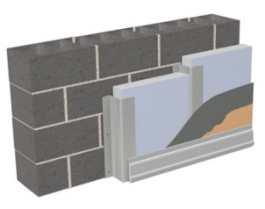
80% for CMU backup

Example Products:
Pos-I-Tie Thermal Clip, Nvelope NV1 Thermal Clip

For Cladding Finish Systems: Girts

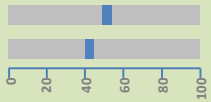
Galvanized Girts



Description

Typical z-girts are usually galvanized steel. Most projects use these to support their cladding systems.

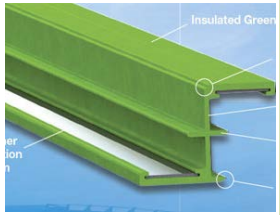
Thermal efficiency per SWA: **43%-53%**



53% for Steel backup
43% for CMU backup

Standard Product

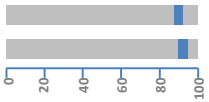
Fiberglass Girts



Description

Fiberglass girts are installed and used the same way as typical metal z-girt. The fiberglass material reduces thermal bridging.

Thermal efficiency per SWA: **91%-95%**



91% for Steel backup
95% for CMU backup

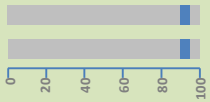
Example Products:
Green Girt- Simple Z

Thermoset Resin Girts

Description

These girts have a low thermal conductivity. Made of fire resistant resin material. Can be spaced 16" or 24" o.c. and is very strong.

Thermal efficiency per SWA: **96%**



96% for Steel backup
96% for CMU backup

Example Products:
Armatherm Z Girt

Description

These girts have a low thermal conductivity. Made of fire resistant resin material. Can be spaced 16" or 24" o.c. and is very strong.

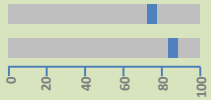
For Brick Veneer Systems: Ties

Galvanized Steel Brick Ties

Description

Typical brick ties are galvanized steel. Most brick veneer projects use this type of product.

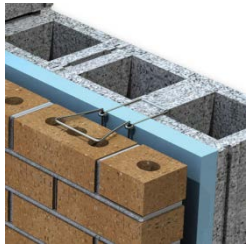
Thermal efficiency per SWA: **75-84%**



75% for Steel backup
84% for CMU backup

Standard Product

Stainless Steel Brick Ties



Description

Stainless steel ties are less conductive than galvanized steel ties.

Thermal efficiency per SWA: **87-93%**

87% for Steel backup
93% for CMU backup

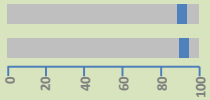
Example Products:
2 Seal Tie Thermal,
Original Pos-I-Tie

Thermal Break Brick Ties

Description

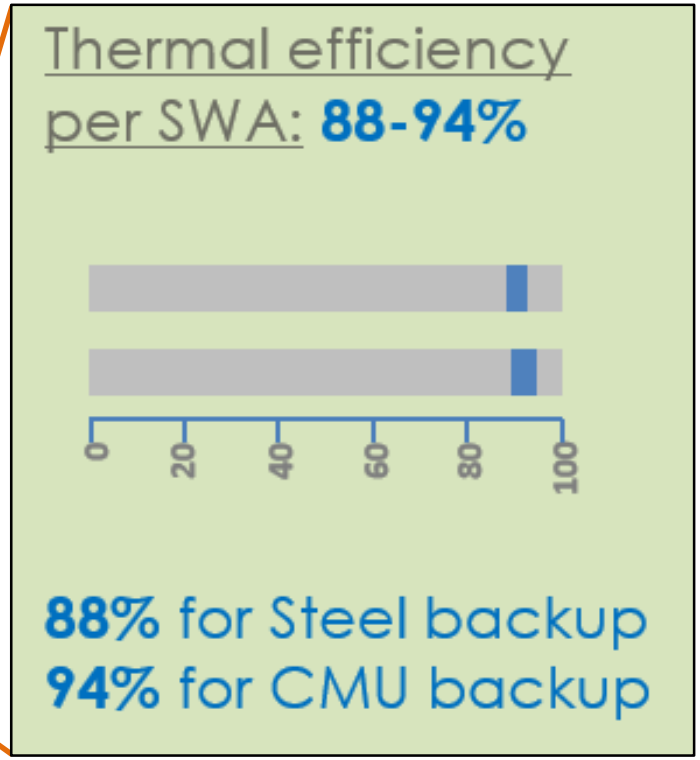
This stainless steel brick tie has a plastic coating, which reduces thermal bridging.

Thermal efficiency per SWA: **88-94%**



88% for Steel backup
94% for CMU backup

Example Products:
2 Seal Tie Thermal
Wing Nut Anchor



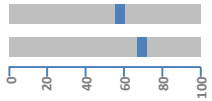
For Brick Veneer Systems: Angles

Typical Shelf Angle

Description

Typically, shelf-angles are made of galvanized steel.

Thermal efficiency per SWA: **58-69%**



58% for Steel backup
69% for CMU backup

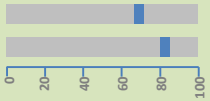
Standard Product

Stand-off Shelf Angle

Description

This stand off shelf angle allows insulation to be installed behind it. The bracket can be used with readily available shelf angles.

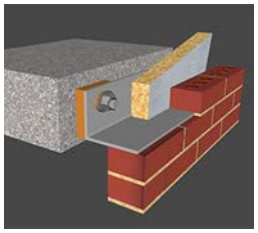
Thermal efficiency per SWA: **73-81%**



73% for Steel backup
81% for CMU backup

Example Products:
FAST (Fero Angle Support Technology),

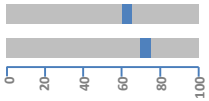
Shelf Angle with Thermal Break



Description

The thermal break plate is installed between the shelf angle and bracket to reduce the thermal bridge at those points.

Thermal efficiency per SWA: **63-74%**

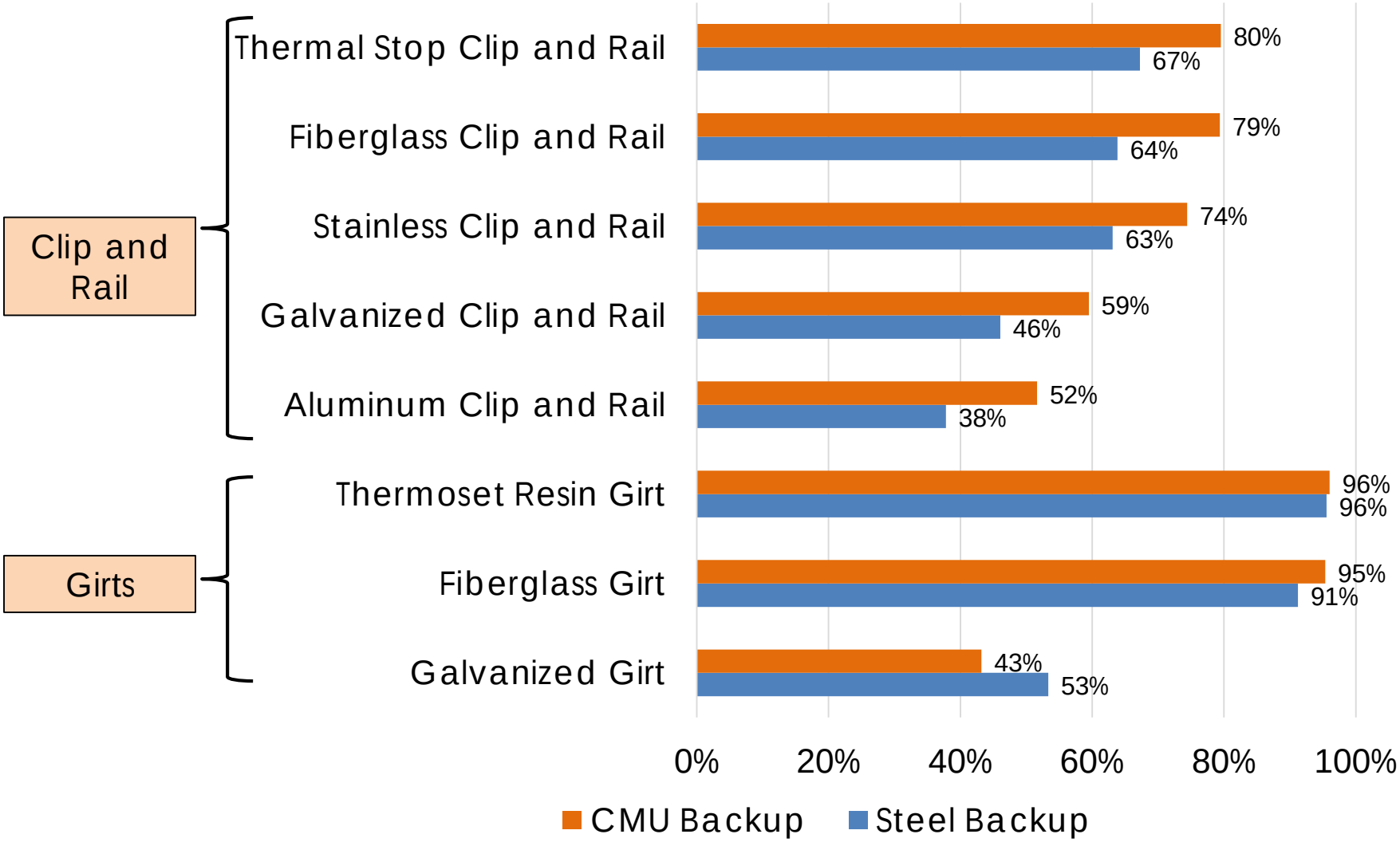


63% for Steel backup
74% for CMU backup

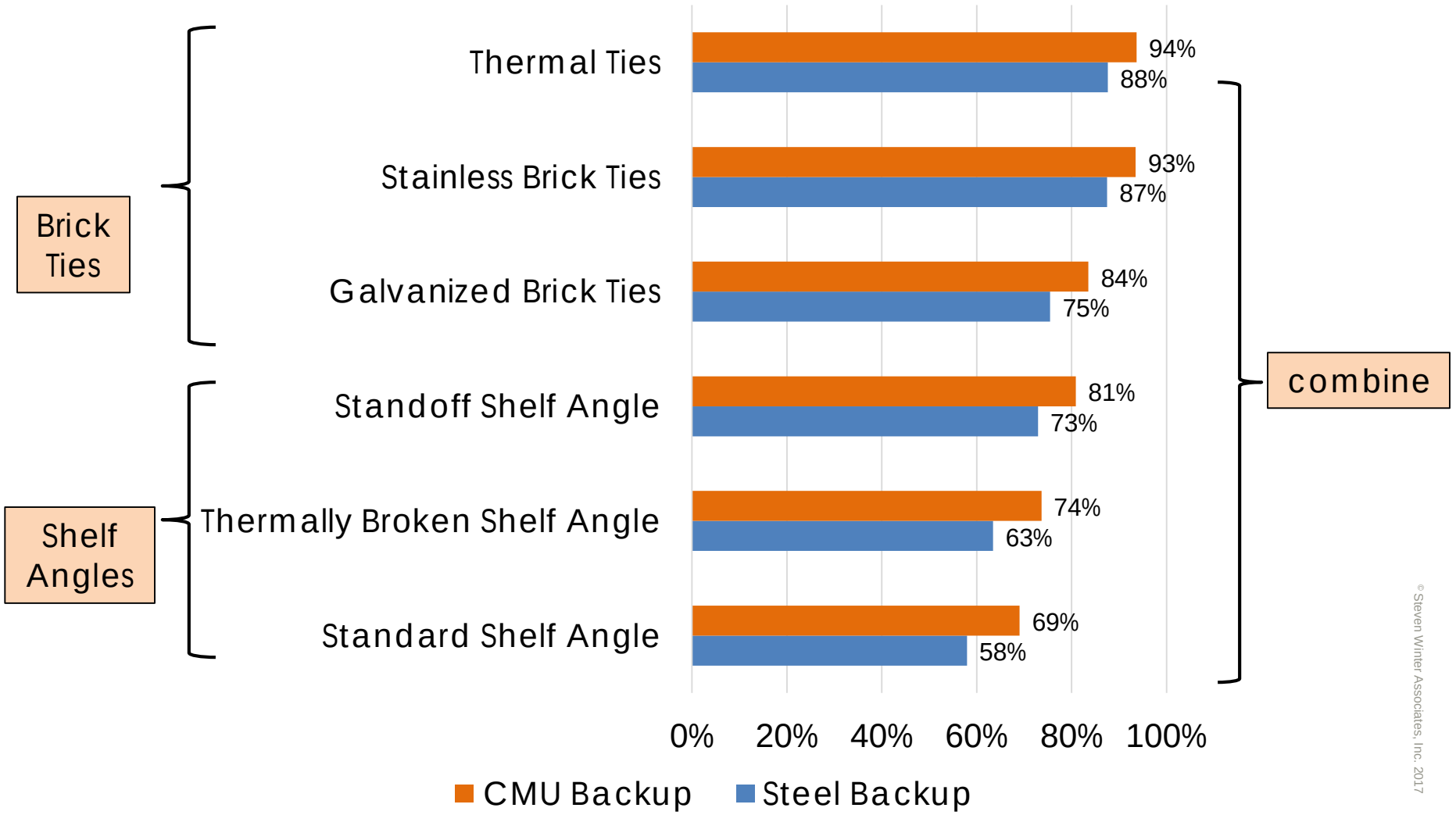
Example Products:
Armatherm Shelf Angle

Example Products:
Armatherm Shelf Angle

Results: Panel Cladding



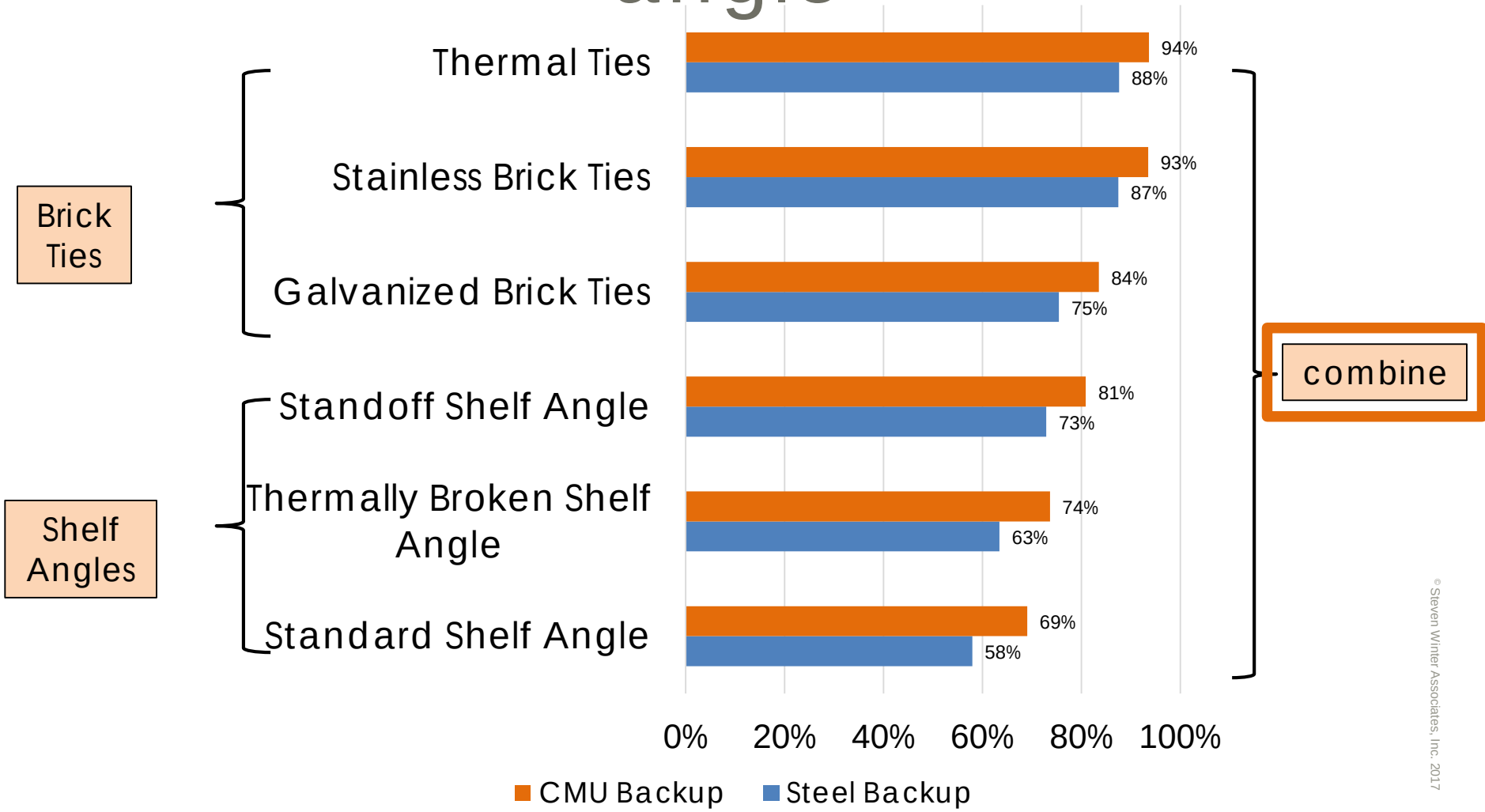
Results: Brick Veneer



Takeaways

1. **Combination brick and shelf angle**
2. Thermal ties vs stainless steel ties
3. Fiberglass clip vs continuous fiberglass girt
4. Clip & rail vs brick veneer

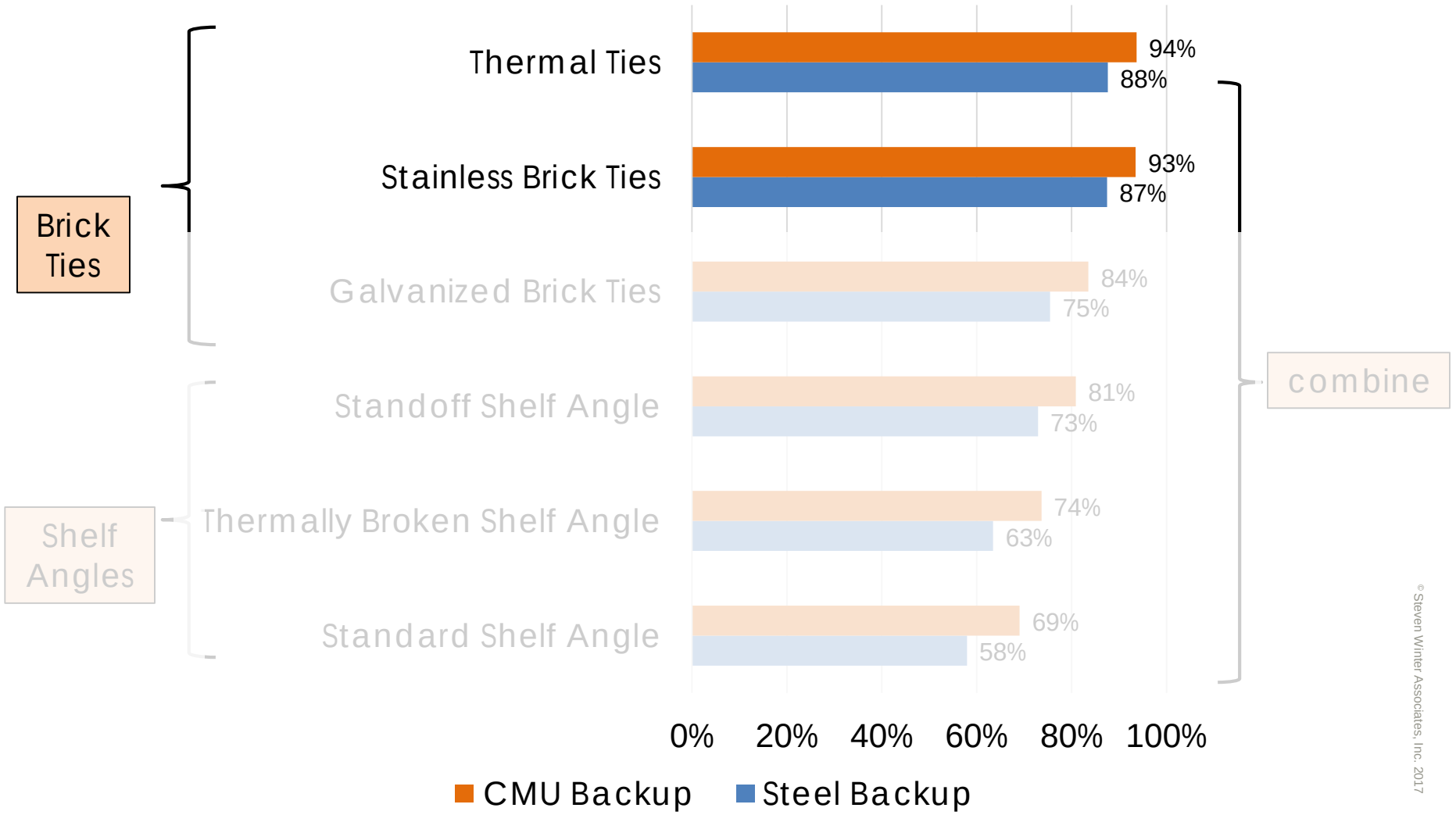
Combination brick and shelf angle



Takeaways

1. Combination brick and shelf angle
2. **Thermal ties vs stainless steel ties**
3. Fiberglass clip vs continuous fiberglass girt
4. Clip & rail vs brick veneer

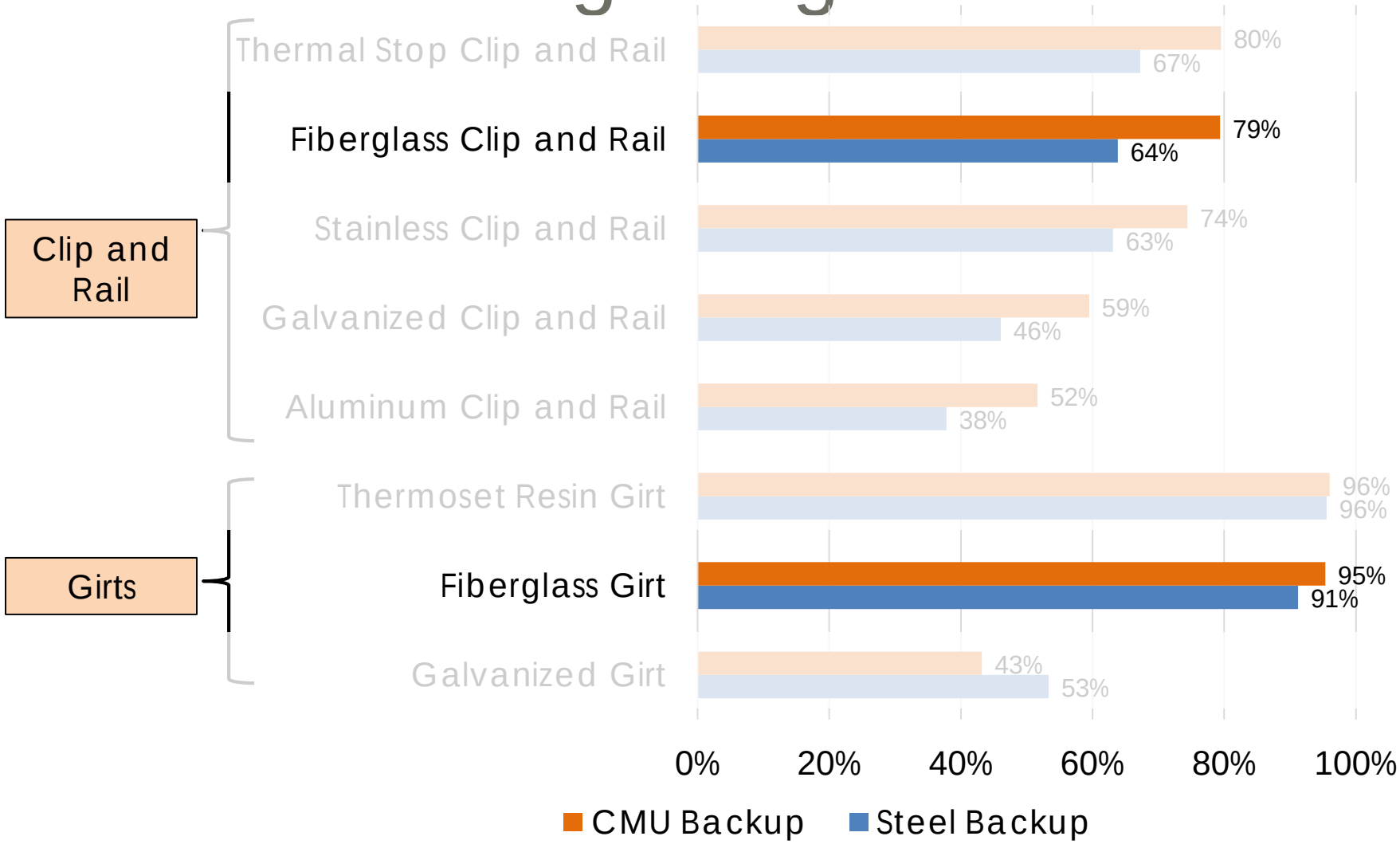
Thermal ties vs stainless steel ties



Takeaways

1. Combination brick and shelf angle
2. Thermal ties vs stainless steel ties
3. **Fiberglass clip vs continuous fiberglass girt**
4. Clip & rail vs brick veneer

Fiberglass clip vs continuous & fiberglass girt



Takeaways

1. Combination brick and shelf angle
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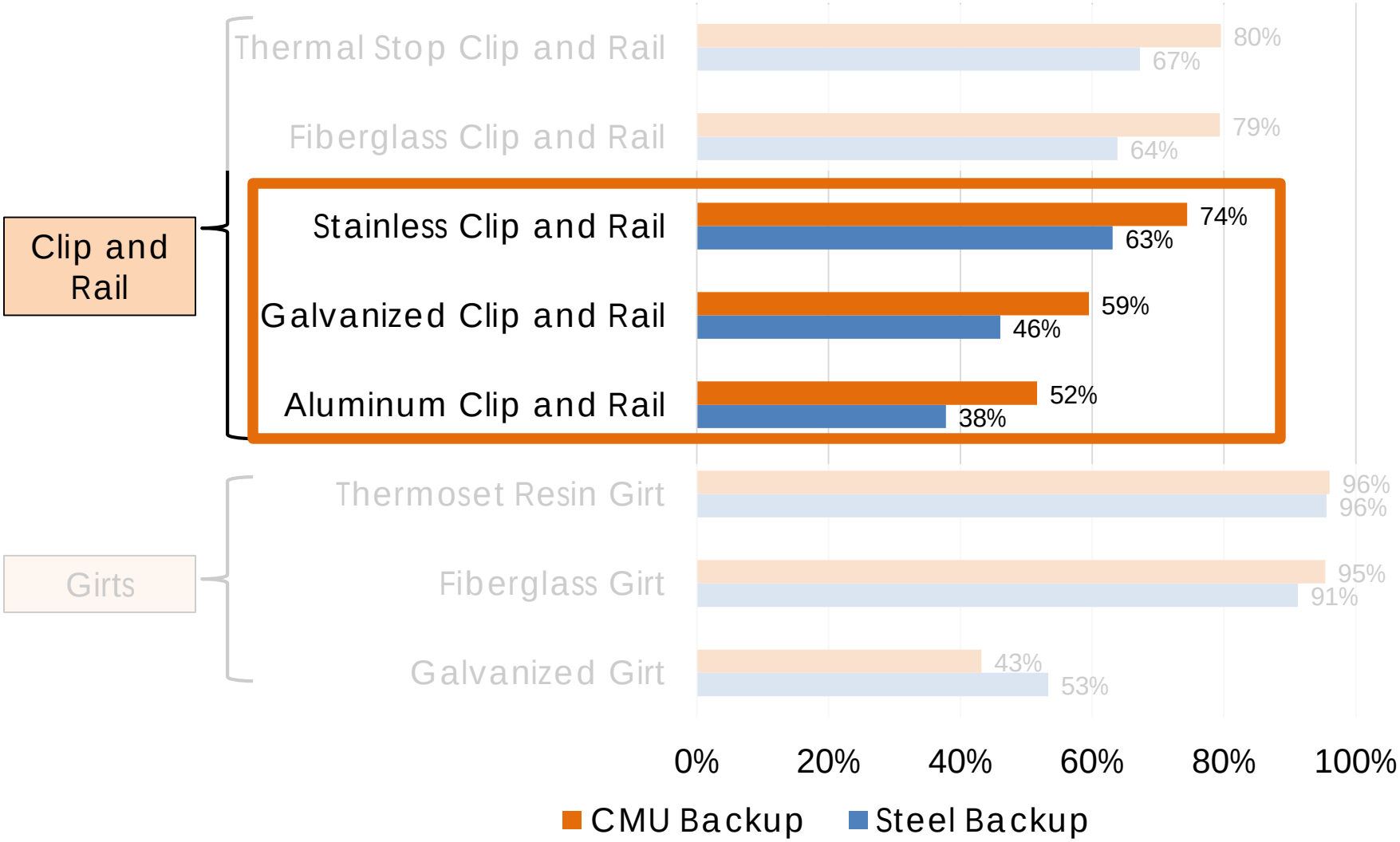
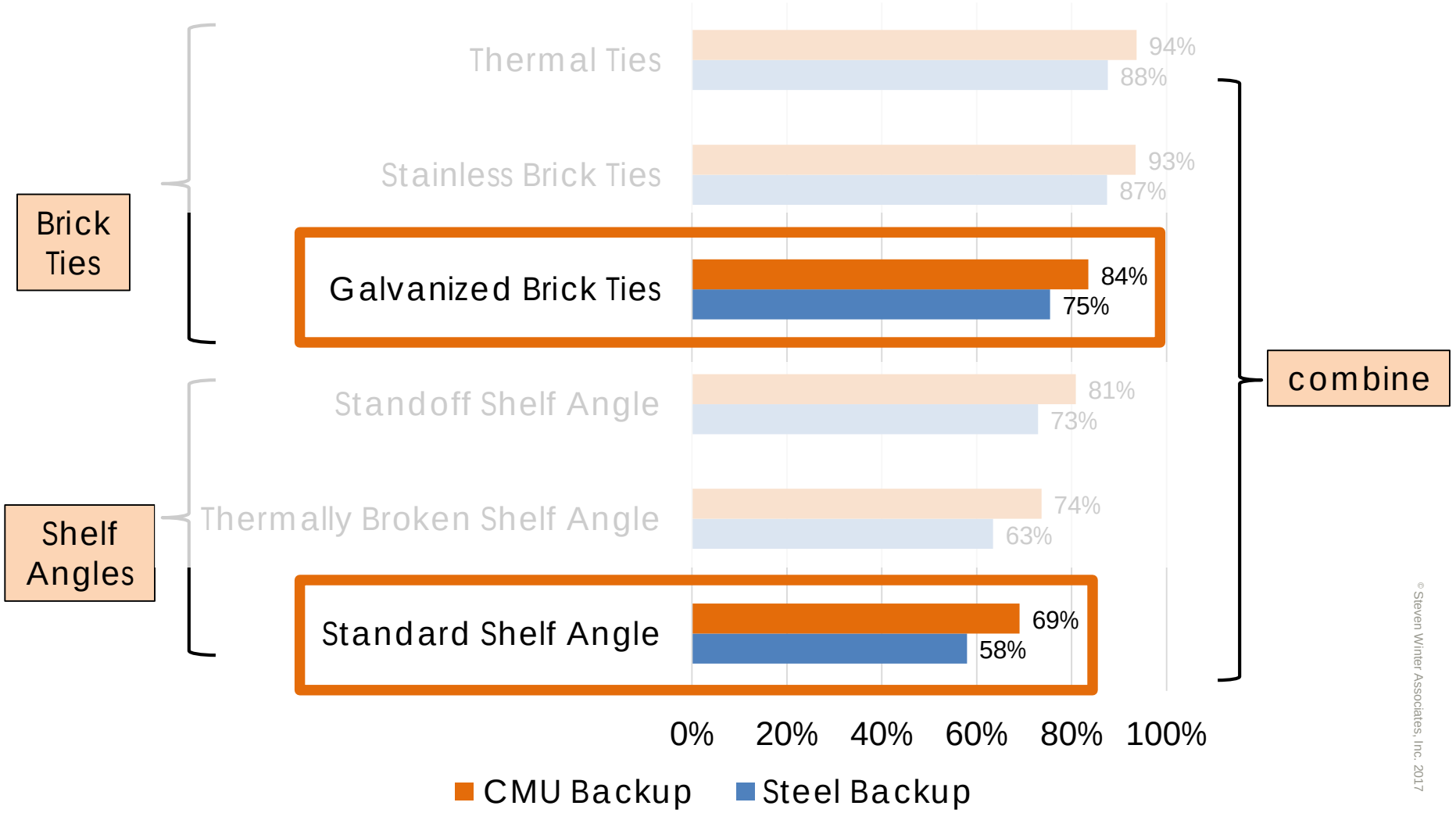
3. Fiberglass clip vs continuous fiberglass girt
4. **Clip & rail vs brick veneer**

Clip & rail vs brick veneer



Clip & rail vs brick veneer



WUFI PASSIVE/PHPP Integration

Nr.	Material / Layer (from outside to inside)	Color	λ [Btu/hr ft °F]
1	XPS (32% de-rate)		R/in
2	CMU		0.11905
3	Mineral Wool		0.01984

Edit assembly

Name

WT-1 Brick Veneer (Galvanized Brick Tie & Stand-off Shelf Angle)

Thermal resistance [hr ft² °F/Btu]: ----

Nr.	Material / Layer (from outside to inside)	Color	λ [Btu/hr ft °F]		Thickness [in]	R [hr ft² °F/Btu]
1	XPS (32% de-rate)			R/in	4	
2	CMU		0.11905		7.5	
3	Mineral Wool		0.01984		2	

Calculator: thermal conductivity <-> R/inch

[BTU/hr ft °F]: 0.02451

[R per inch]: 3.4

Status: OK

Help | OK | Cancel

Calculator: thermal conductivity <-> R/inch

[BTU/hr ft °F]: 0.02451

[R per inch]: 3.4

Status: OK

WUFI PASSIVE/PHPP Integration

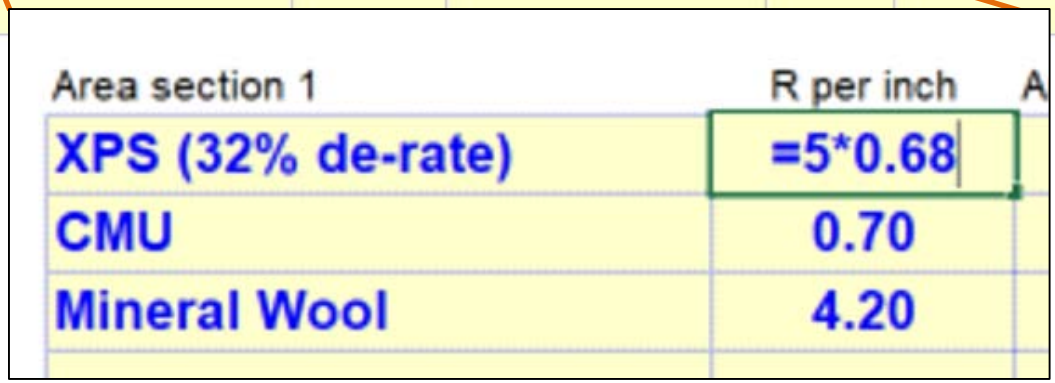
Assembly no.	Building assembly description	Interior insulation?
01ud	WT-1 Brick Veneer (Galvanized Brick Tie & Stand-off Shelf Angle)	

Heat transmission resistance [hr.ft².F/BTU]

Orientation of building element: 2-Wall
Adjacent to: 1-Outdoor air

interior R_{si}: 0.74
exterior R_{se}: 0.23

Area section 1	R per inch	Area section 2 (optional)	R per inch	Area section 3 (optional)	R per inch	Thickness [in]
XPS (32% de-rate)	=5*0.68					4.00
CMU	0.70					7.50
Mineral Wool	4.20					2.00



Percentage of sec. 3

Total: 13.50 in

R-value: 28.2 hr.ft².°F/BTU

Design Integration

Development

Feasibility, schematic, and design models

Accounting

for de-rate is paramount to meet Passive House space conditioning thresholds

Efficiency

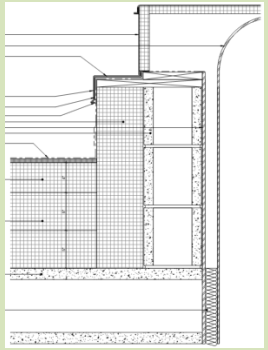
Typical assemblies are variable

High Performance Walls & Roofs

Unique Thermal Bridging

Unique Thermal Bridges: Roof H/ERV Penetration

Roof ERV



Description

Central H/ERV devices require a dedicated outdoor air (OA) and exhaust air (EA) duct to the outside. The duct work typically penetrates the roof.

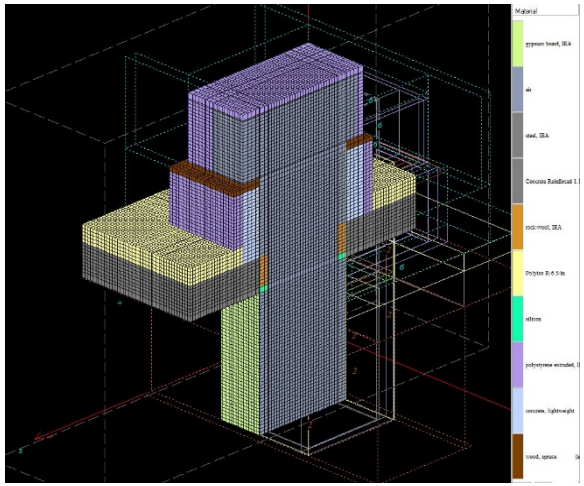
Estimated Chi Value:
2.64 BTU/hr.F

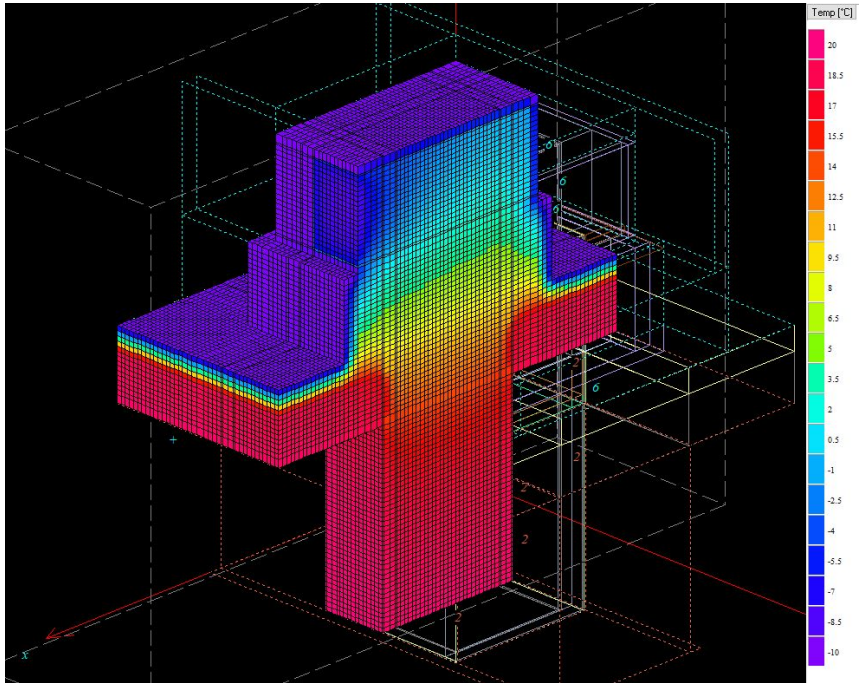
Thermal Efficiency:
1/(1+107.6*(#/Area))

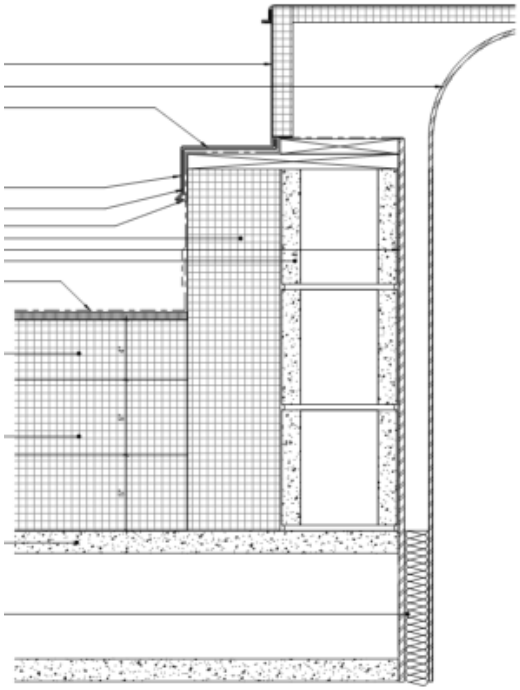
Example:
Area: 20,000 ft²
#: 4

Base R-Value: 40.77
New R-Value: 39.91

Efficiency: 98%







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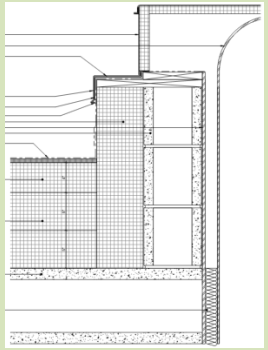

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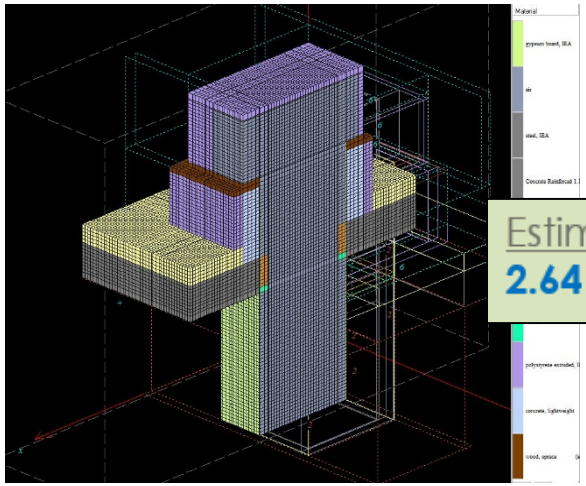

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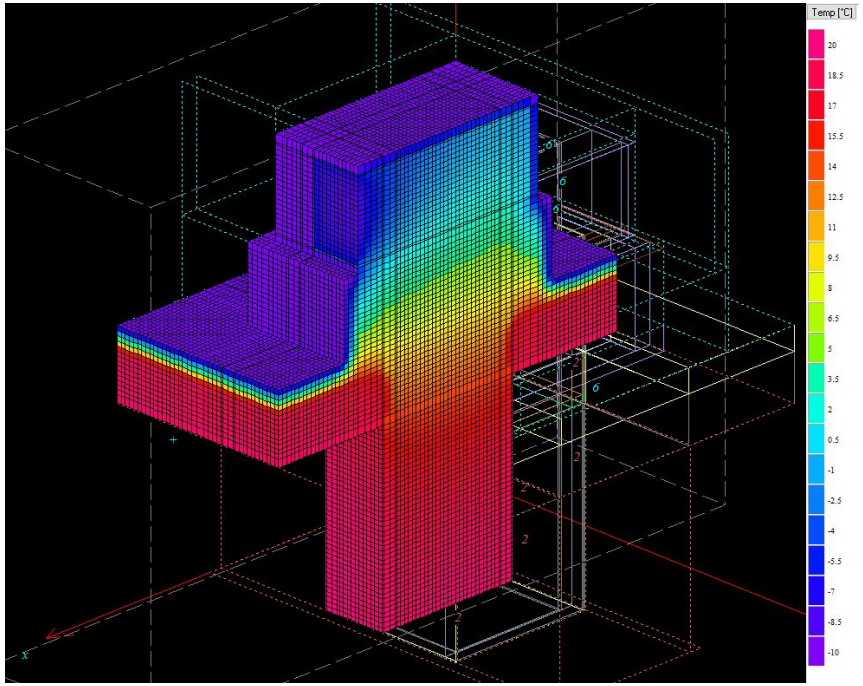

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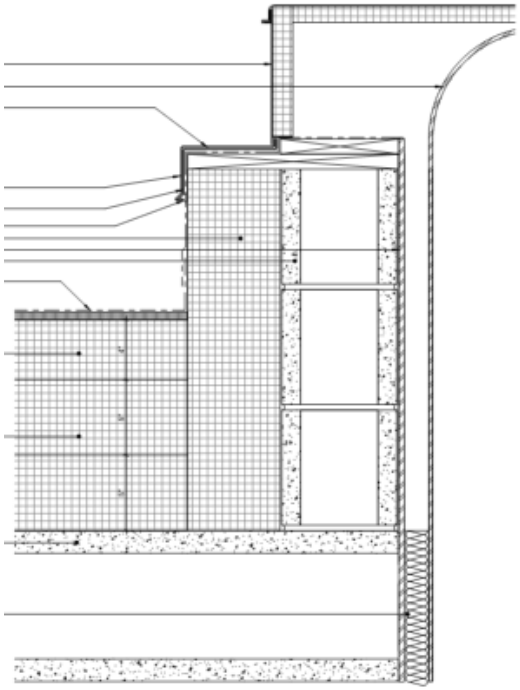
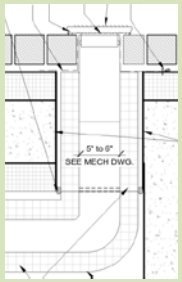


Unique Thermal Bridges: Wall H/ERV Penetration

Wall ERV Penetration



Description

Unitized H/ERV devices require a dedicated outdoor air (OA) and exhaust air (EA) duct to the outside for every unit. The duct work must penetrates the above grade walls.

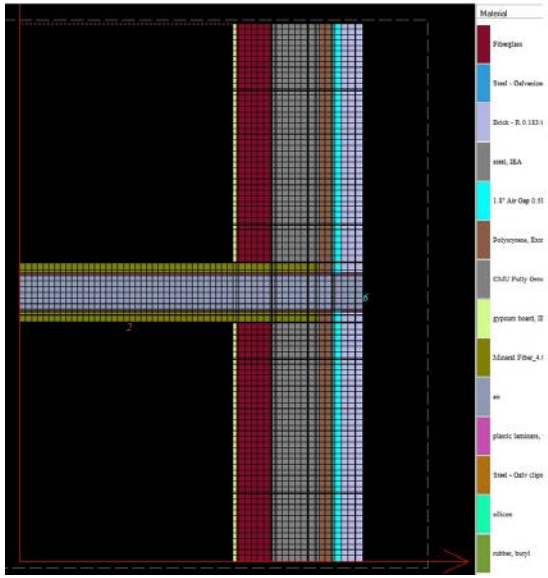
Estimated Chi Value:
0.03 BTU/hr.F

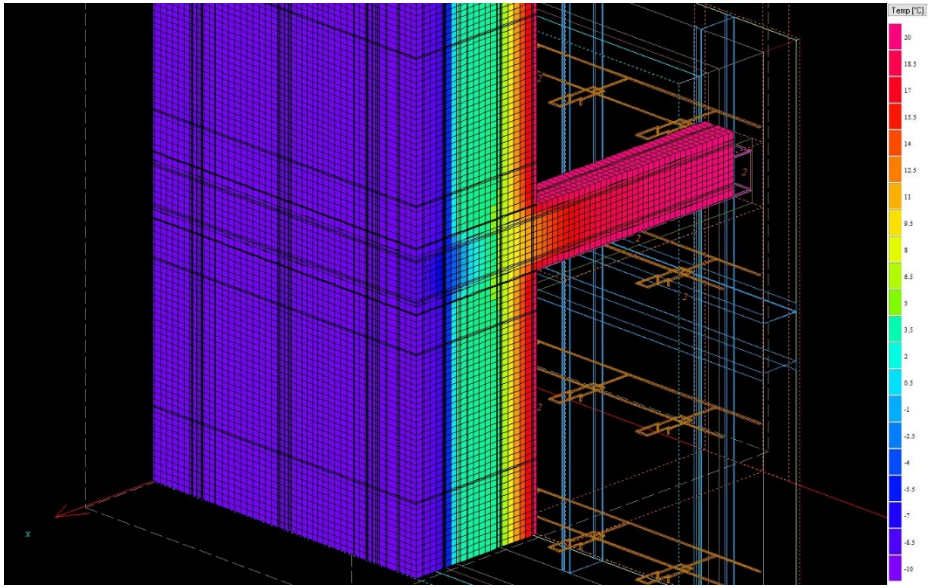
Thermal Efficiency:
1/(1+0.67*(#/Area))

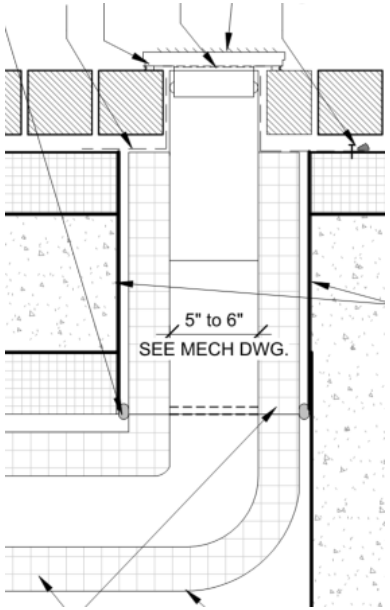
Example:
Area: 250 ft²
#: 2

Base R-Value: 22.34
New R-Value: 22.22

Efficiency: 99%







Unique Thermal Bridges: Wall H/ERV Penetration

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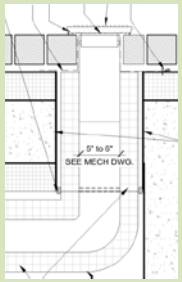

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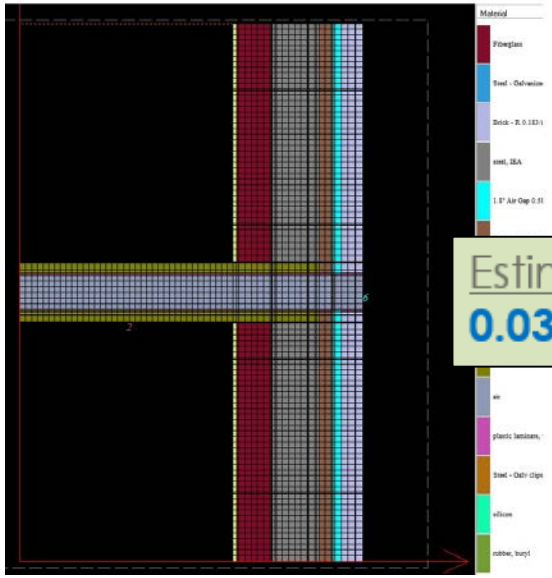

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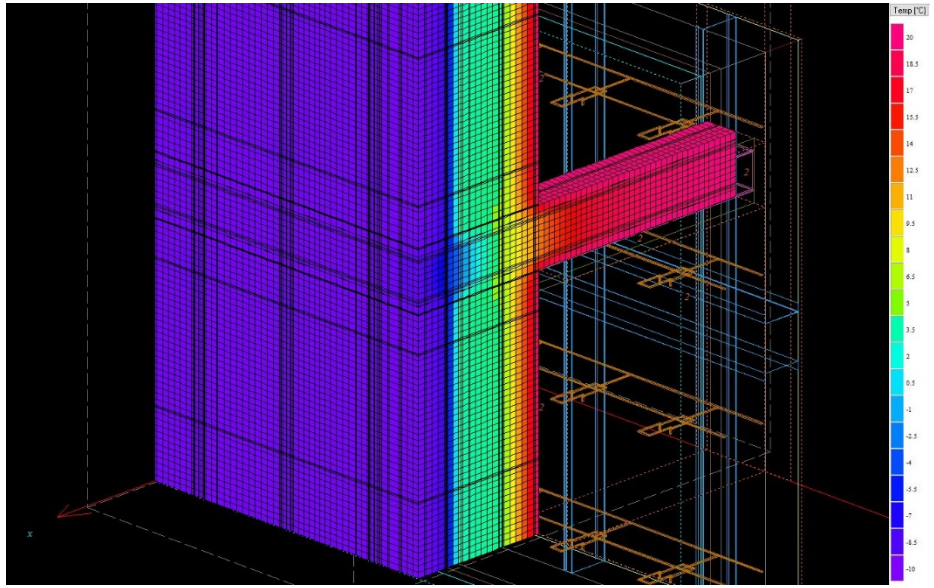

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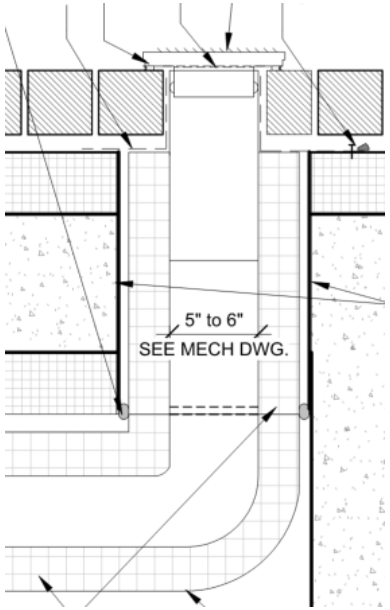
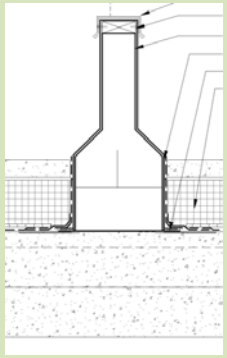


Unique Thermal Bridges: Roof Mechanical Curb

Roof Mech Curb



Description

Mechanical equipment curbs support outdoor units for heating, cooling, ventilation, and utility distribution.

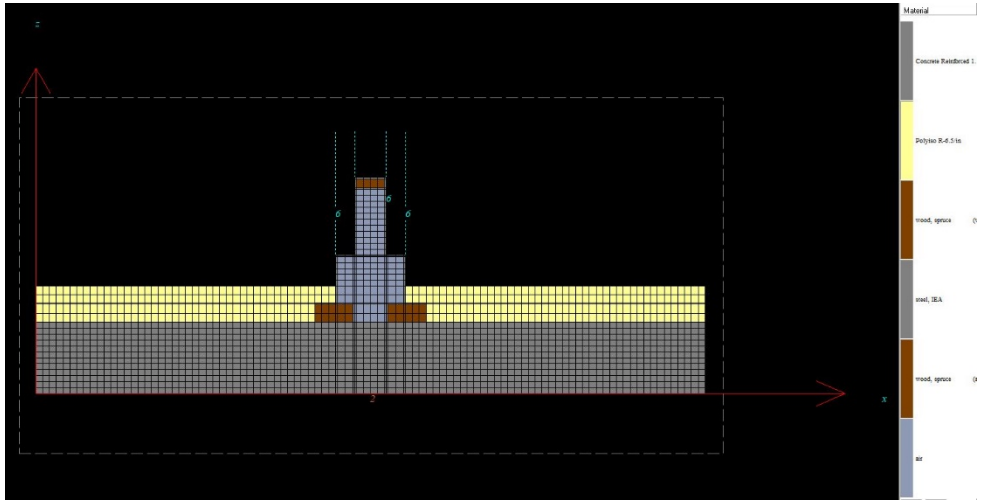
Estimated Chi Value:
1.99 BTU/hr.F

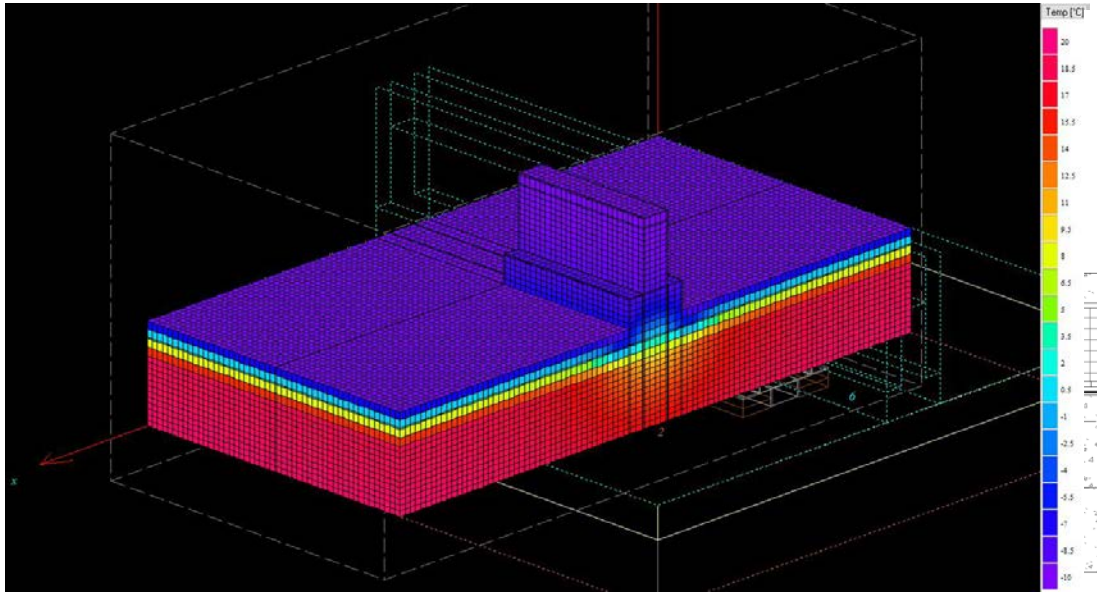
Thermal Efficiency:
1/(1+81.1*(#/Area))

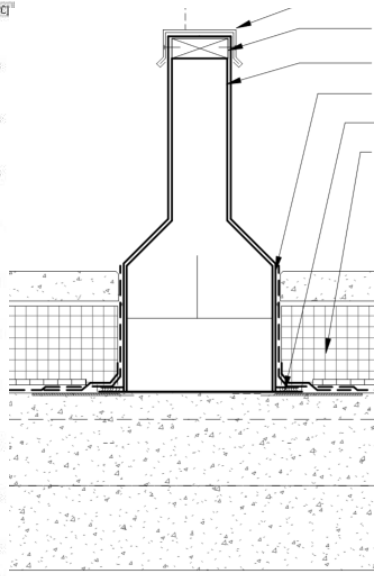
Example:
Area: 20,000 ft²
#: 50

Base R-Value: 40.77
New R-Value: 39.90

Efficiency: 83%







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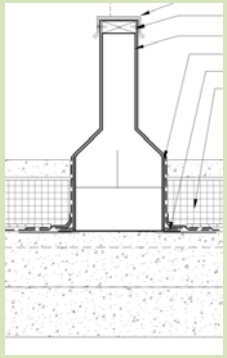

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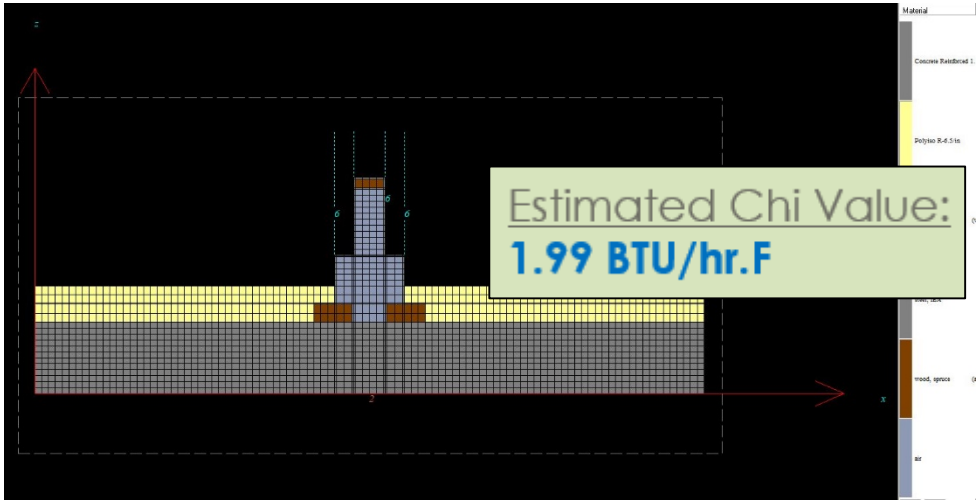

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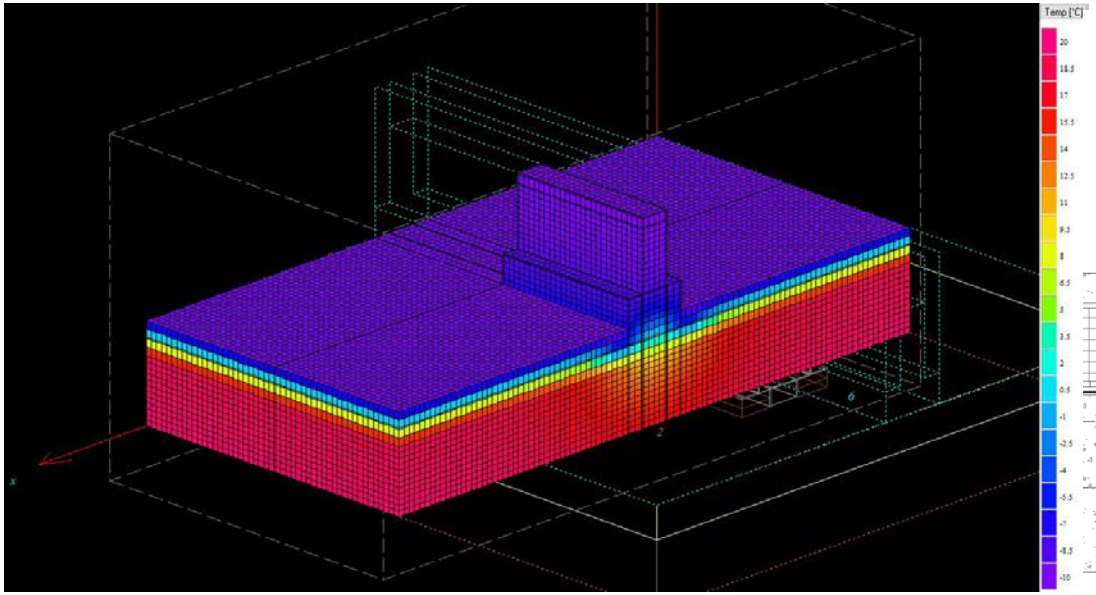
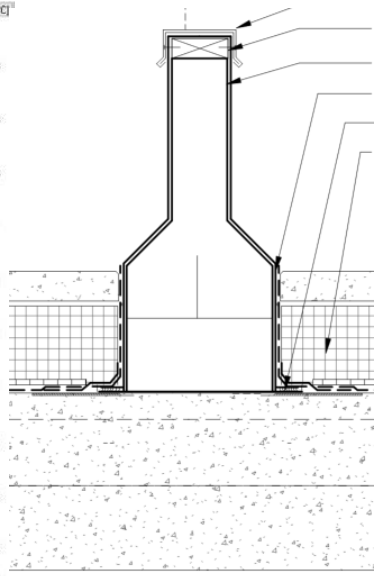
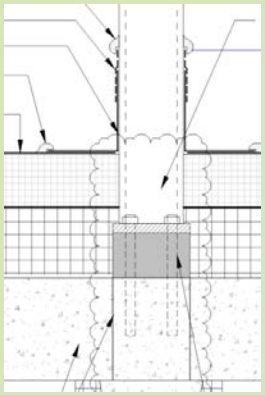




Unique Thermal Bridges: Roof PV Canopy

Roof Mech Curb



Description

Steel PV Canopy supports are used to raise PV systems above mechanical equipment and optimize the solar PV design. Canopy penetrations scale with the PV array size.

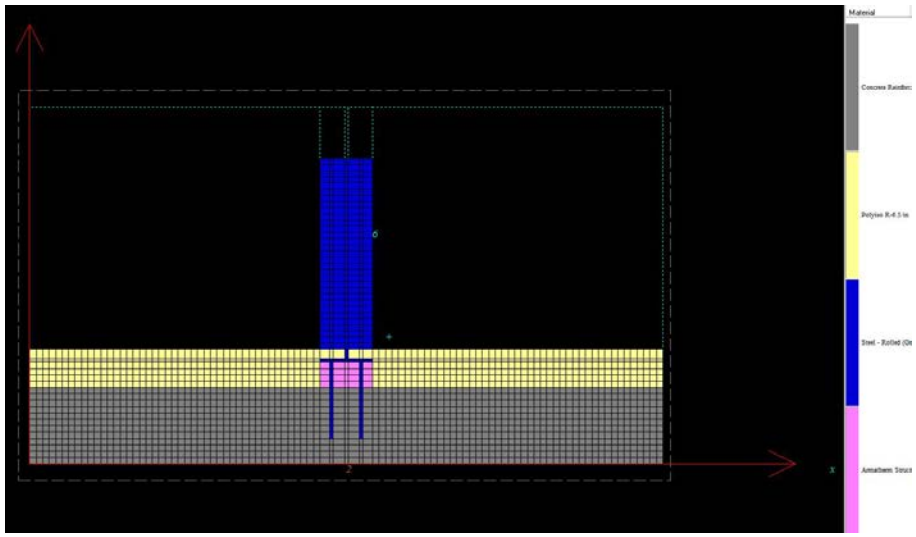
Estimated Chi Value:
0.41 BTU/hr.F

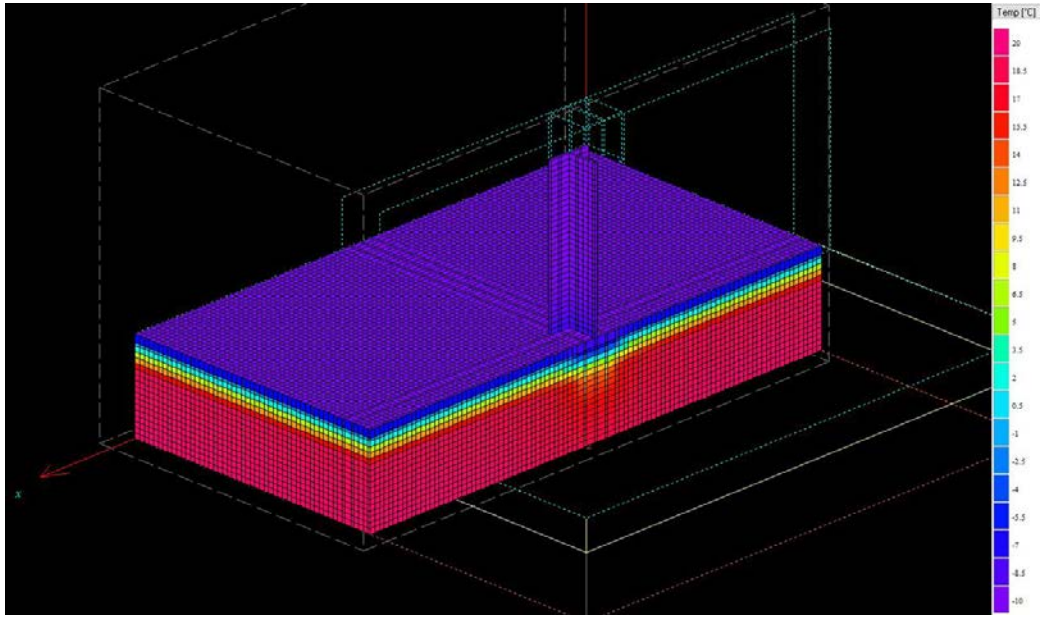
Thermal Efficiency:
1/(1+16.7*(#/Area))

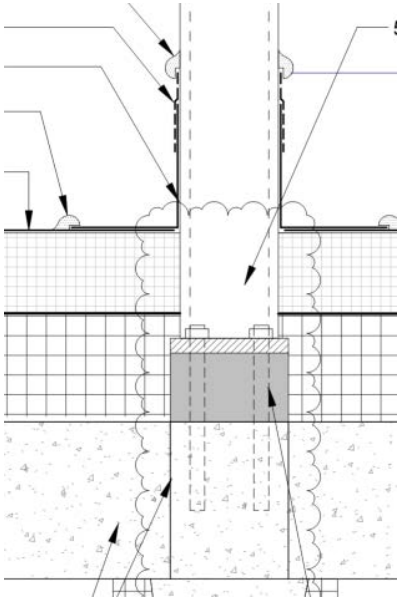
Example:
Area: 20,000 ft²
#: 20

Base R-Value: 40.77
New R-Value: 40.10

Efficiency: 98%







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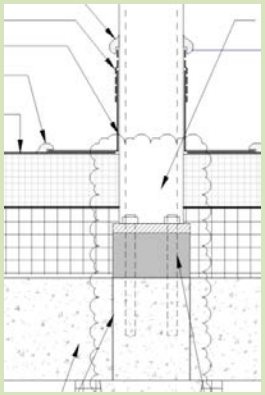

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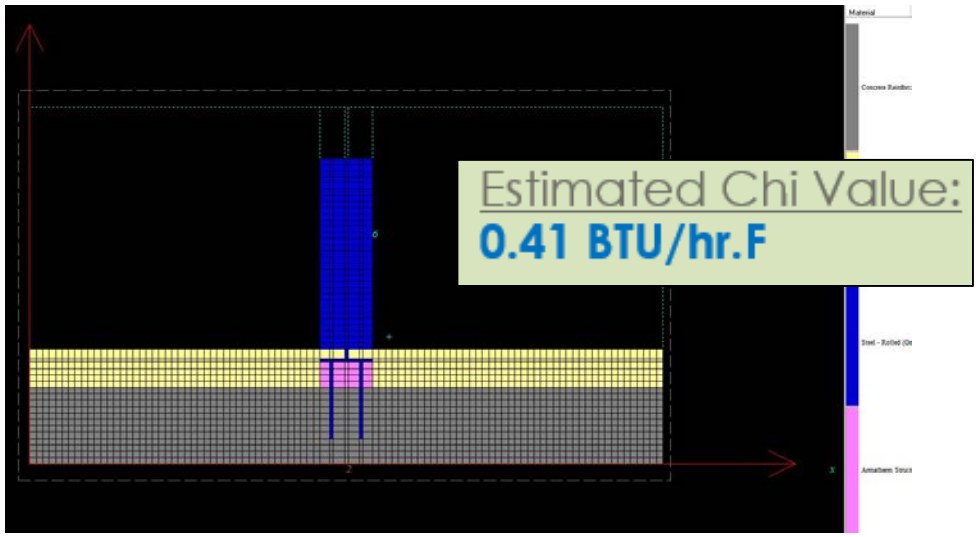

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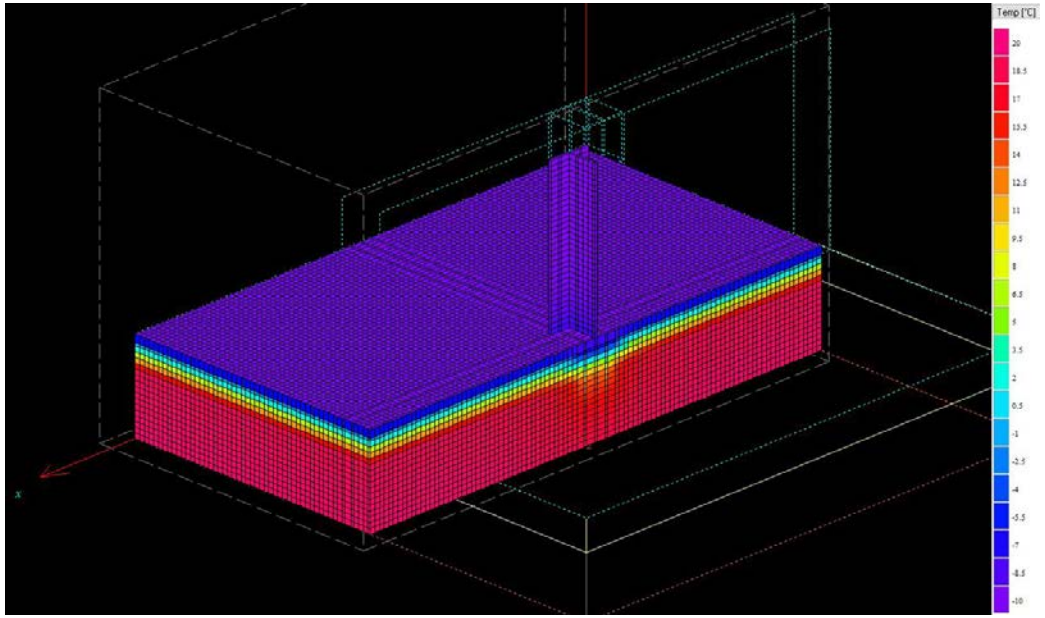
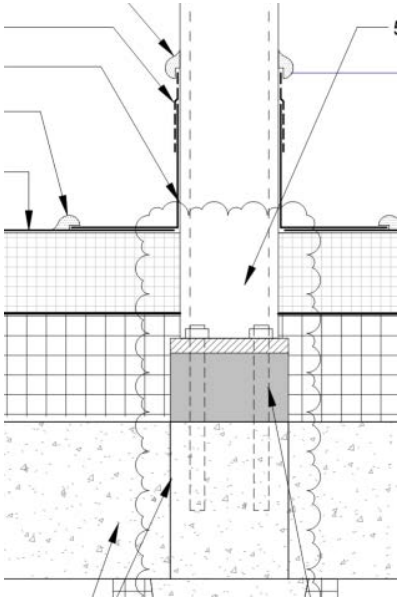
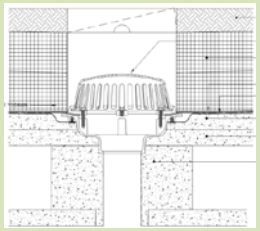




Unique Thermal Bridges: Roof Drain

Roof Drain



Description

Roof drains penetrate the exterior roof insulation layers, creating a thermal bridge. Most buildings have roof drains at multiple locations.

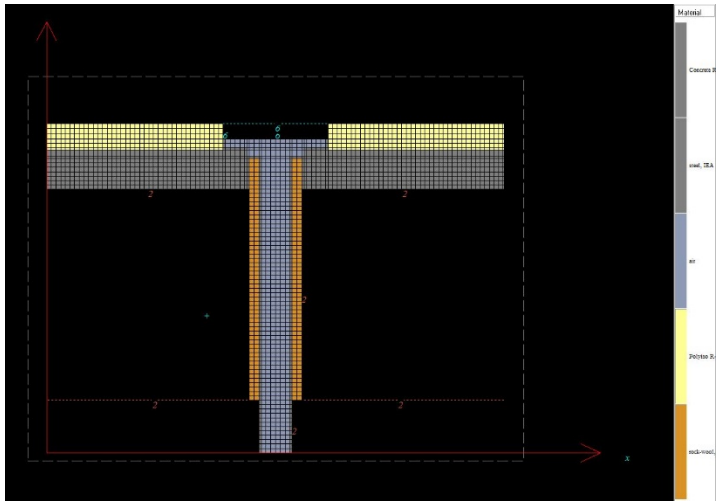
Estimated Chi Value:
3.13 BTU/hr.F

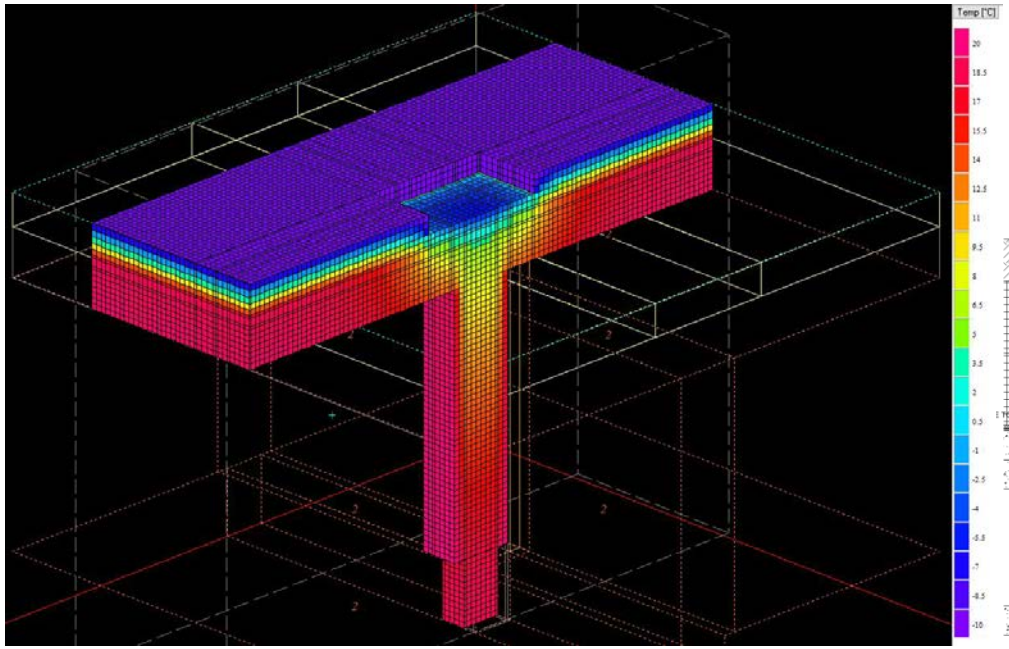
Thermal Efficiency:
1/(1+127.6*(#/Area))

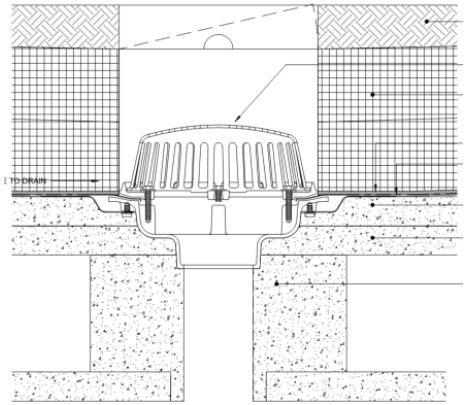
Example:
Area: 20,000 ft²
#: 8

Base R-Value: 40.77
New R-Value: 38.79

Efficiency: 95%







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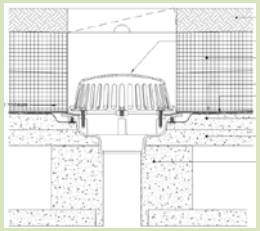

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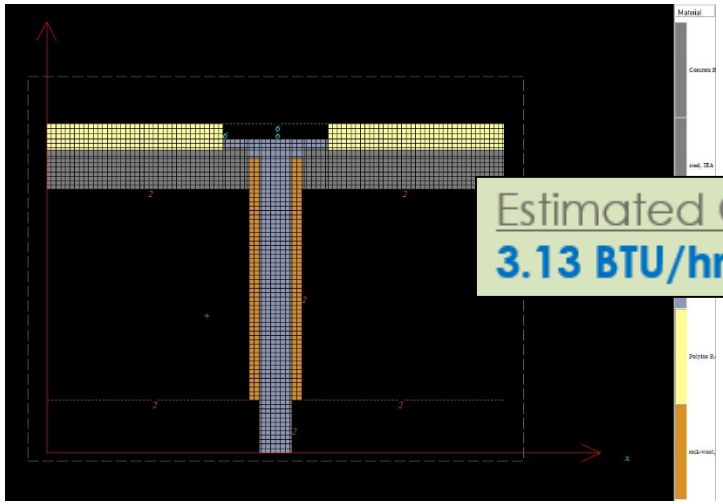

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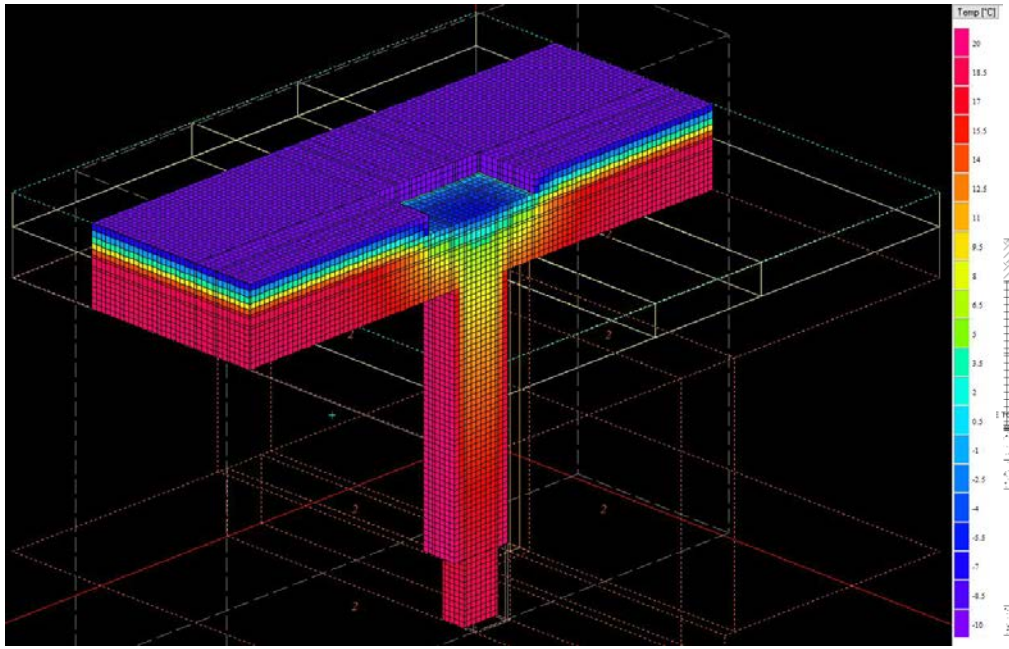
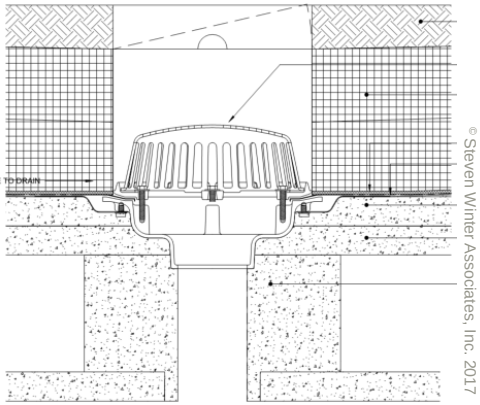
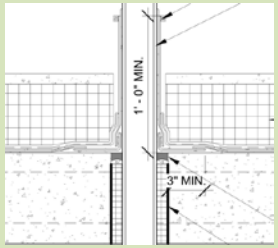




Unique Thermal Bridges: Roof Plumbing Vent

Plumbing Vent



Description

Roof plumbing vents penetrate the exterior roof insulation layers, creating a thermal bridging condition. Most buildings have plumbing vents at waste water risers.

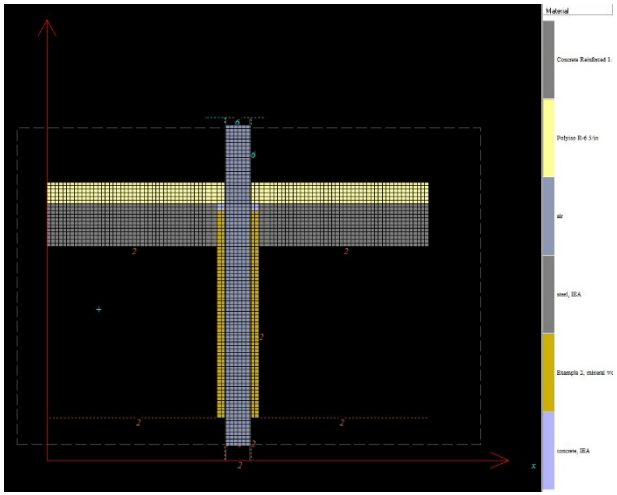
Estimated Chi Value:
0.87 BTU/hr.F

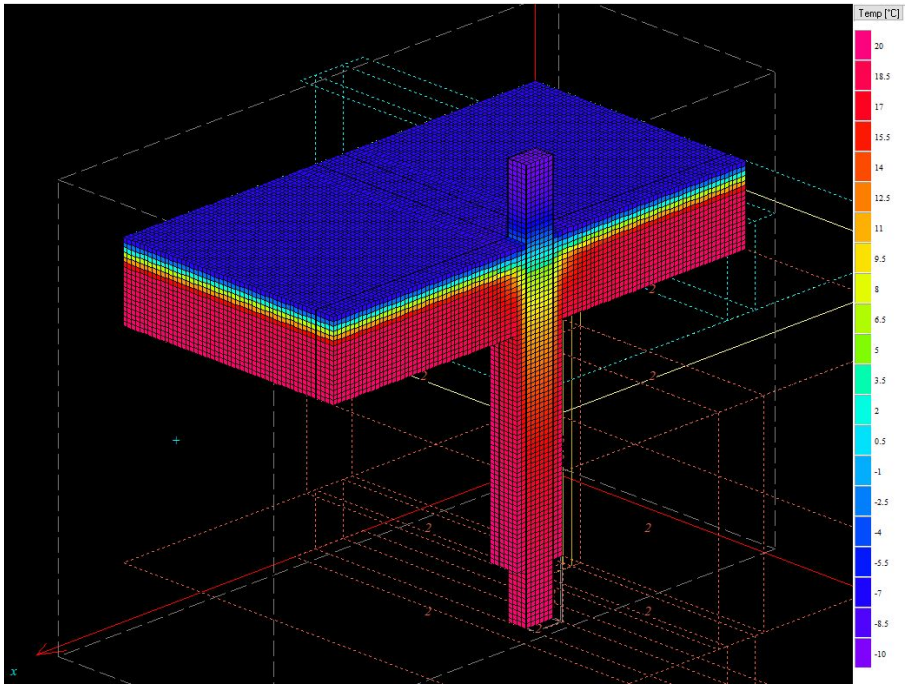
Thermal Efficiency:
1/(1+35.5*(#/Area))

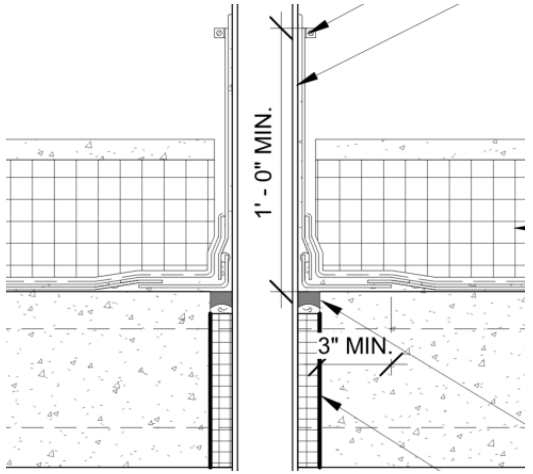
Example:
Area: 20,000 ft²
#: 20

Base R-Value: 40.77
New R-Value: 39.37

Efficiency: 97%

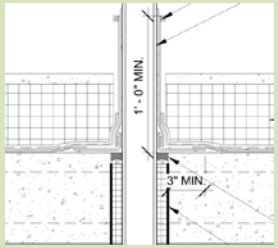






Unique Thermal Bridges: Roof Plumbing Vent

Plumbing Vent



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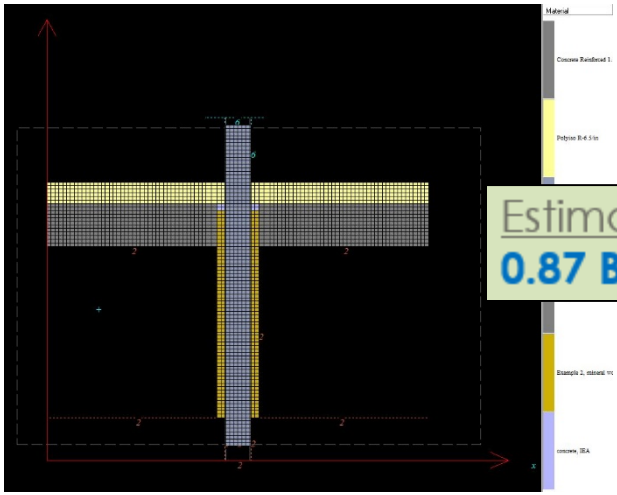

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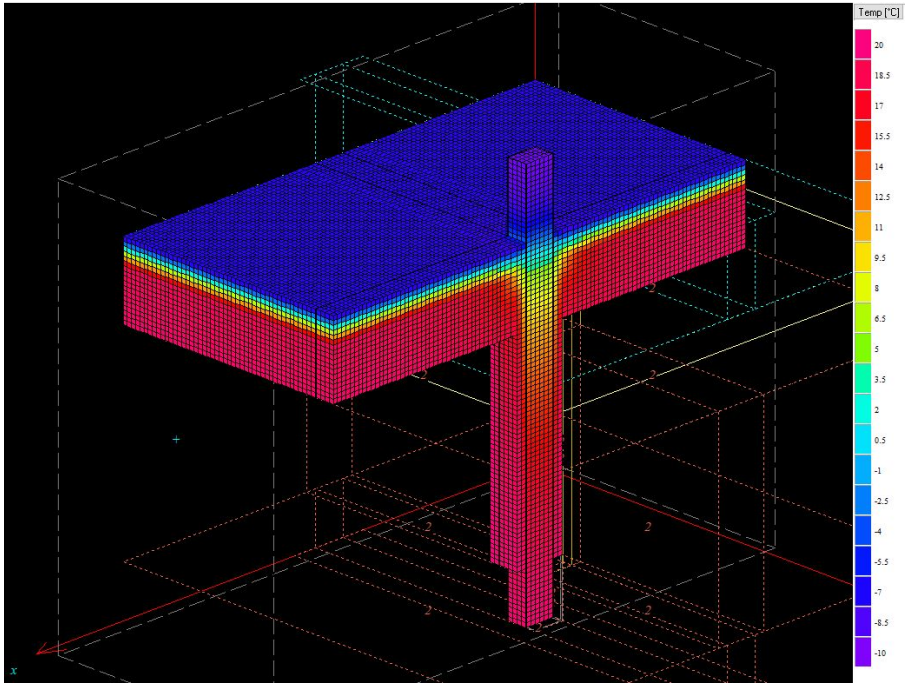

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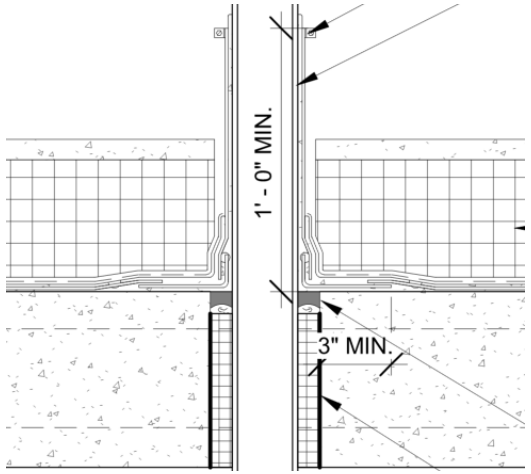
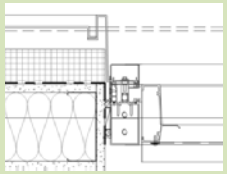
Efficiency: 97%



Unique Thermal Bridges: Wall Mechanical Louver

Wall Mechanical Louver



Description

Mechanical louvers occur at bulkheads, elevator shafts, gas rooms, and laundry rooms.

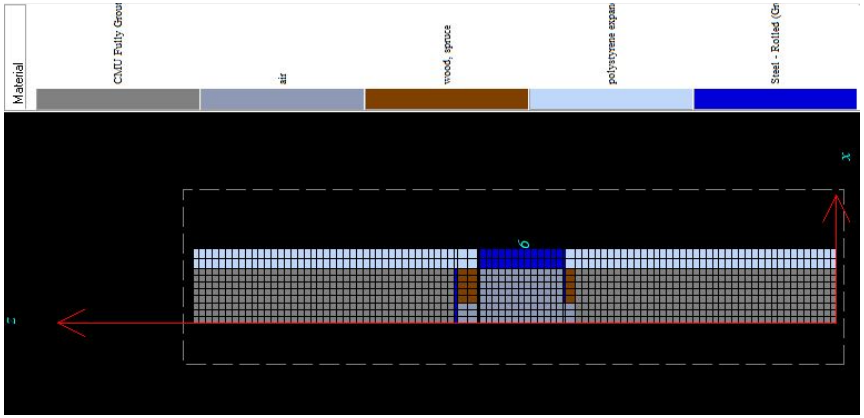
Estimated Chi Value:
1.6 BTU/hr.F

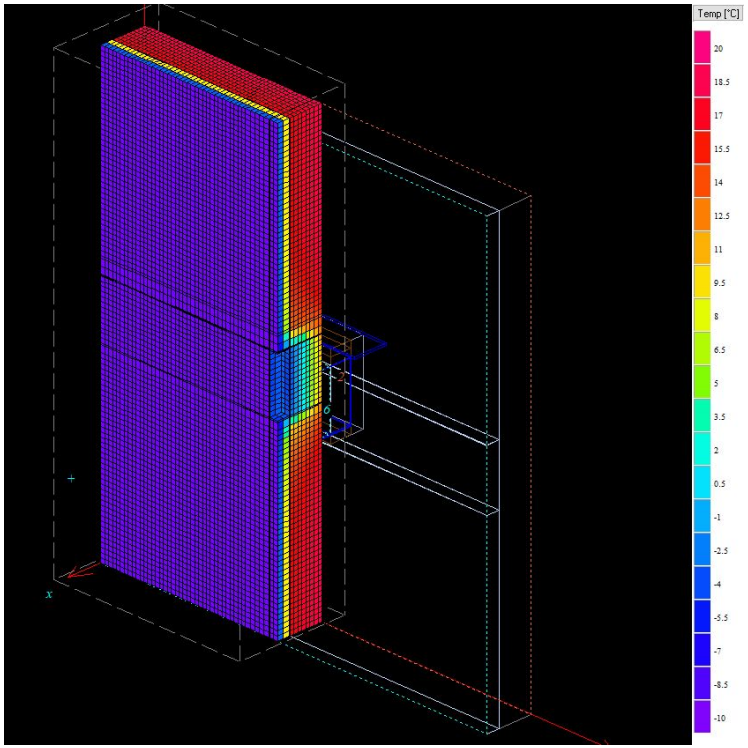
Thermal Efficiency:
1/(1+24.2*(#/Area))

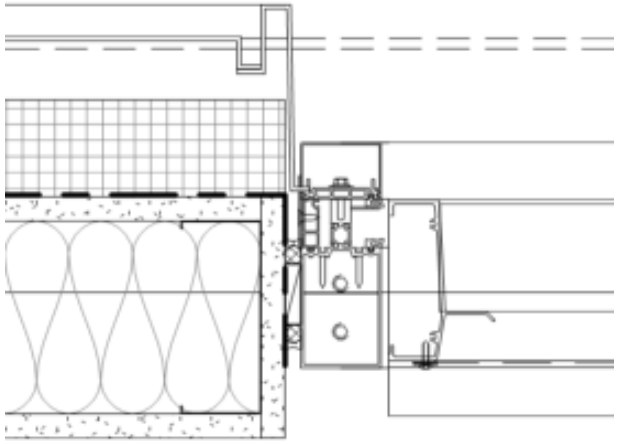
Example:
Area: 150 ft²
#: 1

Base R-Value: 15.15
New R-Value: 13.04

Efficiency: 86%







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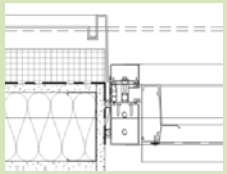

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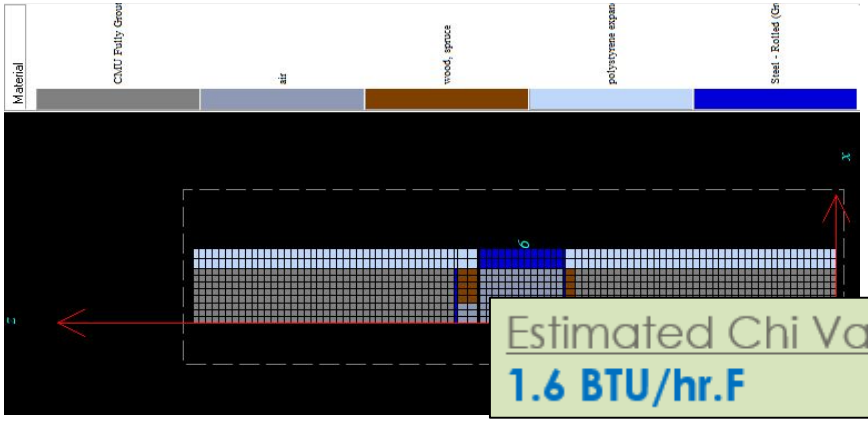

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1.6 BTU/hr.F

Example:
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#: 1

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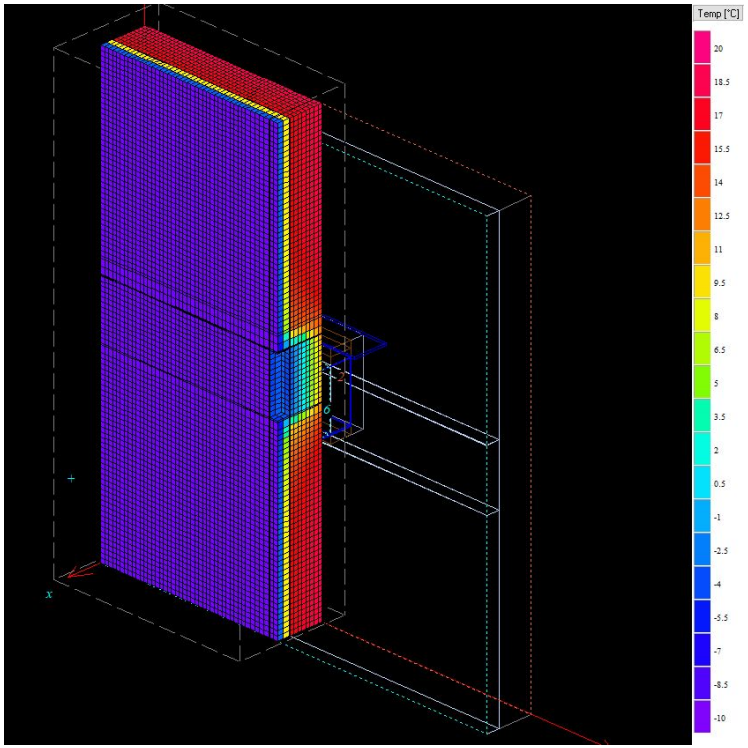
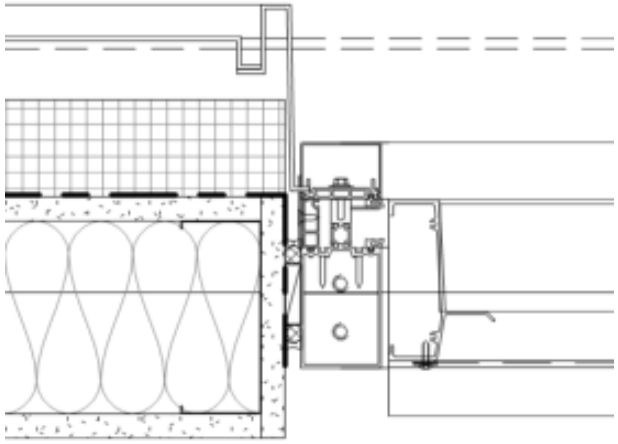
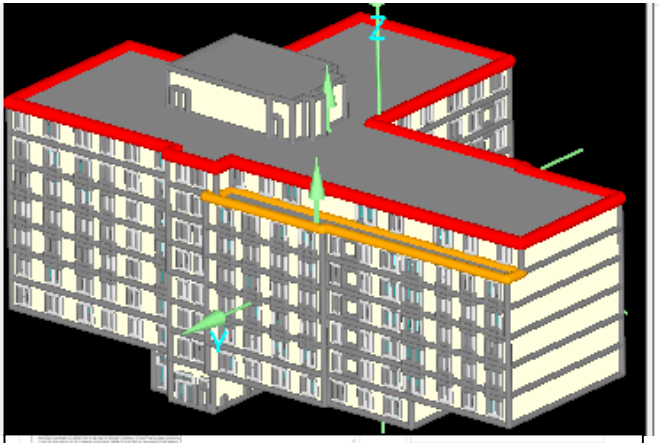
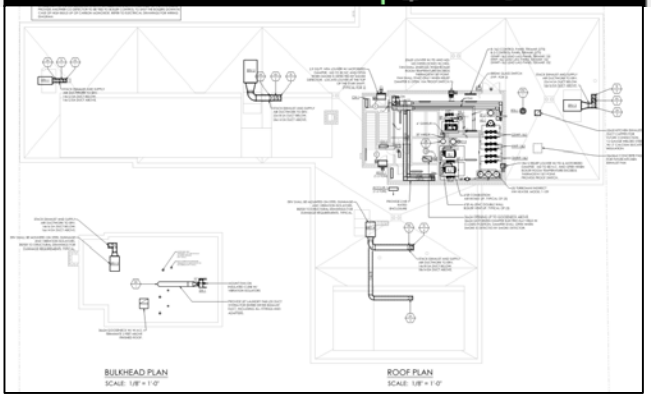




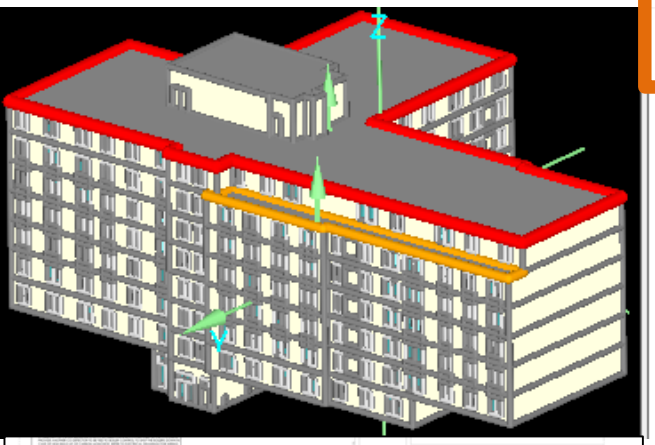
WUFI Passive Results

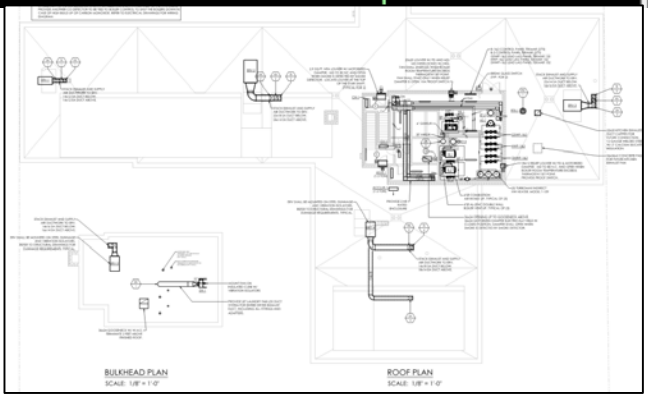


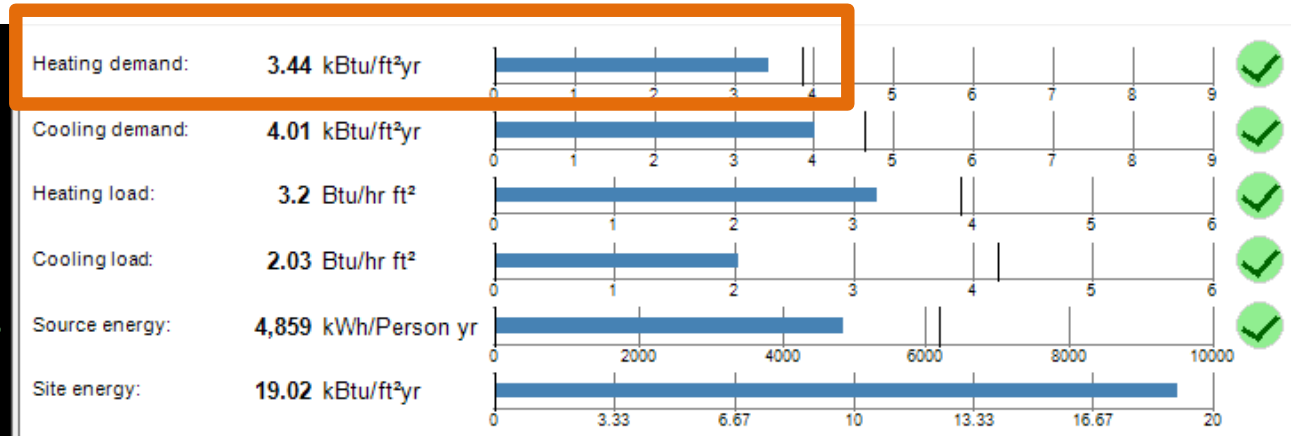


Heating demand:	**3.31** kBtu/ft²yr	
Cooling demand:	**4.02** kBtu/ft²yr	
Heating load:	**3.15** Btu/hr ft²	
Cooling load:	**2.03** Btu/hr ft²	
Source energy:	**4,850** kWh/Person yr	
Site energy:	**18.99** kBtu/ft²yr	

WUFI Passive Results

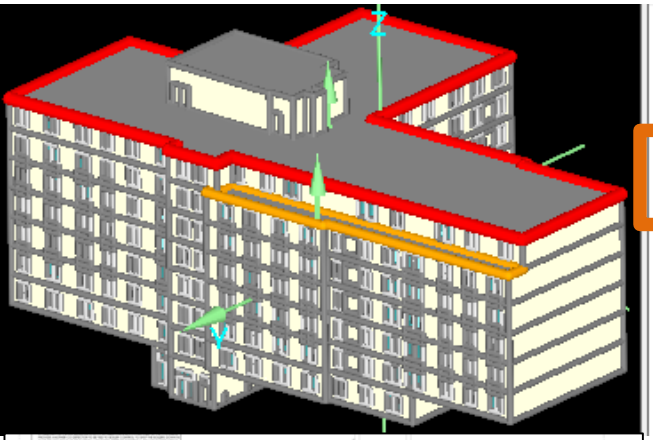


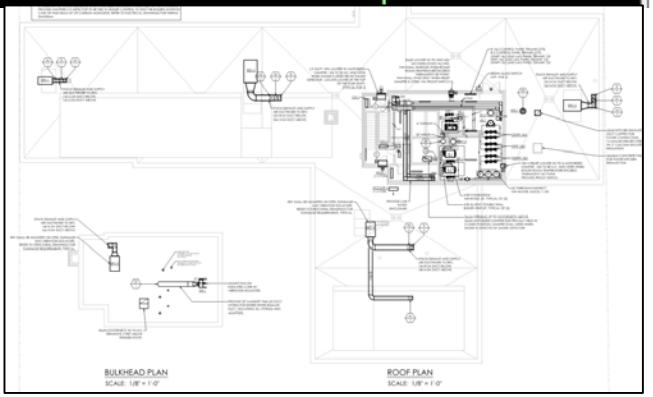


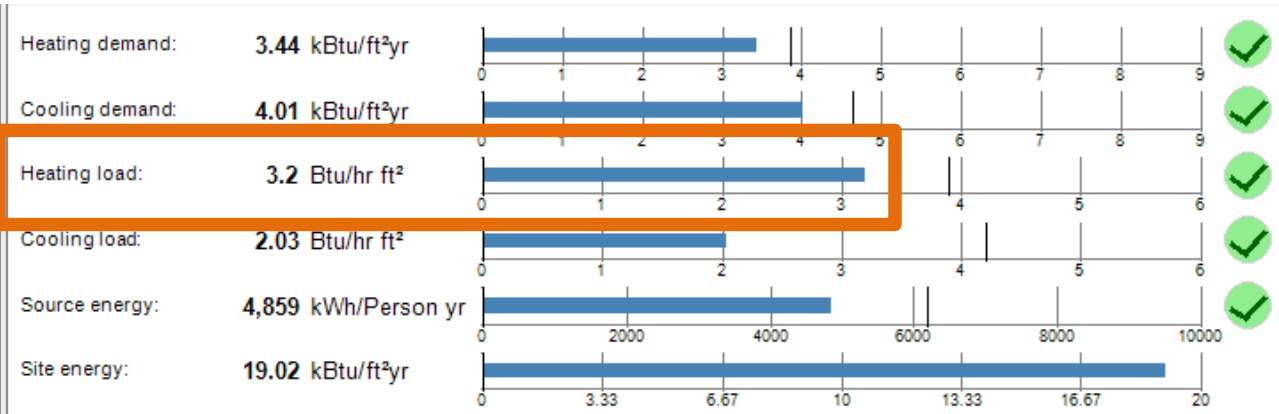


1. Heating Demand ^ 3.7%

WUFI Passive Results







1. Heating Demand ^ 3.7%
2. Heating Load ^ 1.5%
3. PH Compliance

Takeaways

Development

Feasibility, schematic, and design models

Accounting

for de-rate is paramount to meet Passive House space conditioning thresholds

Efficiency

Typical assemblies are variable

High Performance Walls

RESOURCES

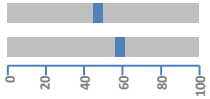
For Cladding Finish Systems: Clips

Galvanized Metal Clips

Description

These clips are usually galvanized steel and are used to support rainscreen and panel cladding systems.

Thermal efficiency per SWA: **46-59%**



46% for Steel backup
59% for CMU backup

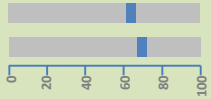
Standard Product

Stainless Steel Clips

Description

Replacing galvanized steel clips with stainless steel ones can greatly reduce the thermal conductivity.

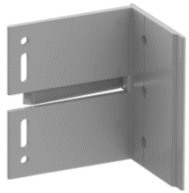
Thermal efficiency per SWA: **63-74%**



63% for Steel backup
74% for CMU backup

Example Products:
A-Clip. MFSSCHAN

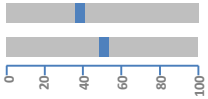
Aluminum Clips



Description

Aluminum clips are light weight and strong. They are a more elastic and non corrosive alternative to traditional metal clips.

Thermal efficiency per SWA: **38-52%**



38% for Steel backup
52% for CMU backup

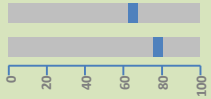
Example Products:
Alpha Brackets

Fiberglass Clips

Description

Fiberglass clips have a much lower thermal transmittance coefficient than any metal equivalent.

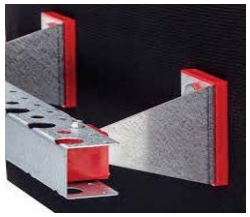
Thermal efficiency per SWA: **64-79%**



64% for Steel backup
79% for CMU backup

Example Products:
Cascada Clip

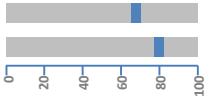
Thermal Stop Clips



Description

This clip has a plastic thermal stop at the base and head to help mitigate thermal bridging.

Thermal efficiency per SWA: **67-80%**

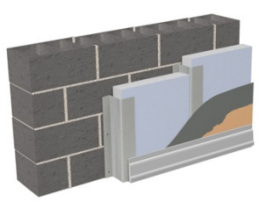


67% for Steel backup
80% for CMU backup

Example Products:
Pos-I-Tie Thermal Clip, Nvelope NV1 Thermal Clip

For Cladding Finish Systems: Girts

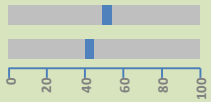
Galvanized Girts



Description

Typical z-girts are usually galvanized steel. Most projects use these to support their cladding systems.

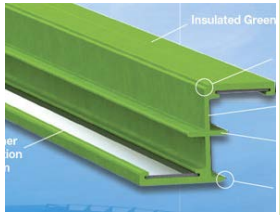
Thermal efficiency per SWA: **43%-53%**



53% for Steel backup
43% for CMU backup

Standard Product

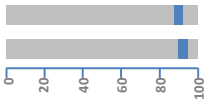
Fiberglass Girts



Description

Fiberglass girts are installed and used the same way as typical metal z-girt. The fiberglass material reduces thermal bridging.

Thermal efficiency per SWA: **91%-95%**



91% for Steel backup
95% for CMU backup

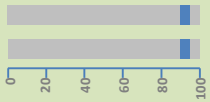
Example Products:
Green Girt- Simple Z

Thermoset Resin Girts

Description

These girts have a low thermal conductivity. Made of fire resistant resin material. Can be spaced 16" or 24" o.c. and is very strong.

Thermal efficiency per SWA: **96%**



96% for Steel backup
96% for CMU backup

Example Products:
Armatherm Z Girt

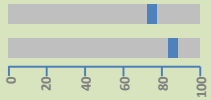
For Brick Veneer Systems: Ties

Galvanized Steel Brick Ties

Description

Typical brick ties are galvanized steel. Most brick veneer projects use this type of product.

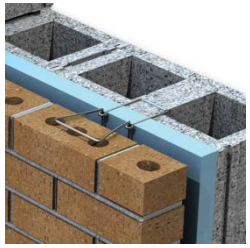
Thermal efficiency per SWA: **75-84%**



75% for Steel backup
84% for CMU backup

Standard Product

Stainless Steel Brick Ties



Description

Stainless steel ties are less conductive than galvanized steel ties.

Thermal efficiency per SWA: **87-93%**

87% for Steel backup
93% for CMU backup

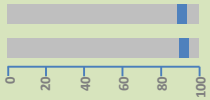
Example Products:
2 Seal Tie Thermal,
Original Pos-I-Tie

Thermal Break Brick Ties

Description

This stainless steel brick tie has a plastic coating, which reduces thermal bridging.

Thermal efficiency per SWA: **88-94%**



88% for Steel backup
94% for CMU backup

Example Products:
2 Seal Tie Thermal
Wing Nut Anchor

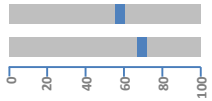
For Brick Veneer Systems: Angles

Typical Shelf Angle

Description

Typically, shelf-angles are made of galvanized steel.

Thermal efficiency per SWA: **58-69%**



58% for Steel backup
69% for CMU backup

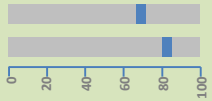
Standard Product

Stand-off Shelf Angle

Description

This stand off shelf angle allows insulation to be installed behind it. The bracket can be used with readily available shelf angles.

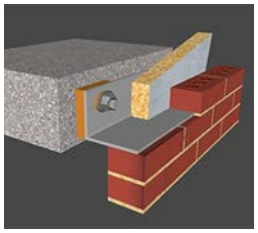
Thermal efficiency per SWA: **73-81%**



73% for Steel backup
81% for CMU backup

Example Products:
FAST (Fero Angle Support Technology),

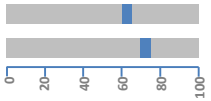
Shelf Angle with Thermal Break



Description

The thermal break plate is installed between the shelf angle and bracket to reduce the thermal bridge at those points.

Thermal efficiency per SWA: **63-74%**



63% for Steel backup
74% for CMU backup

Example Products:
Armatherm Shelf Angle

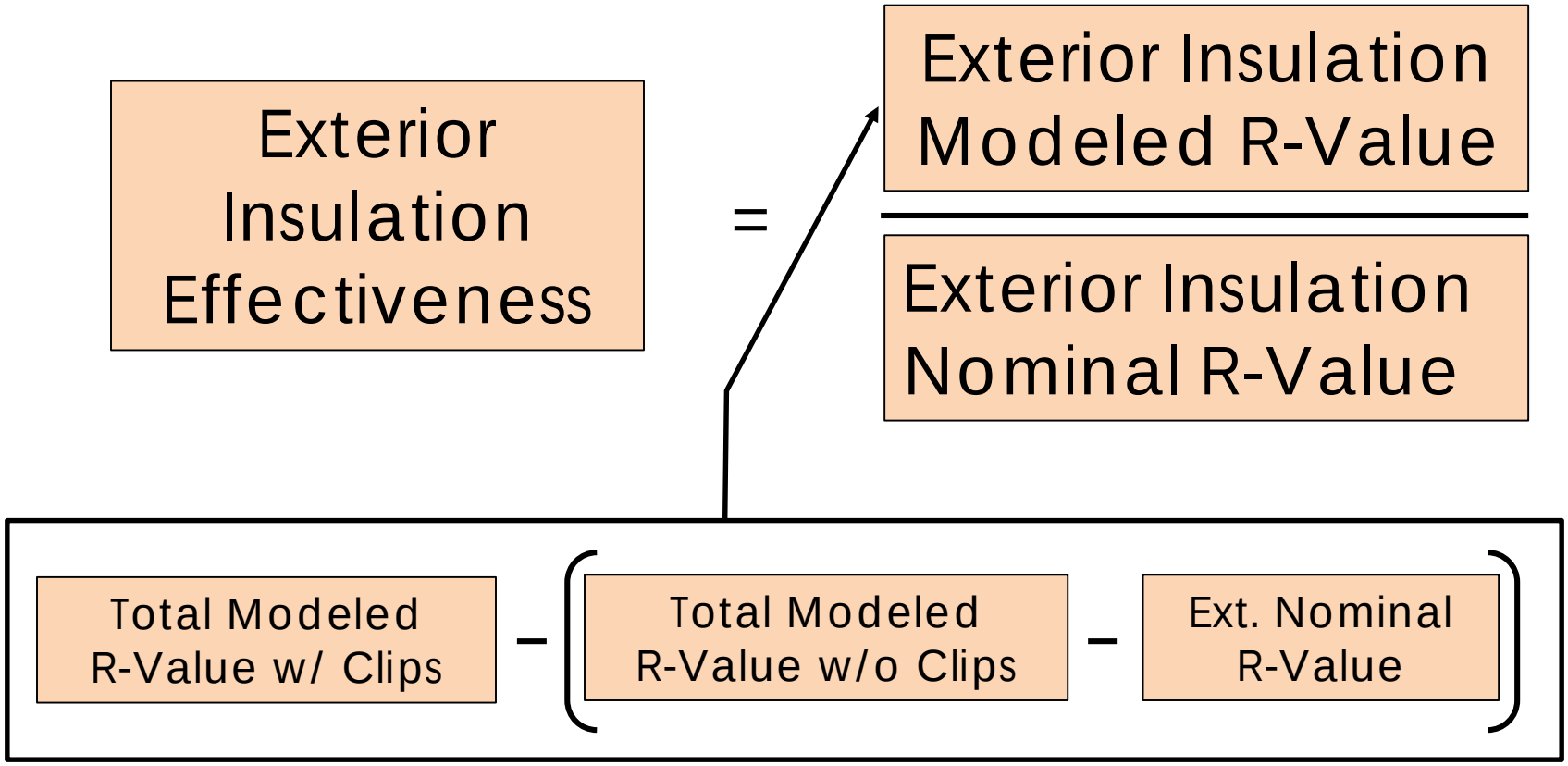
Questions

tmoore@swinter.com

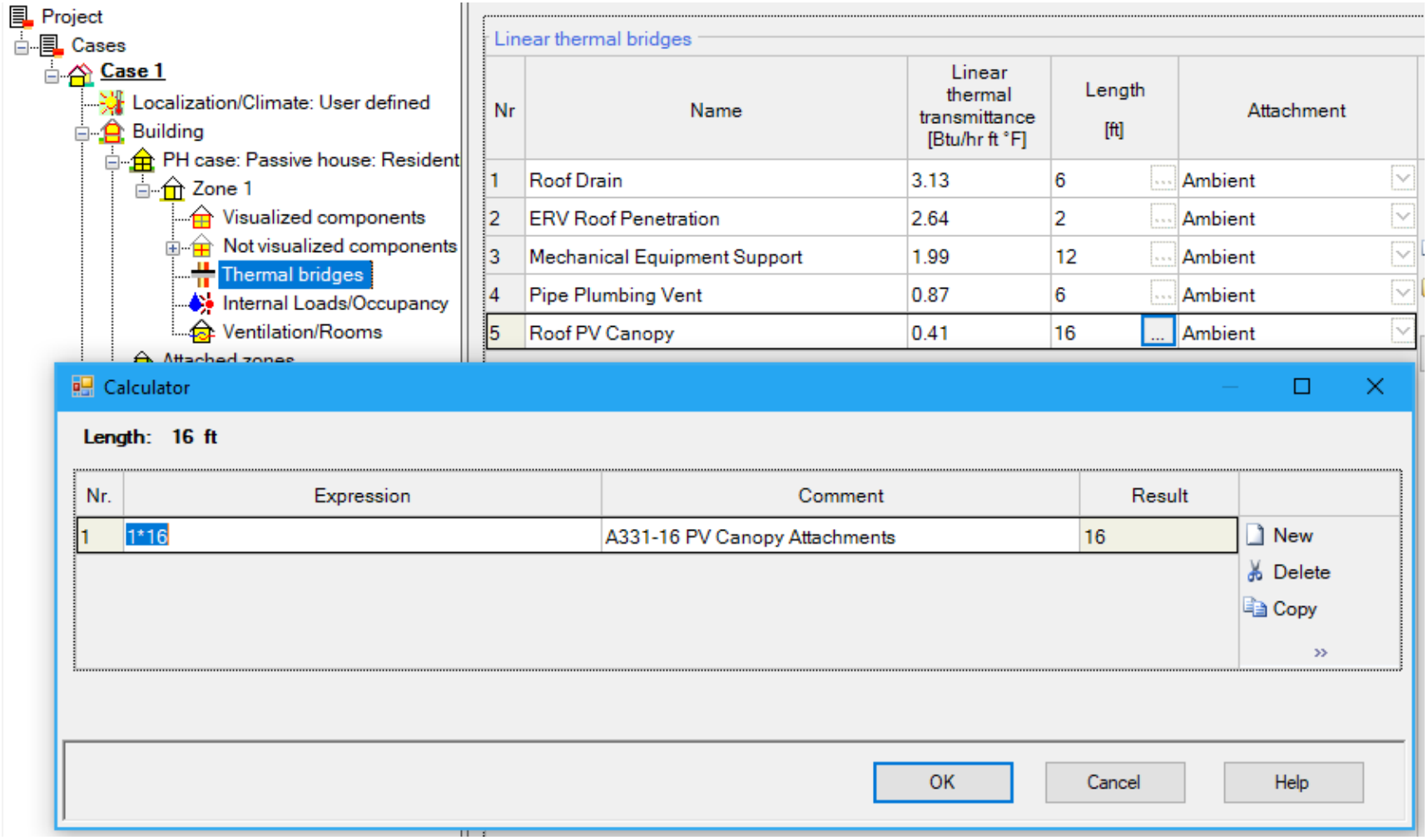
Modeling Considerations

- Based on 0.375 attachments/ft^2
- Achieve around R-30
  - 2” of exterior XPS
- Spacing the same for all systems
  - 16” horizontally, 24” vertically
- Typical backup systems modeled
  - CMU
  - Steel Stud
- Slab edge included for angles

Exterior Insulation Effectiveness



WUFI PASSIVE/PHPP Integration



WUFI PASSIVE/PHPP Integration

Thermal bridge inputs

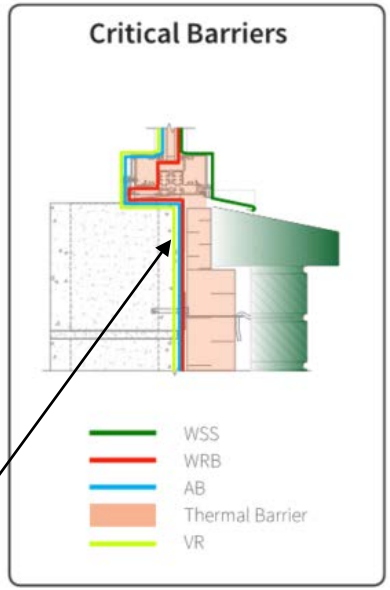
No.	Thermal bridge - denomination	Group No.	Assigned to group	Quantity	x (	Length [ft]	-	Subtraction length [ft]	)=	Length ℓ [ft]	User determined psi value [BTU/hr.ft.F]
1	Roof Drain	15	Thermal bridges Ambient	6	x (	1.00	-		) =	6.00	3.130
2	ERV Roof Penetration	15	Thermal bridges Ambient	2	x (	1.00	-		) =	2.00	2.640
3	Mechanical Equipment Support	15	Thermal bridges Ambient	12	x (	1.00	-		) =	12.00	1.990
4	Pipe Plumbing Vent	15	Thermal bridges Ambient	6	x (	1.00	-		) =	6.00	0.870
5	Roof PV Canopy	15	Thermal bridges Ambient	16	x (	1.00	-		) =	16.00	0.410
6					x (		-		) =		
7					x (		-		) =		

updates | Brief instructions | Verification | Check | Climate | R-Values | RefDims | Areas | Ground | Components | Windows | WinTypes | Shading | Ventilation | Addl vent | Annual heating | Heat

Existing Resources

Source:
Masonry Systems Guide
www.masonrysystemsguide.com

Detailing Guidance



Masonry Systems Guide, p. 1-27

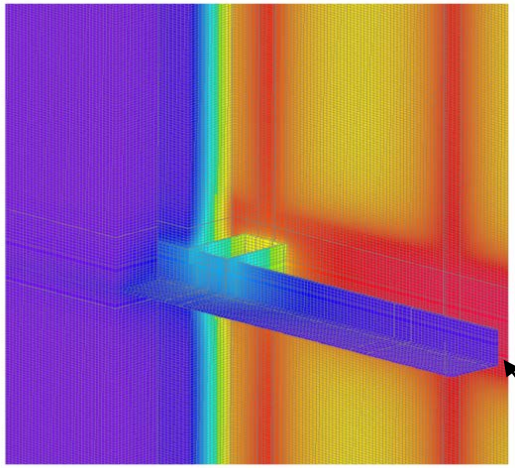


Fig. i-19 Three-dimensional thermal model of a masonry veneer standoff shelf angle at a floor line

Masonry Systems Guide, p. i-31

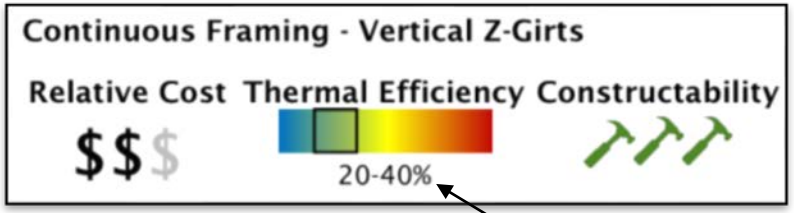
Thermal Modeling

- RDH Building Science
  - Masonry Systems Guide Collaborator (www.masonrysystemsguide.com)
  - Technical Bulletins
    - No. 011: "Cladding Attachment Solutions for Exterior Insulated Commercial Walls"

Existing Resources

- Percent Insulation Effectiveness
  - Percentage of nominal R-value achieved with attachment system

Source:
RDH Technical Bulletin 011



RDH TB-011 – p. 5

Percent "Insulation Effectiveness"