BUILDINGENERGY NYC

Thermal Bridging '22: What to Know and What to Do

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Northeast Sustainable Energy Association (NESEA)
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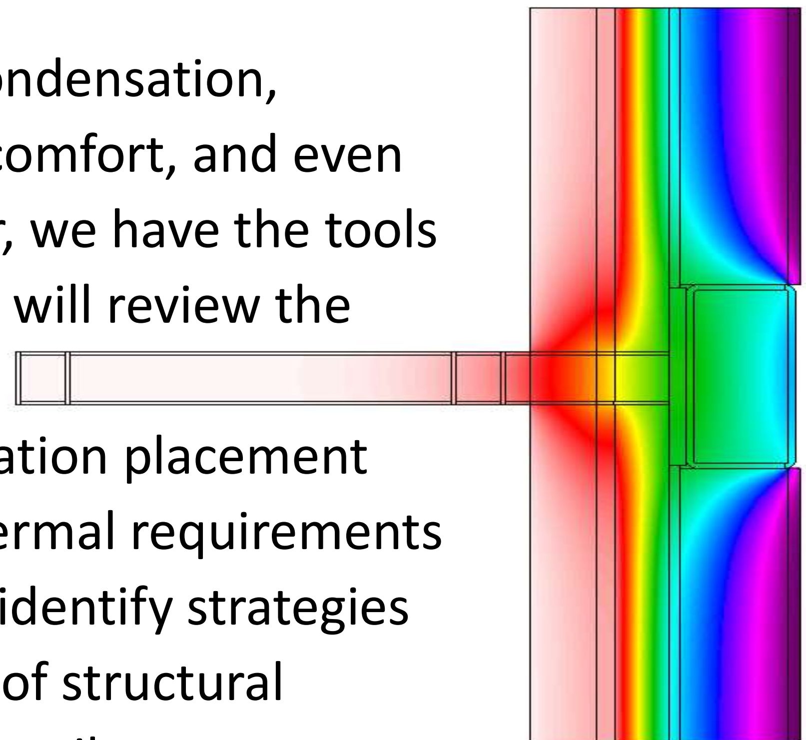
Abstract

Thermal Bridging can lead to problematic condensation, increased energy usage, reduced occupant comfort, and even noncompliance with energy codes. However, we have the tools to address this challenge. In this session, we will review the three types of structural thermal bridging, briefly cover foundation and slab edge insulation placement and detailing, summarize the conductive thermal requirements of the Energy Codes and, most importantly, identify strategies to calculate the impact on code compliance of structural thermal bridging conditions and mitigated details.



THERM IR image output

LEARNING OBJECTIVES

1. Realize the impact of structural details and elements on energy code compliance.
2. Differentiate thermal bridging conditions that can have a significant effect on building energy loss vs. those that have minimal effect.
3. Compare and contrast the benefits and drawbacks of some of the design options available for mitigation of structural thermal bridging.
4. Review current NYC Energy Code requirements for assessing and mitigating thermal bridging conditions.

AGENDA

WHY

SHOULD DESIGNERS CARE?

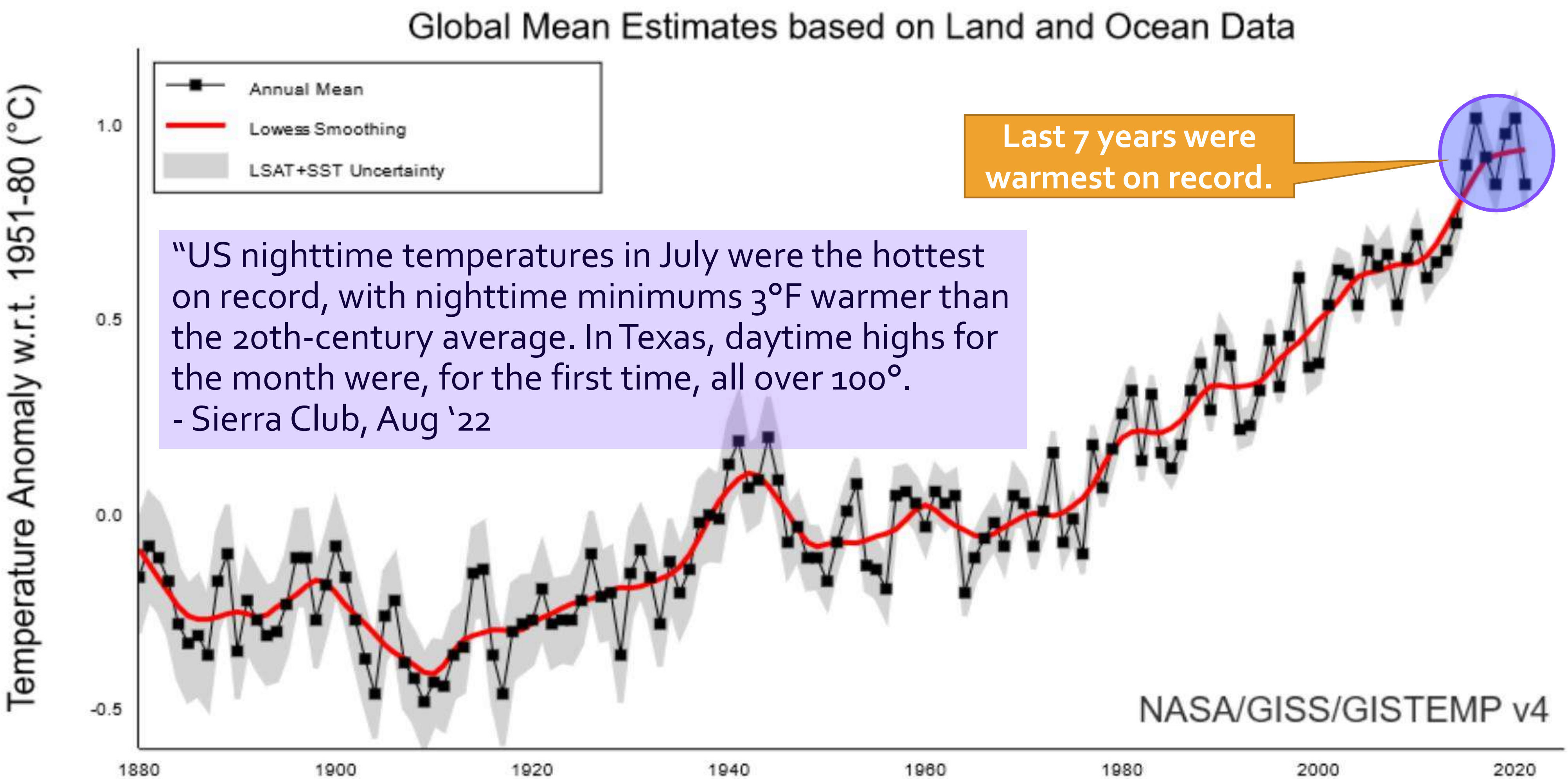
Can result in CO$TLY problematic conditions on your project!

Building Performance Problems

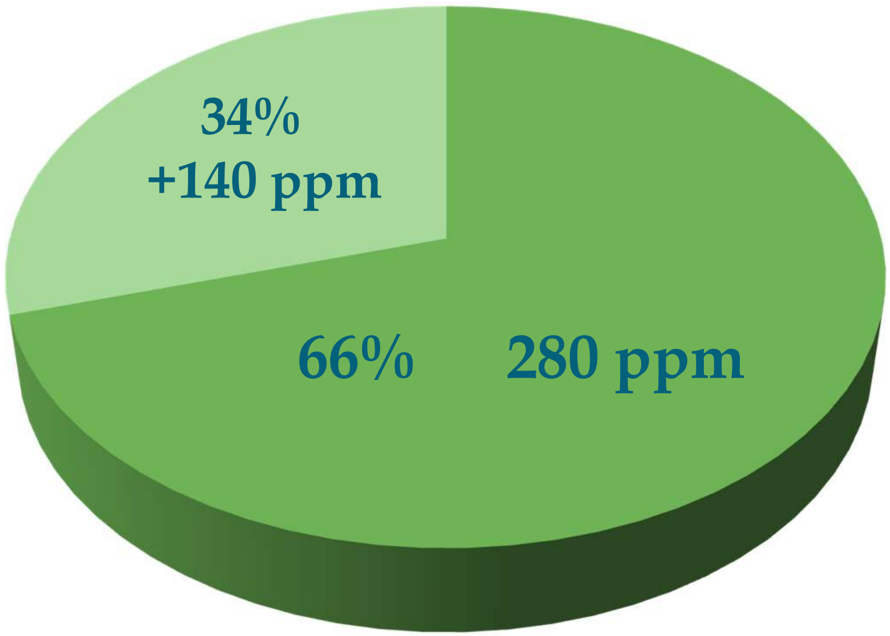
Condensation

Icicles and Ice Dams

Global Temperature Data updated Jan 2022



Atmospheric CO_2 Increase Since 1800's



- Prior to 1800's
- Added 1800's-2022

110 Million Tons of global warming gases emitted by human activities every day…

280 ppm to 420 ppm = 50% increase in CO_2

Thermal Properties o Various Materials

R → Thermal Resistance

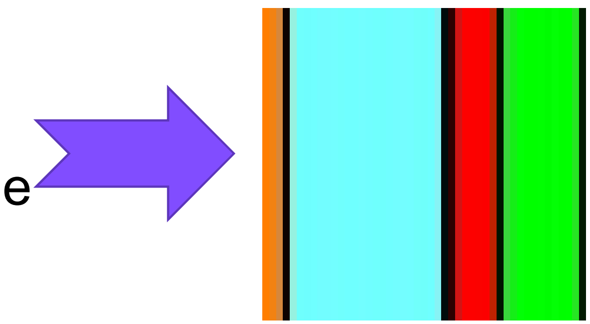
U → Thermal Conductivity

R = 1/U U = 1/R

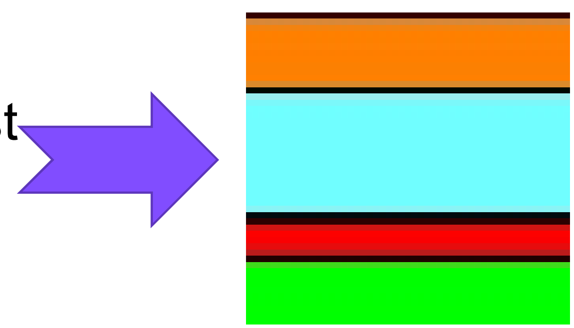
	U.S. Units per inch		
Material	**R-Value**	**U-Factor**	
Polyisocyanurate	5.7	0.17	
Rigid Rock Wool	4.2	0.24	
Dense-Pack Cellulose	4.0	0.25	
EPS	3.7	0.27	
FRP	2 – 3	0.5 - 0.33	
Softwood	1.25	0.80	
LW Concrete	0.10 - 0.20	5 - 10	
NW Concrete	0.0625	16	
Stainless Steel	0.0009	111	1
Carbon Steel	0.0032	323	3
Aluminum	0.00058	1724	15

Conductive Heat Transfer Paths

- Series
  - Add up R-values along the path of heat flow

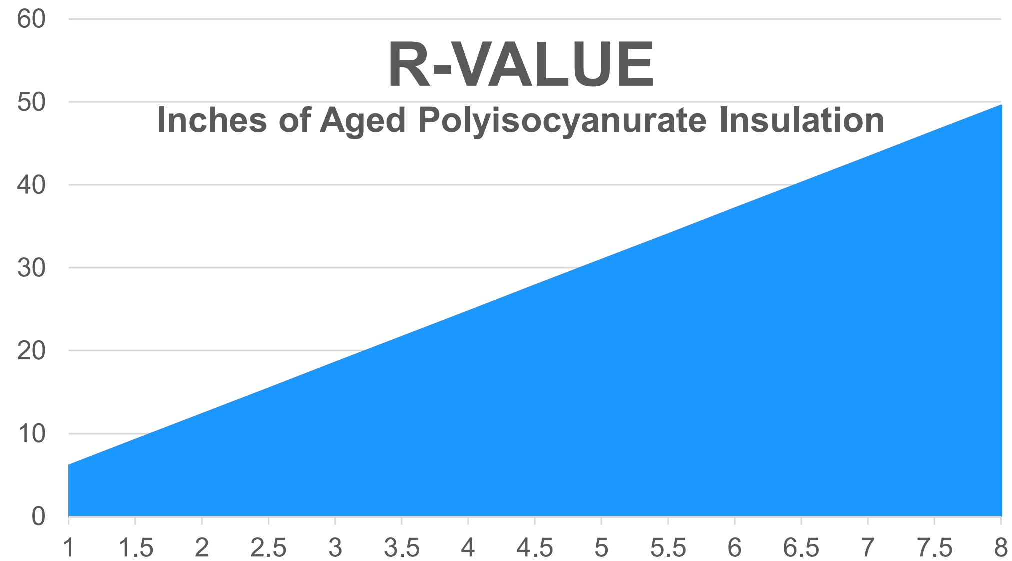


- Parallel
  - Heat chooses path of least resistance

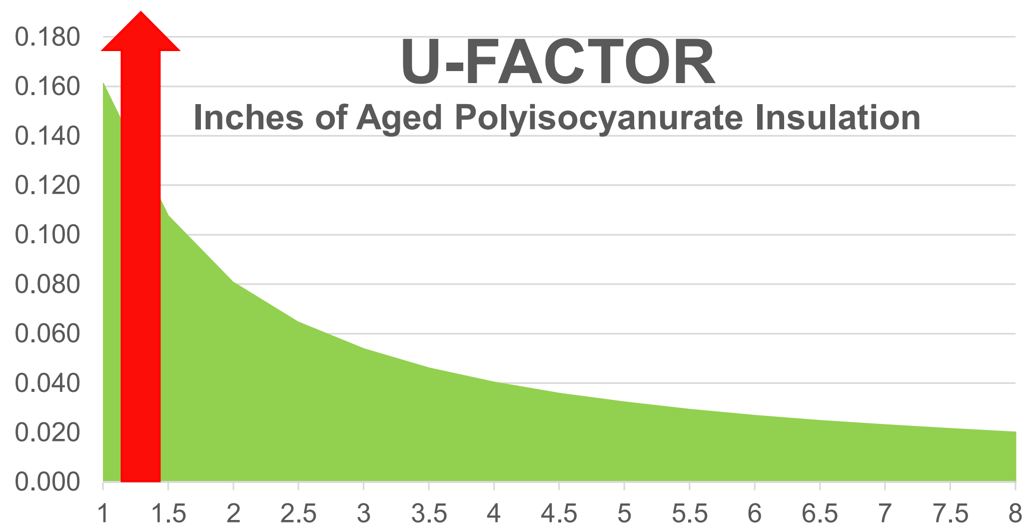


R-Values vs. U-Factors

The R-Value is simply the amount of heat resistance.
R=1/U



The U-Factor is the actual rate of heat flow through the assembly.
U=1/R



Reff = (Rmax-Rmin)/ln(Rmax/Rmin)

WHY DON'T

SOME STRUCTURAL ENGINEERS CARE ABOUT THERMAL BRIDGING?

- They don't perceive it as their responsibility.
- They believe they have no obligation to comply with the governing Energy Code.
- They aren't aware of the potential magnitude of thermal losses and problems that structural thermal bridging can create.
- They haven't been educated in the problem and solutions.
- Developing new details takes time, effort, and fee.
- It's easier to ignore it than to address it.

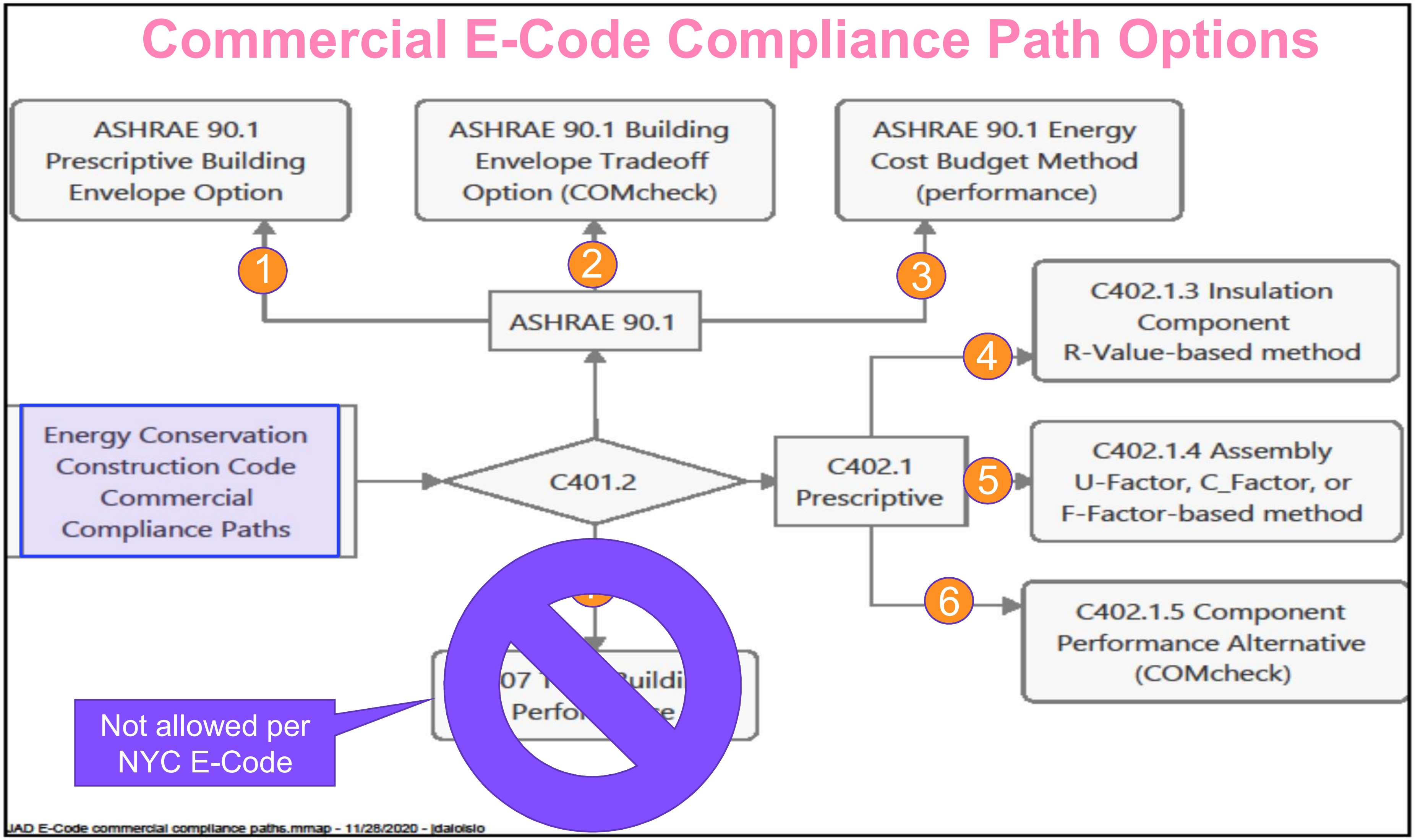
COMMERCIAL ENERGY CODES AND THERMAL BRIDGING

For all but the prescriptive R-value compliance path:

Quantifying the thermal flow through all components of the thermal envelope, including at all thermal bridging conditions, is required to show Energy Code compliance.

For the prescriptive R-value compliance path:

Thermal bridging that creates heat paths that bypass the required insulation is not allowed. If there are such conditions, another Energy Code compliance path must be used.



Commercial E-Code Compliance Path Options
ASHRAE 90.1 Prescriptive Building Envelope Option
ASHRAE 90.1 Building Envelope Tradeoff Option (COMcheck)
ASHRAE 90.1 Energy Cost Budget Method (performance)
1
2
3
ASHRAE 90.1
C402.1.3 Insulation Component R-Value-based method
4
Energy Conservation Construction Code Commercial Compliance Paths
C401.2
C402.1 Prescriptive
5
C402.1.4 Assembly U-Factor, C_Factor, or F-Factor-based method
6
C402.1.5 Component Performance Alternative (COMcheck)
Not allowed per NYC E-Code
JAD E-Code commercial compliance paths.mmap - 11/28/2020 - jdaloisio

ENERGY CODES AND THERMAL BRIDGING

What the Energy Codes do NOT say:

If large pieces of highly conductive material extend through the building's thermal envelope, you can ignore the resulting huge U-factor of the envelope component that they occur in.

ENERGY CODES
AND STRUCTURAL THERMAL BRIDGING

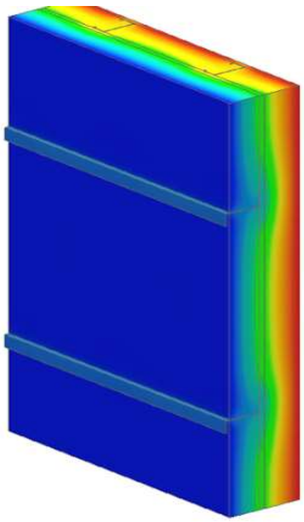
NYStretch Code 2020 and NYC Energy Code 2020

Balconies and Parapets that interrupt thermal envelopes require continuous insulation of R-3 or a thermal break (NYStretch C402.2.9 also ASHRAE 90.1 5.5.3.7)

Balcony

Parapet

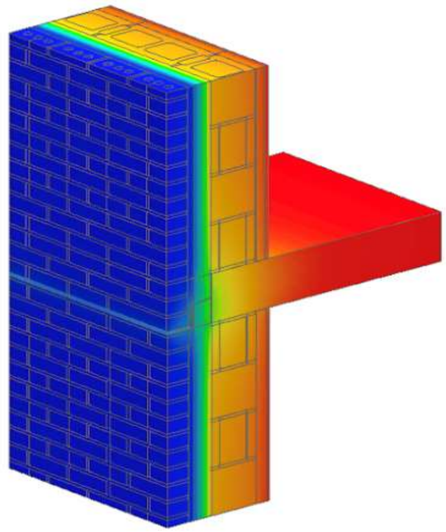
The Three Types of Thermal Bridges



Clear Field

U_o

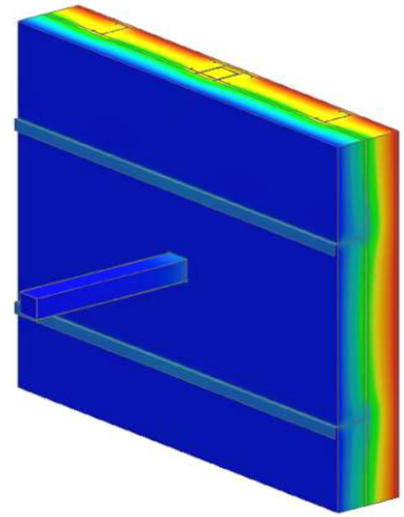
Heat Transfer Coefficient
Btu/sf



Linear

Ψ "psee"

psi
Btu/lf



Point

χ "chee"

chi
Btu

NYC ECCC (R) – THERMAL BRIDGING

- C406.2.1 - Clear Field Thermal Bridges: Include in calculated U, C, F factors OR "shall be noted as such in the drawings."
- C406.2.2 – Point Thermal Bridges Greater than 8 in^2: "shall be noted as thermal bridges in the drawings."
- C406.2.3 – Linear Thermal Bridges: Identify type, length, relevant detail, and Ψ-factor - either from Table R402.6 or calculated.

TABLE R402.6

AVERAGE THERMAL TRANSMITTANCE FOR UNMITIGATED LINEAR THERMAL BRIDGES

TYPE OF THERMAL BRIDGE	Ψ-value[a] [Btu/hr • ft • °F]	Ψ-value[a] W/mK
Steel Frame, Steel Stud, Poured-in-place Concrete, Concrete Block, Curtain-wall		
Balcony	0.50	0.871
Floor[b]	0.44	0.755
Slab to Ground	n/a	n/a
Fenestration Perimeter Transition[c]	0.32	0.550
Parapet	0.42	0.735
Eaves	n/a	n/a
Shelf Angle	0.41	0.713
Wood Frame Construction		
Balcony	n/a	n/a
Floor[b]	0.336	0.582
Slab to Ground	n/a	n/a
Fenestration Perimeter Transition[c]	0.15	0.26
Parapet	0.032	0.056
Eaves	n/a	n/a
Shelf Angle	0.186	0.322

NYC ECCC (C) – BALCONIES & PARAPETS

C402.2.9 Continuous Insulation

In new construction, balconies and parapets that interrupt the building thermal envelope shall comply with one of the following:

1. Shall be insulated with continuous insulation having a minimum thermal resistance equivalent to the continuous insulation component required in the adjacent wall assembly as listed in Table C402.1.3. Where more than one wall assembly is interrupted by an adjacent balcony, the higher thermal resistance shall be followed.

2. Shall incorporate a minimum R-3 thermal break where the structural element penetrates the building thermal envelope.

NYSTRETCH (C) – BALCONIES & PARAPETS

C402.2.8 Continuous insulation (Mandatory). In new construction, structural elements of balconies and parapets that penetrate the *building thermal envelope*, shall comply with one of the following:

1. Structural elements penetrating the *building thermal envelope* shall be insulated with *continuous insulation* having a minimum thermal resistance of R-3.
2. Structural elements of penetrations of the *building thermal envelope* shall incorporate a minimum R-3 thermal break where the structural element penetrates the *building thermal envelope*.

- Similar requirement for ASHRAE compliance path
- No similar requirement for Residential

NYC ECCC (C) – THERMAL BRIDGING

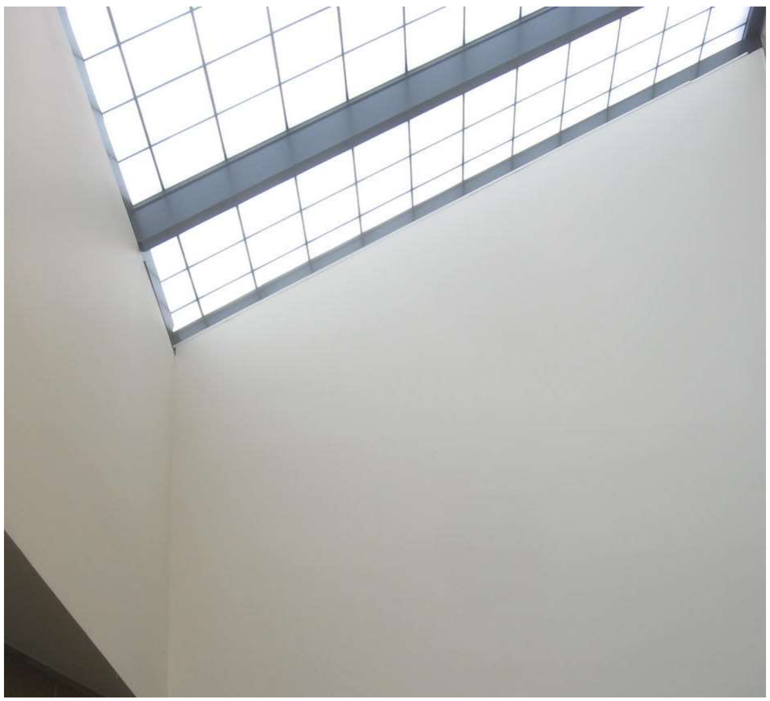
- C406.2.1 - Clear Field Thermal Bridges: Include in calculated U, C, F factors OR "shall be noted as such in the drawings."
- C406.2.2 – Point Thermal Bridges Greater than 12 in^2: "shall be noted as thermal bridges in the drawings."
- C406.2.3 – Linear Thermal Bridges: Identify type, length, relevant detail, and Ψ-factor - either from Table C402.6 or calculated.

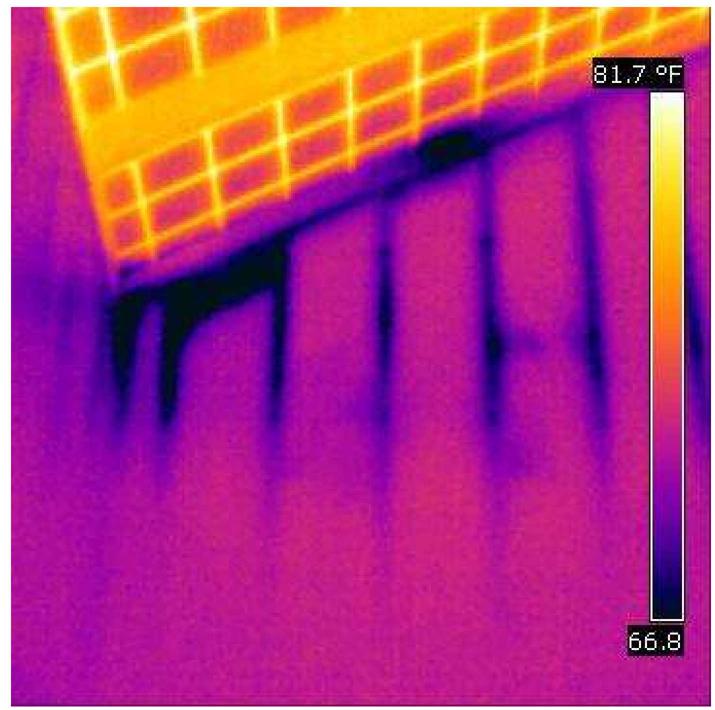
TABLE C402.6

AVERAGE THERMAL TRANSMITTANCE FOR UNMITIGATED LINEAR THERMAL BRIDGES

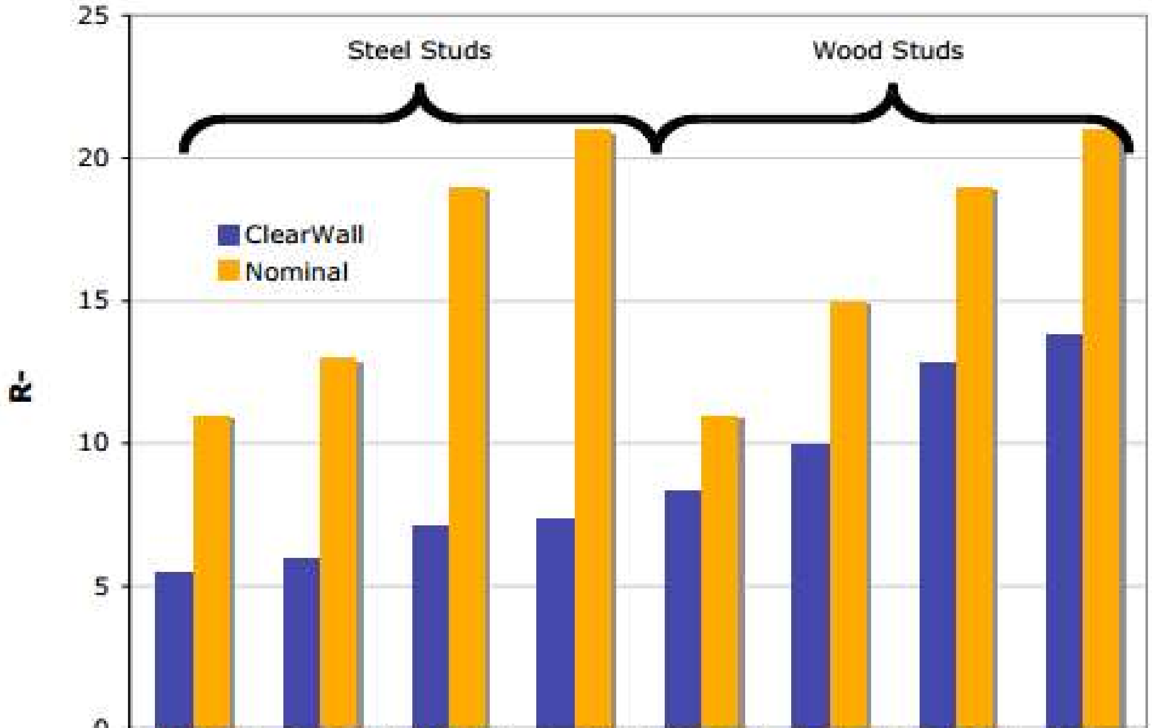
TYPE OF THERMAL BRIDGE	Ψ-VALUE[a] [Btu/hr • ft • °F]
Balcony	0.50
Floor Slab	0.44
Fenestration Perimeter Transition[b]	0.32
Parapet	0.42
Shelf Angle	0.41

Clear Field –
Steel Stud Thermal Bridging





Insulation Between Studs

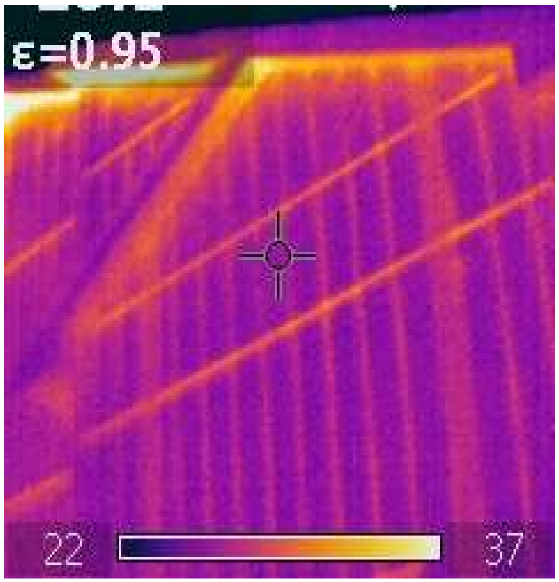


	R-11 3.5in	R-13 3.5in	R-19 6in	R-21 6in	R-11 3.5in	R-15 3.5in	R-19 6in	R-21 6in
ClearWall	5.5	6.0	7.1	7.4	8.4	10.0	12.9	13.8
Nominal	11	13	19	21	11	15	19	21

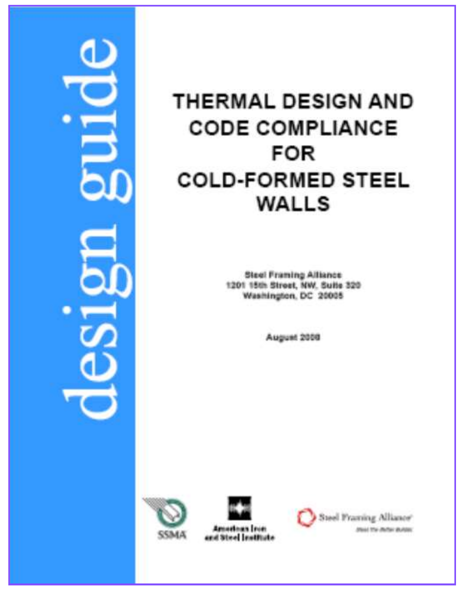
Figure 3: Nominal and Clear Wall Insulation R-values (after ASHRAE 90.1-1999) for Several Different Stud Materials and Insulation

J. Straube, 2007, Building Science Corp.

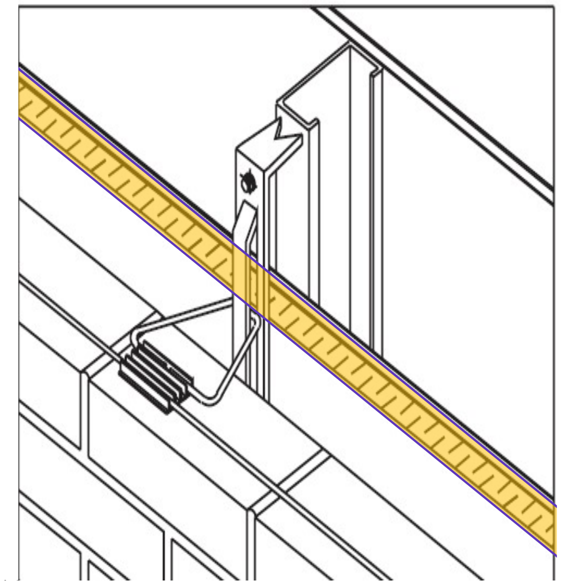
Clear Field –
Steel Stud Thermal Bridging



Infrared scans can clearly identify building heat loss through steel studs.

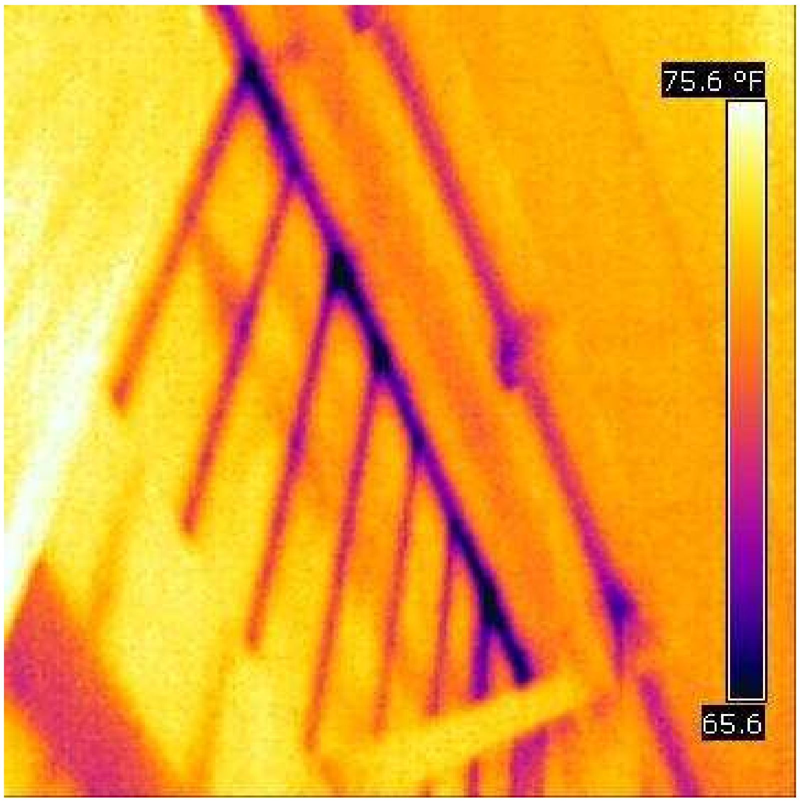


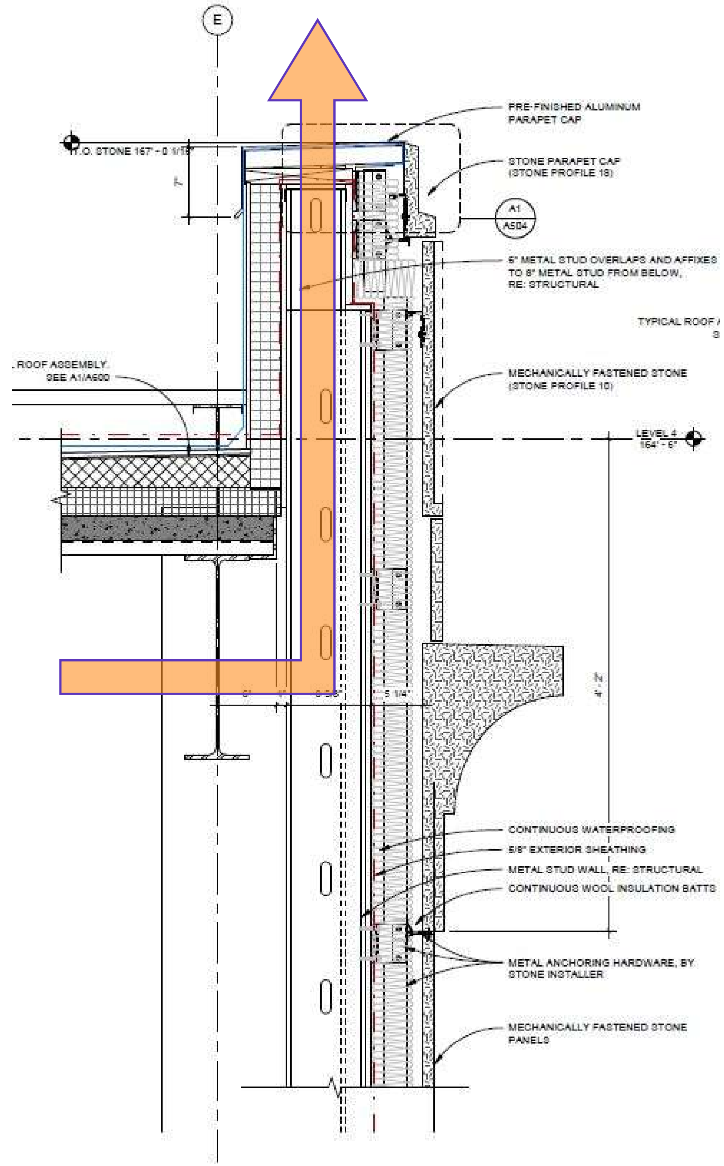
The Steel framing Alliance has a Design Guide.



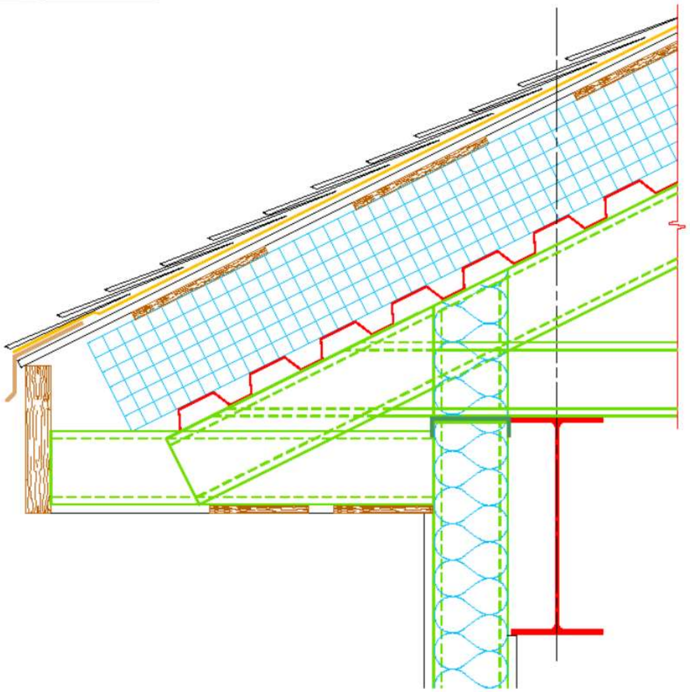
Continuous rigid insulation eliminates thermal bridging.

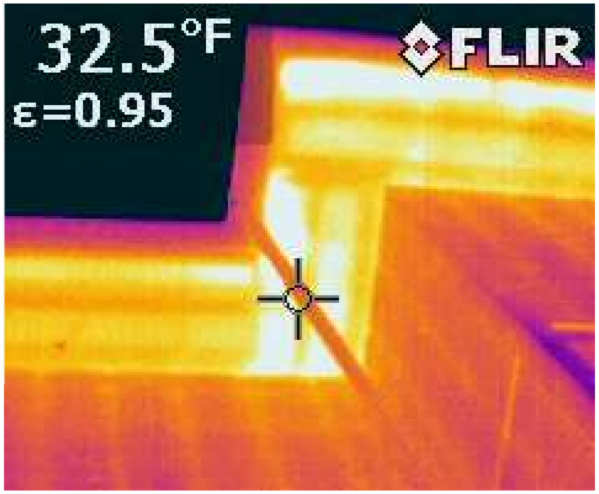
Clear Field – Steel Stud Parapets





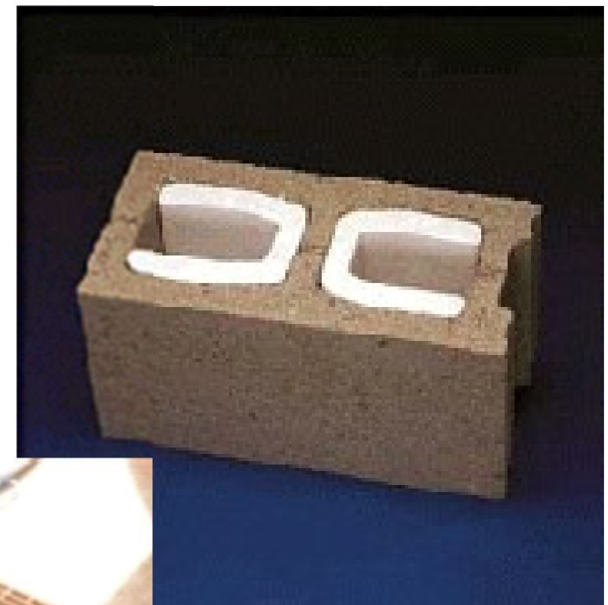
Clear Field – Cold-Formed Steel Roof Trusses





Single Wythe CMU Walls With Insulation Inserts

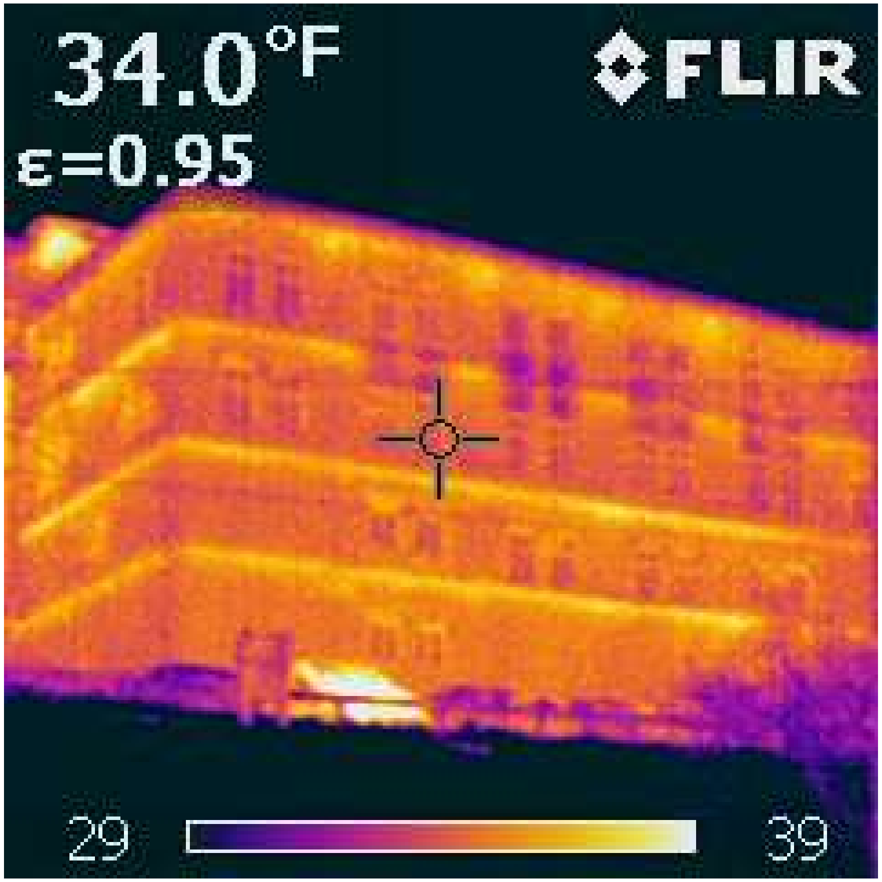
- Use lightweight concrete.
- Consider using insulation inserts ***even in grouted and reinforced cores.***
- Minimize web areas with new ASTM C90 web requirements.

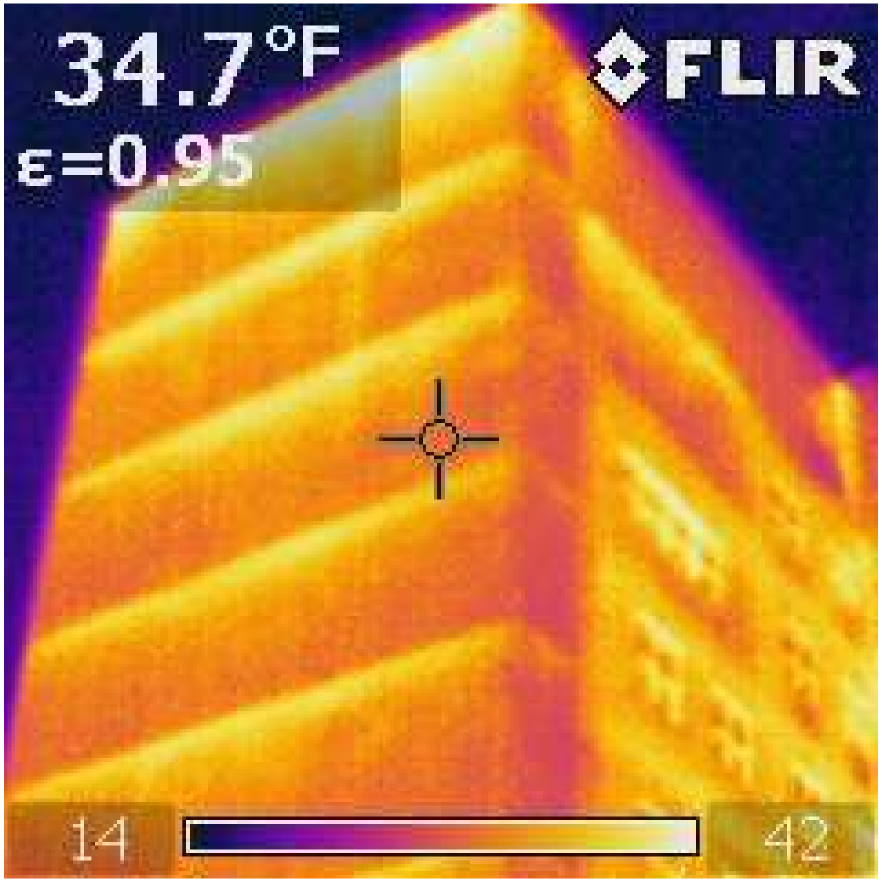


ASTM C-90 concrete masonry unit

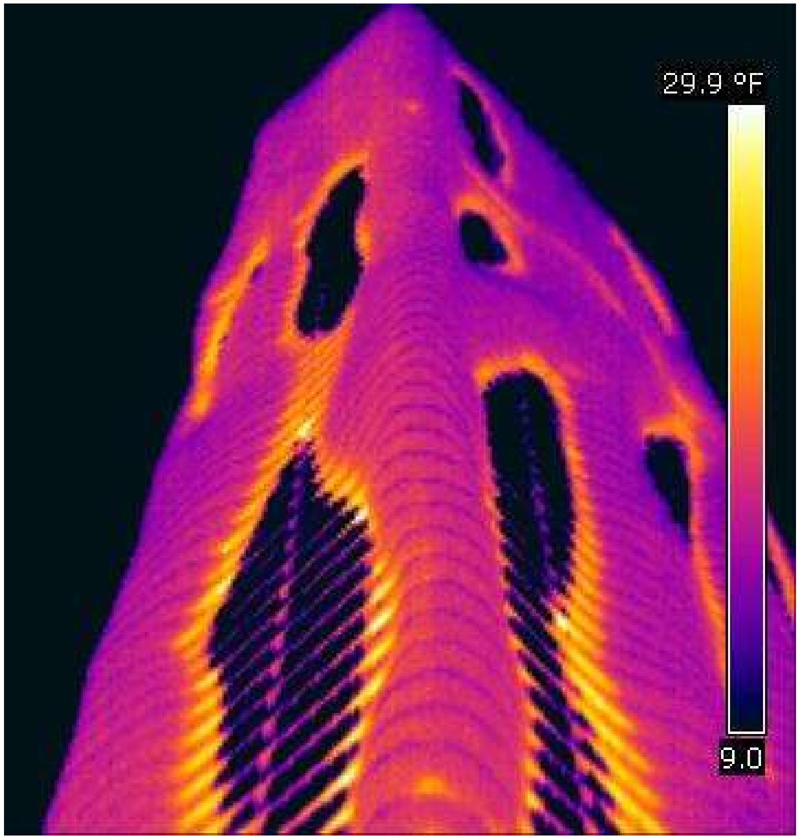
German Ziegel block – extruded clay tile

<u>Linear</u> Thermal Bridging – Relieving Angles





Linear Thermal Bridging – Concrete Balconies

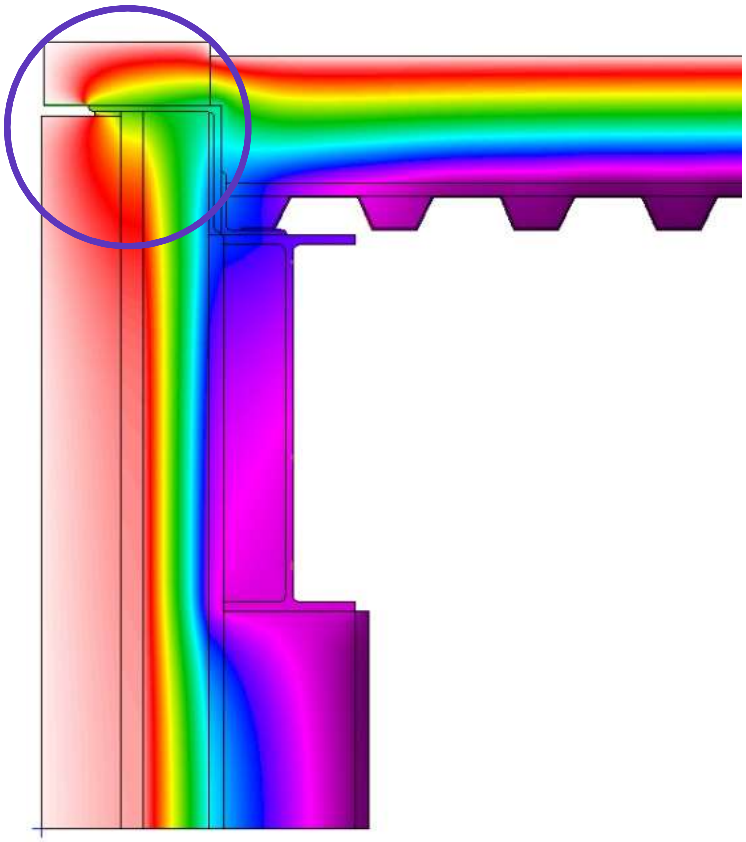


FIVE STRATEGIES
TO MITIGATE THERMAL BRIDGING

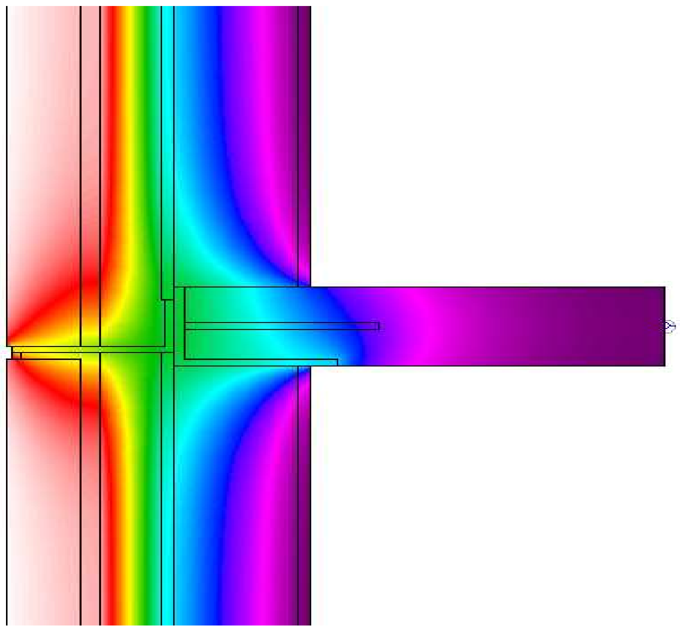
1. Separate inside materials from outside materials.
2. Use continuous insulation completely around structure.
3. Change continuous bridging elements to discrete.
4. Use lower-conducting materials for connections or shims.
5. Use Manufactured Structural Thermal Break Assemblies.

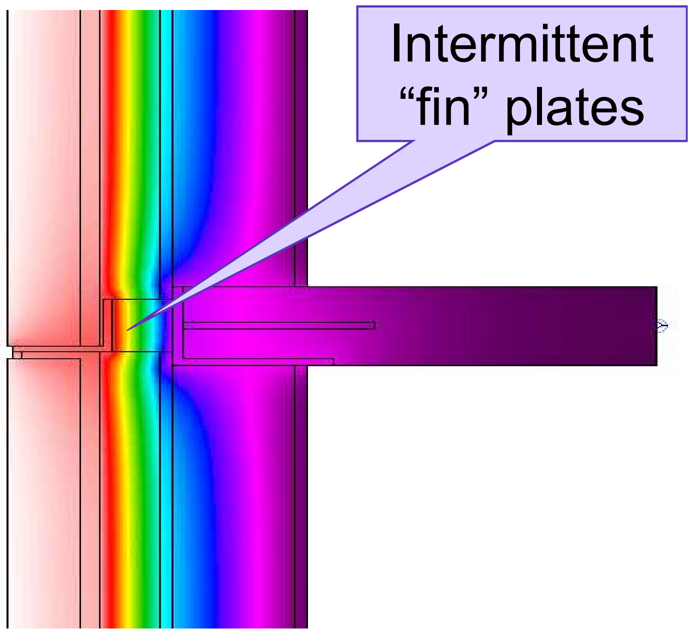
… and beware of minimally effective solutions!

Linear Thermal Bridging: Roof Edge Conditions



Linear Thermal Bridging – Relieving Angles





Unmitigated Detail:

U-Factor for 36" height = 0.44

240% INCREASE in conductive heat flow

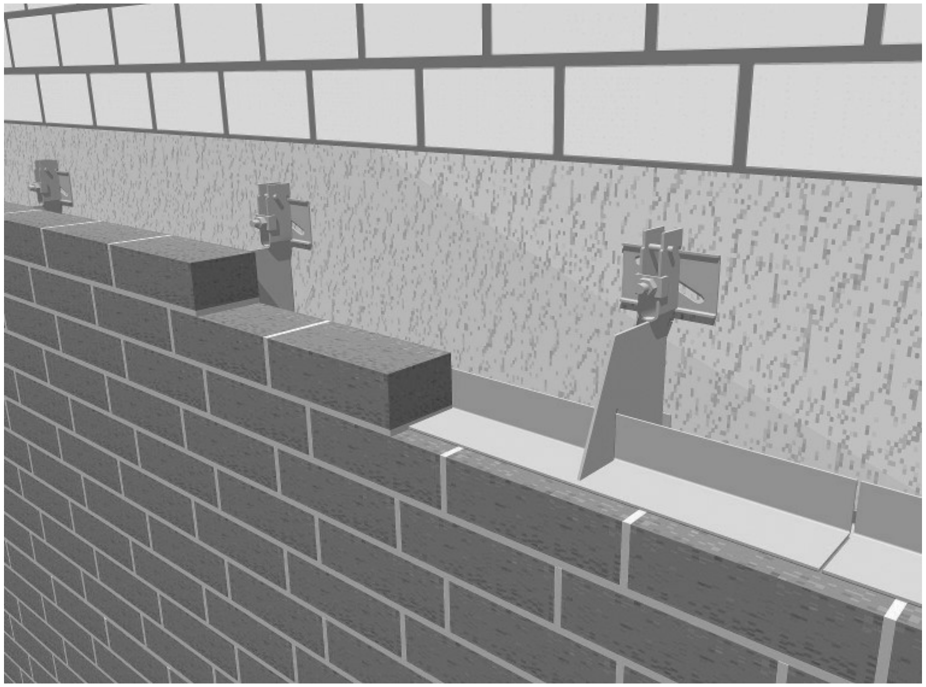
Alternate Detail:

U-Factor for 36" height = 0.13

70% REDUCTION in conductive heat flow

Linear Thermal Bridging – Relieving Angles – Fin Plate Supports

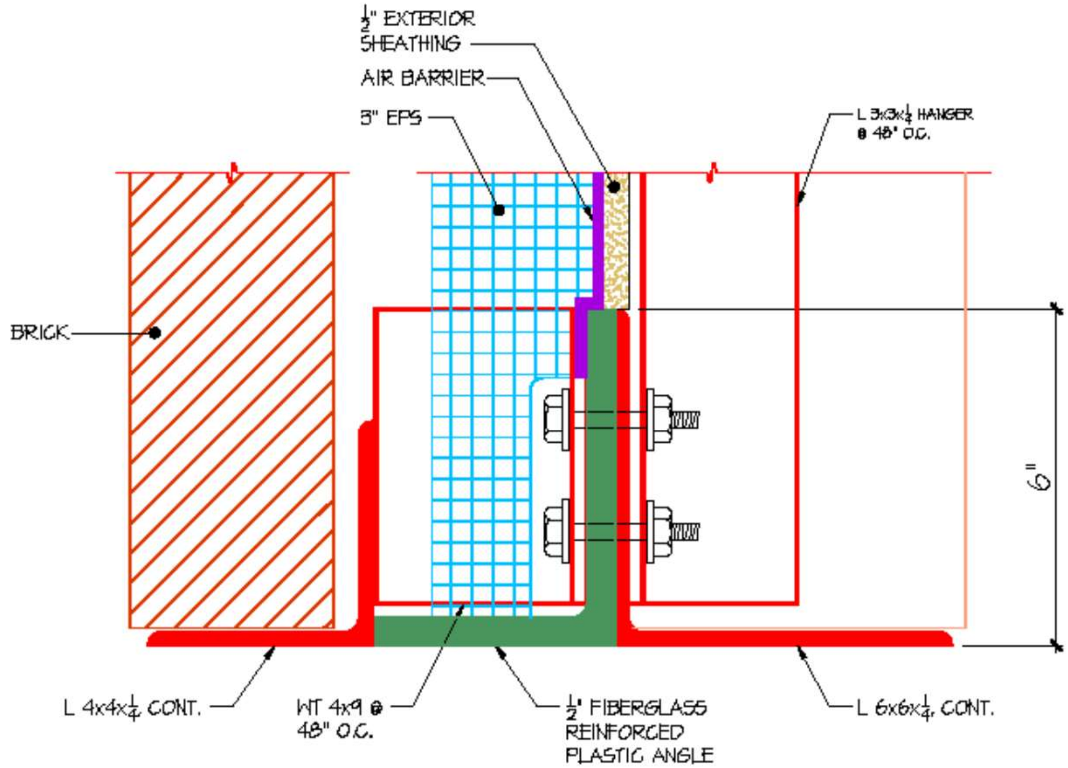
Linear Thermal Bridging – Relieving Angles



European Glass Fiber
Reinforced Plastic Lintel

Proprietary system for brick shelf angle support
Comes in both galvanized & stainless steel

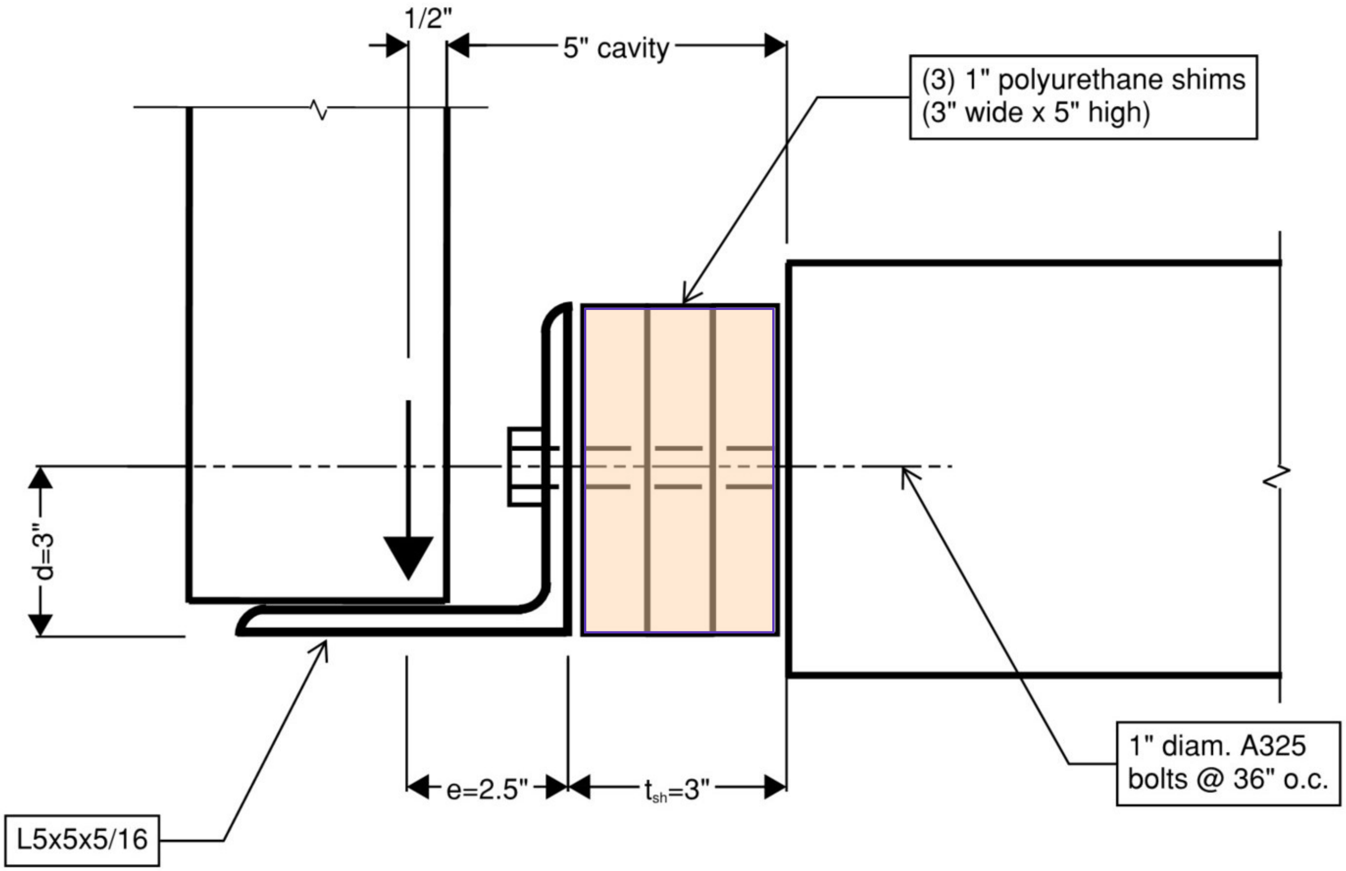
Linear Thermal Bridging: Lintel With FRP Separator



STEEL / FIBERGLASS REINFORCED PLASTIC LINTEL DETAIL

FIBERGLASS-STEEL ENVELOPE DETAILS

Shelf Angle With Insulative Shims

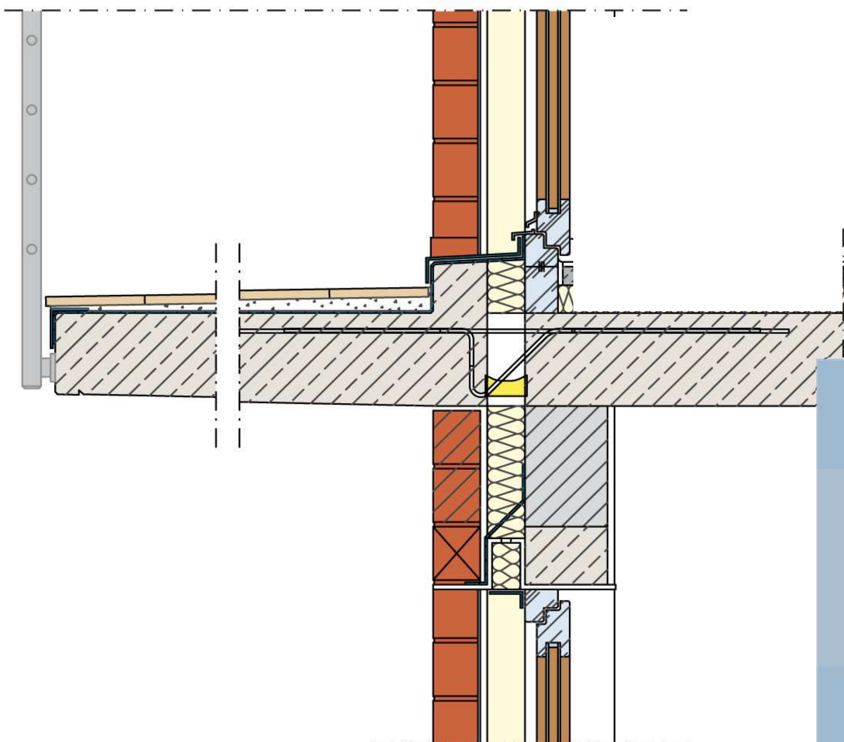


Ref: Tide, R. H. R., and Krogstad, V. (1993). “Economical Design of Shelf Angles,” *Masonry: Design and Construction, Problems and Repair, ASTM STP 1180*, Melander, J. M. and Lauersdorf, L. R. (eds.), ASTM, Philadelphia.

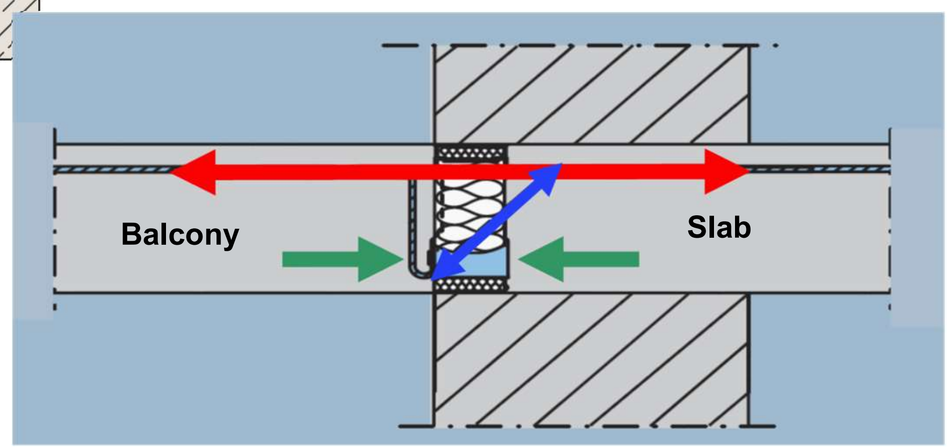
Image credit:
M.D. Webster, SGH

Manufactured Structural Thermal Break Assemblies (MSTBA's)

For CONCRETE

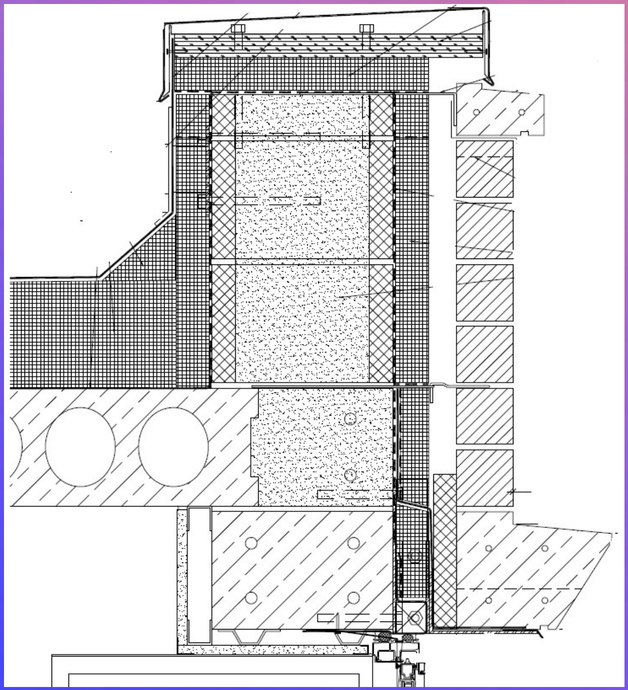


Images courtesy of Schock, Inc.



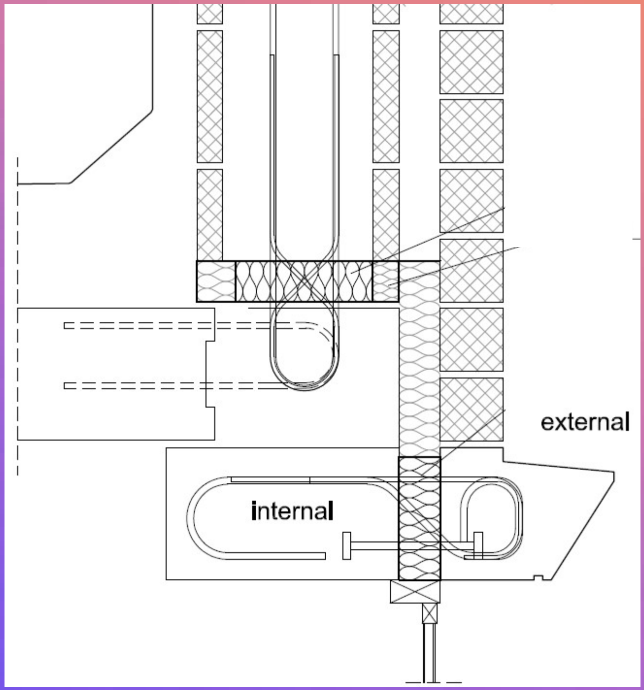
Concrete-to-Concrete MSTBA

OPTIONS FOR MASONRY PARAPETS



Insulation Wrap

Courtesy Schock



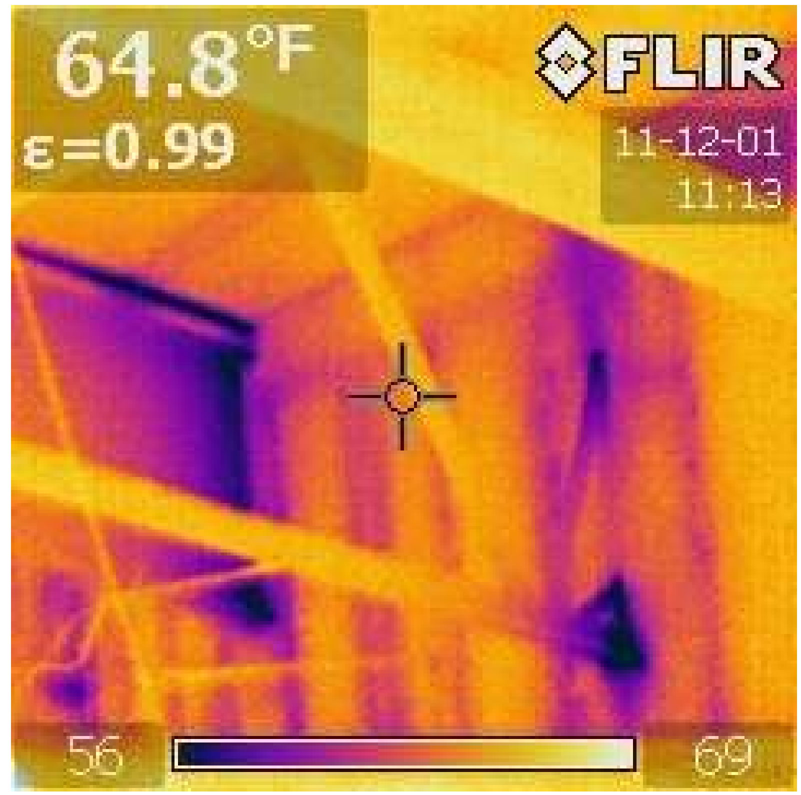
Manufactured Structural Thermal Break Assembly

Courtesy Schock

Thermal Block

Courtesy Thermal Bridging Solutions

“Point” Thermal Bridging – Structural Steel Beams and Joists



“Point” Thermal Bridging – Low-Conductance Thermal Shims

Manufactured Structural Thermal Break Assemblies (MSTBA's)

For STEEL

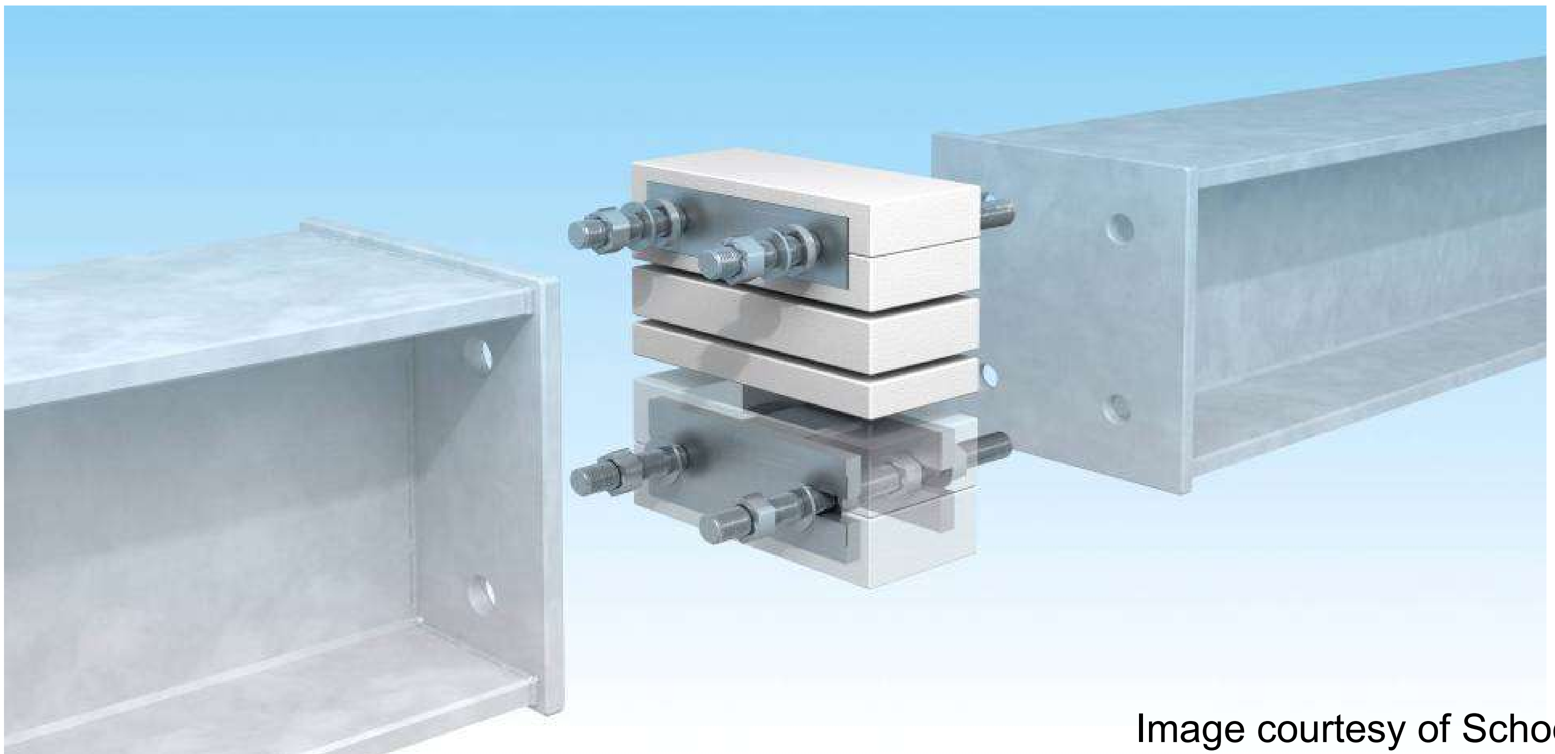


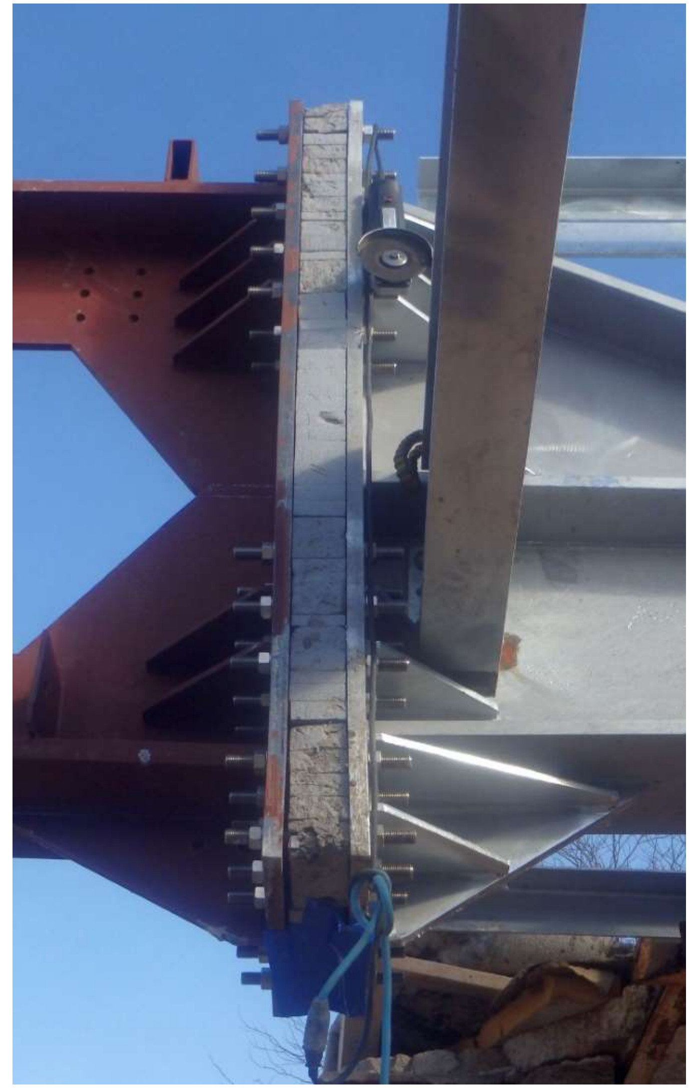
Image courtesy of Schock, Inc.

Manufactured Structural Thermal Break Assemblies – for Steel

SYRACUSE UNIVERSITY
MANLEY FIELDHOUSE
ICE STORAGE ADDITION - 2012

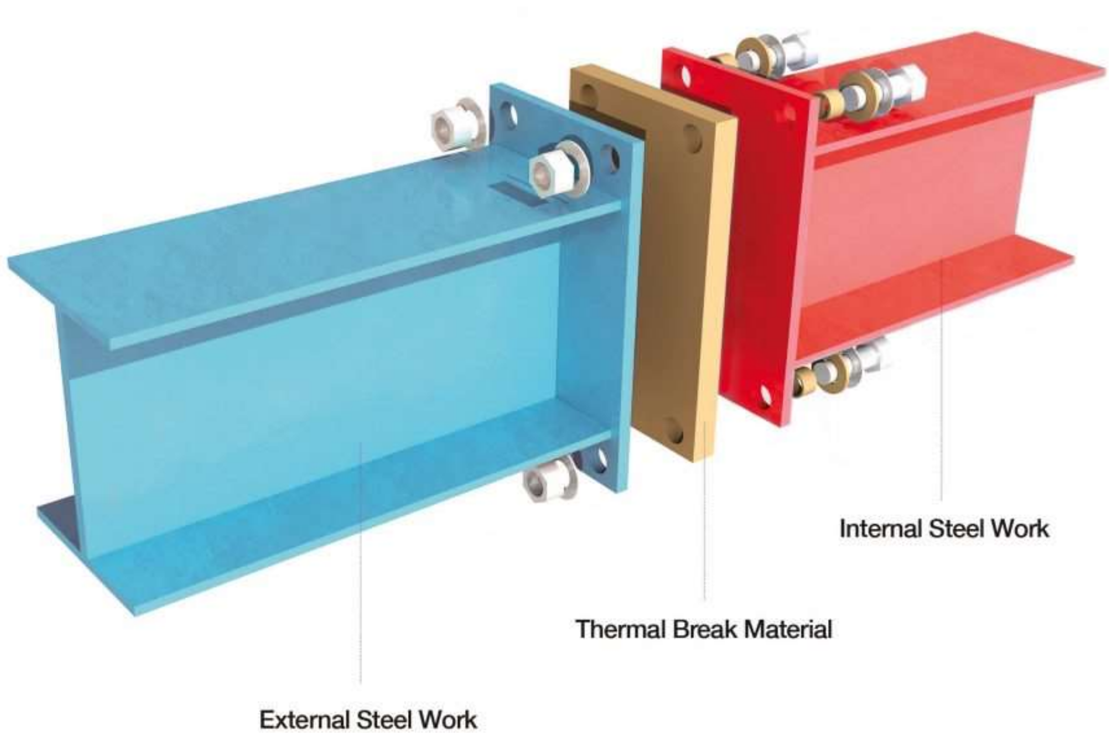
MSTBA – for Steel

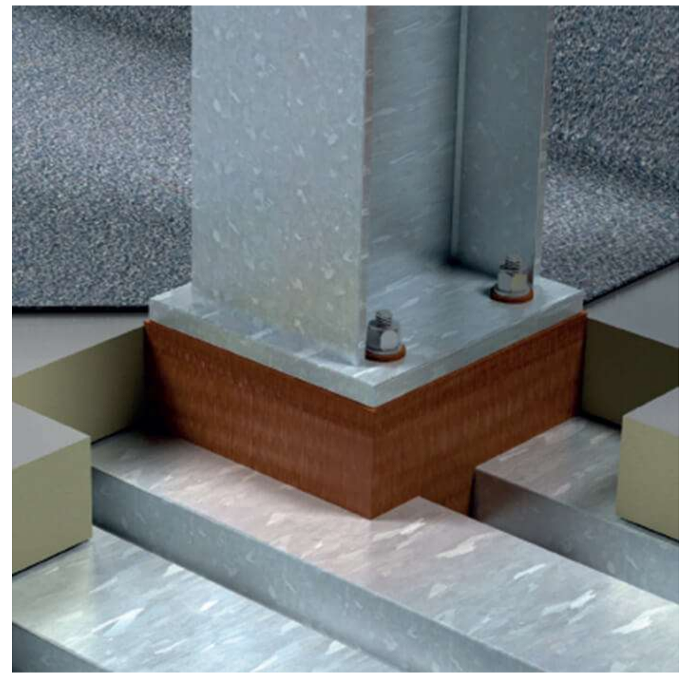
VVS CSD STEAM ADDITION 2020



Thermal Break Pads

For STEEL





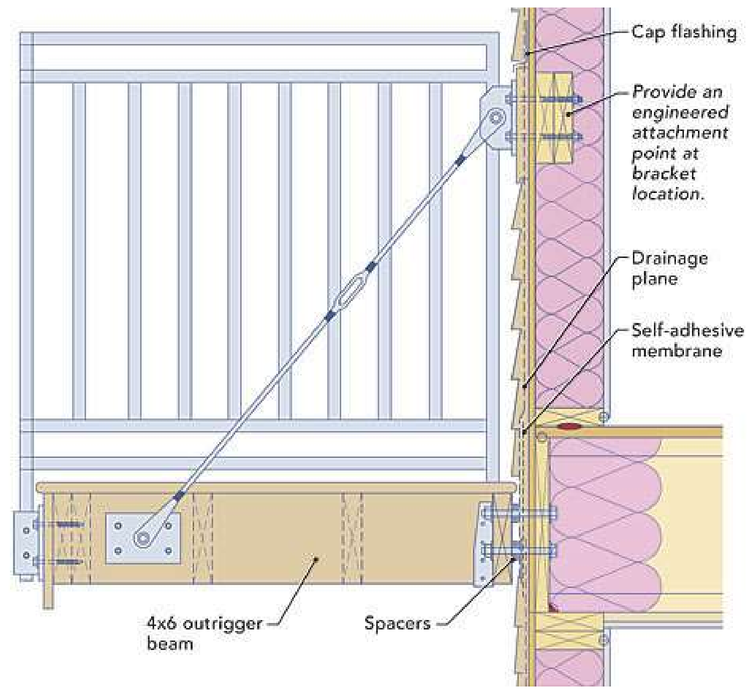
Images courtesy of Armatherm, Inc.

Insulative Coatings

Images courtesy of Greg Pope / Righter Group, Inc.

- **Paint with aerogel insulation added for conductive resistance**
- **R-4.1 per inch, applied 25-50 mils = R-0.1 to 0.2 total**
- **Mainly used to reduce potential for condensation**
- **Requires surface prep, prime coat, and protection coat**
- **Apply to steel 24 inches out from insulation plane – on both interior and exterior sides**
- **Verify insulation properties of paint - there are imposters!**

Structural Wood Details – Balconies



https://www.finehomebuilding.com/2013/05/16/second-story-balconies

References

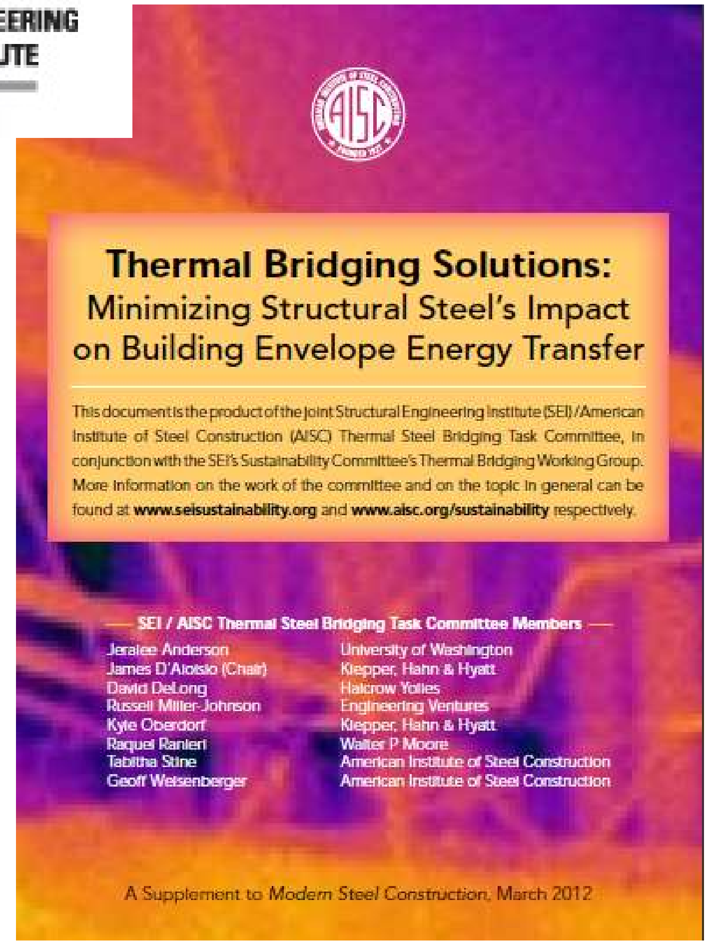
Thermal Steel Bridging Insert in Modern Steel Construction March '12

SEI Sustainability Committee Thermal Steel Bridging Task Committee

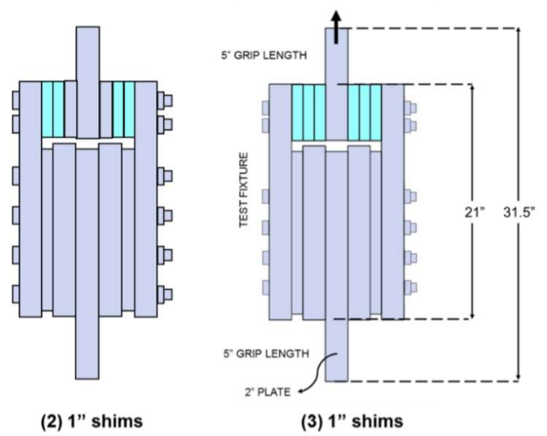
Free!

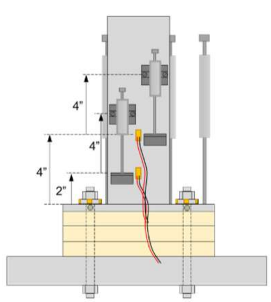
http://structureandsustainability.blogspot.com/2012/03/pubs-5.html

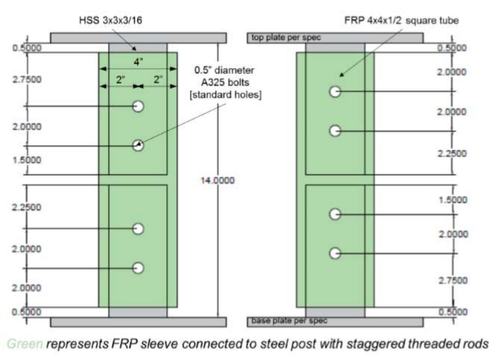
STRUCTURAL ENGINEERING INSTITUTE

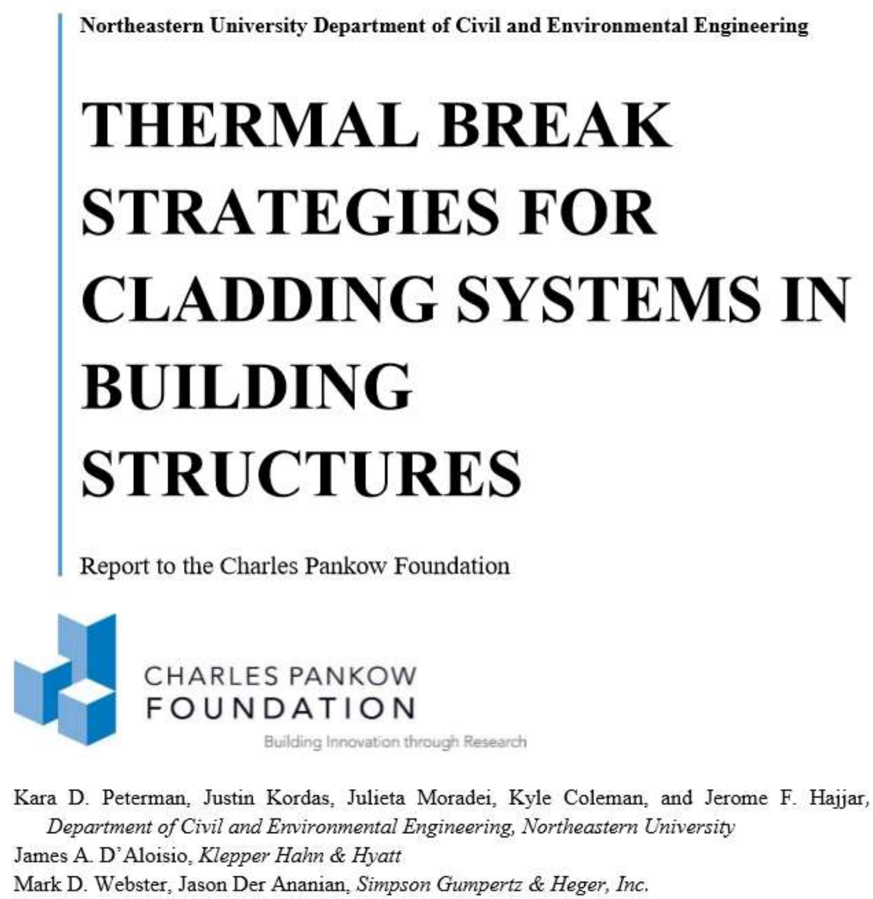


Pankow/AISC/ACMA/PIC – Sponsored Research








Northeastern University Department of Civil and Environmental Engineering

THERMAL BREAK STRATEGIES FOR CLADDING SYSTEMS IN BUILDING STRUCTURES

Report to the Charles Pankow Foundation

CHARLES PANKOW FOUNDATION
Building Innovation through Research

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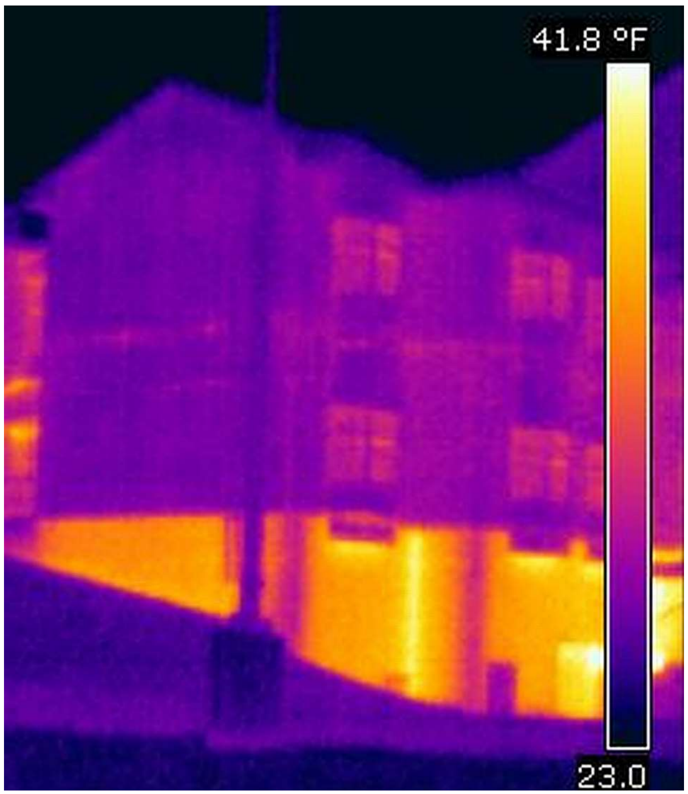
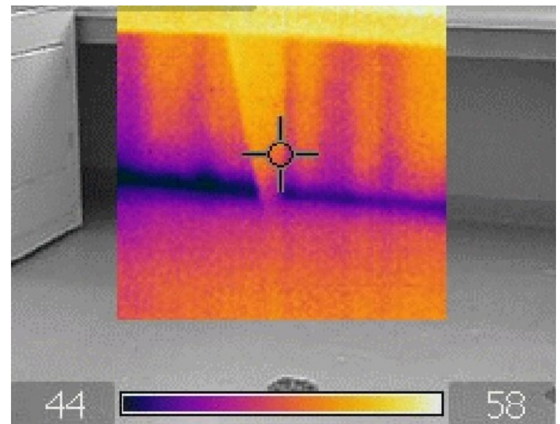
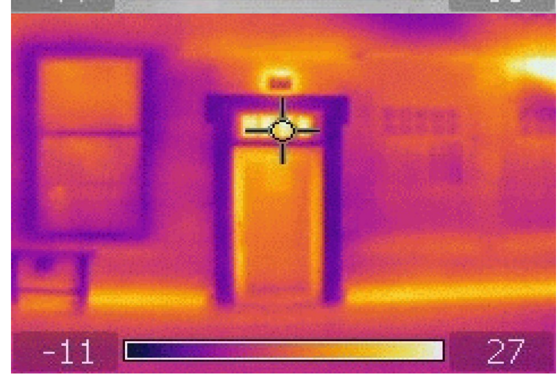
James A. D'Aloisio, *Klepper Hahn & Hyatt*
Mark D. Webster, Jason Der Ananian, *Simpson Gumpertz & Heger, Inc.*

Basement and Foundation Walls and Exterior Slab Edges



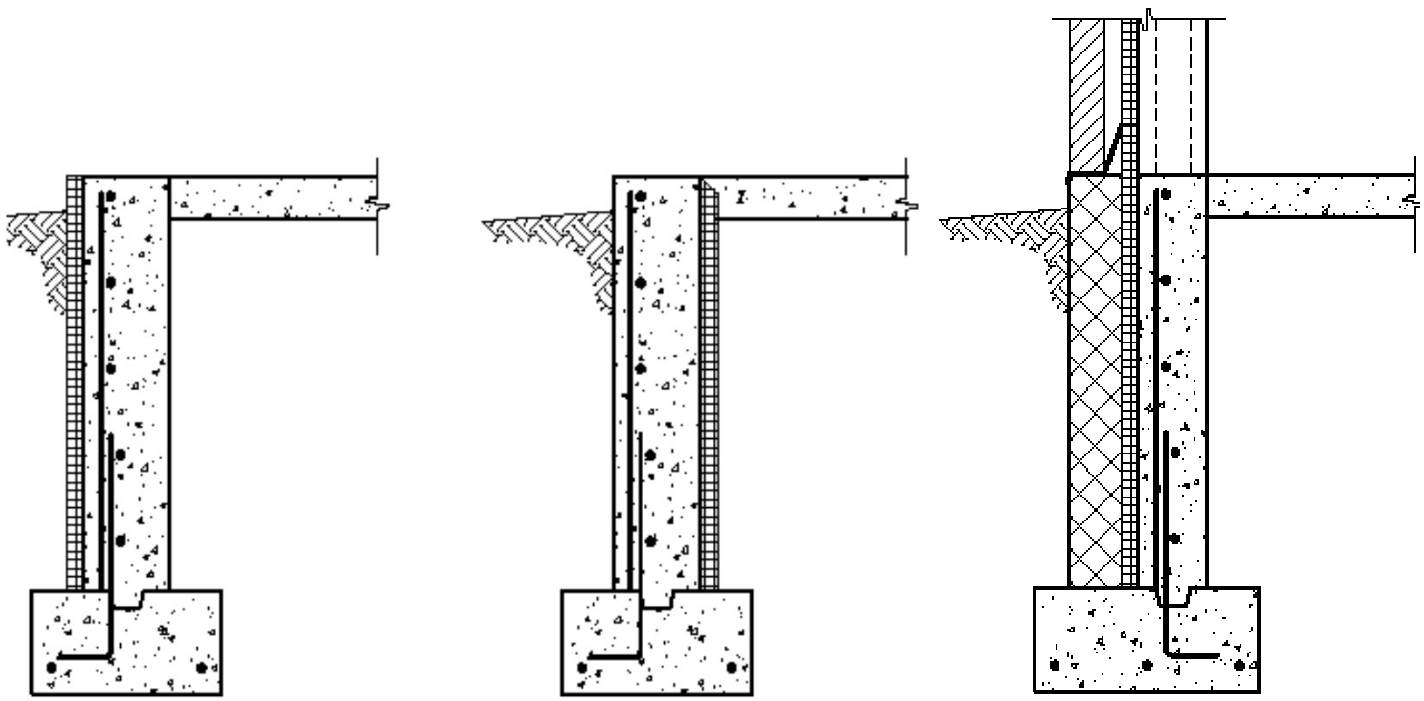




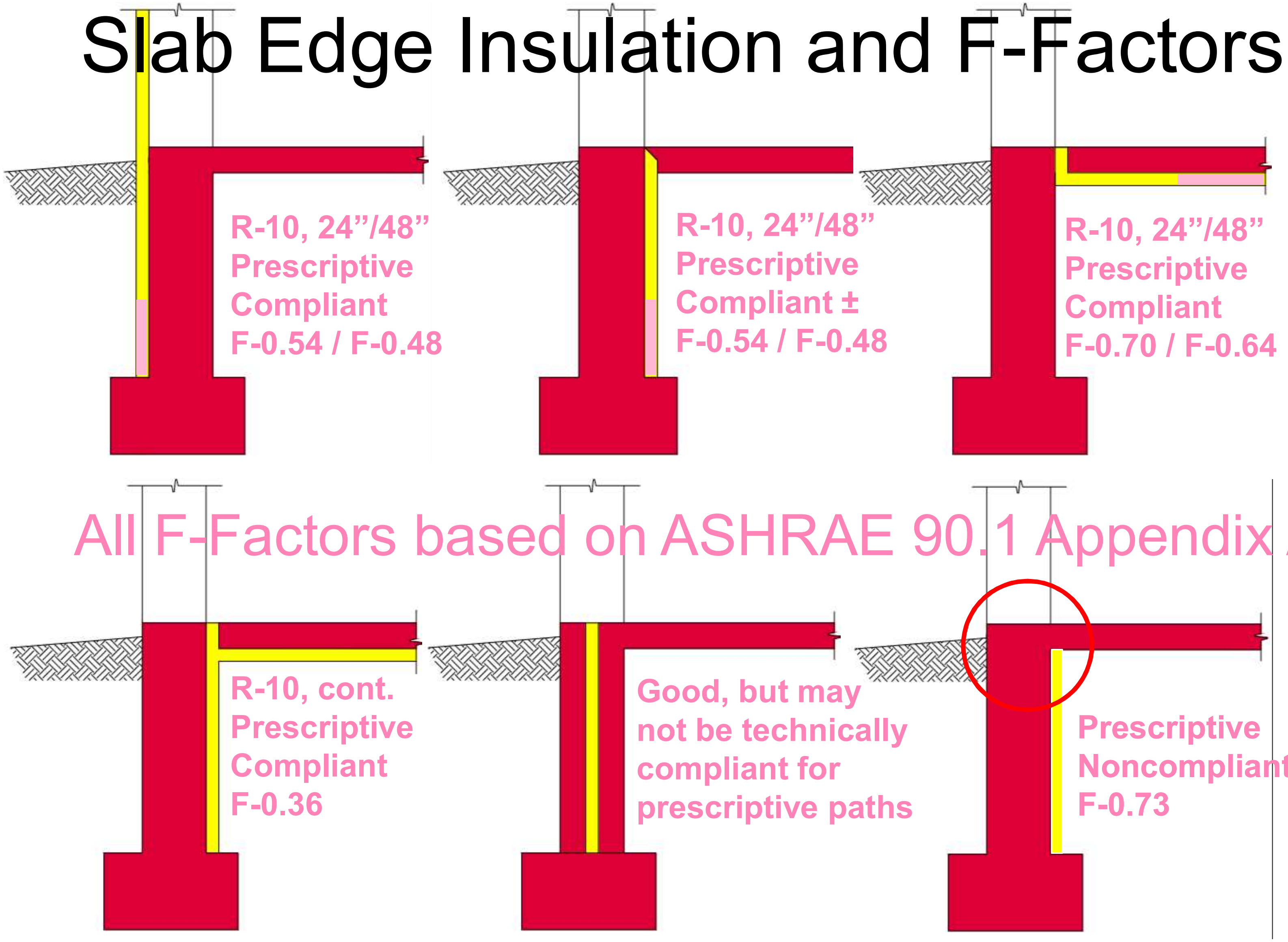
Foundation Insulation

- Can save significant building use energy in heating climates – not so much cooling energy
- Required for prescriptive Energy Code compliance paths
- Can increase occupant comfort
- Should define a continuous plane
- If provided, maintain continuity at slab edges
- Consider mineral fiber insulation (“rock wool”)
- Question for discussion: How much of this is the responsibility of the Structural Engineer?

Foundation Insulation: Outside, or Inside, or In Between



Slab Edge Insulation and F-Factors



All F-Factors based on ASHRAE 90.1 Appendix A

Foundation Insulation: Outside or Inside?

Outside:

- Must protect top-down to 6” below grade
- Consider site conditions
- SOG can butt right up against foundation wall
- Insulation reduces footing depth required for frost protection
- Much less common

Inside:

- No protection needed
- No need to consider site conditions
- SOG should be insulated at edge
- Insulation eliminates doing shallow frost protected foundations
- Much more common

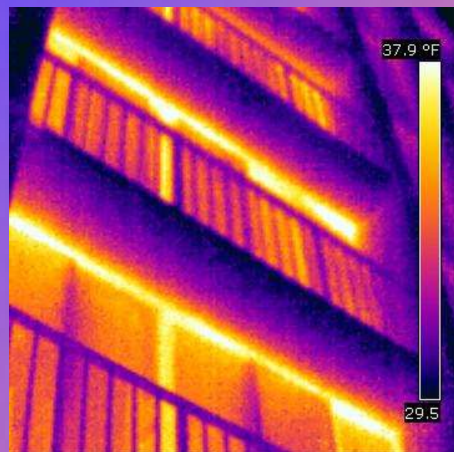
Foundation Wall With "Inner" Insulation Wythe

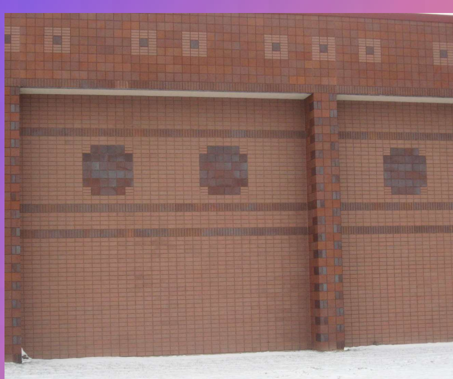
High School Classroom
Addition October 2009

Elementary School Music
Addition August 2009

QUIZ

1. Why should structural engineers be aware of the magnitude of, and solutions to, thermal bridging?
2. What are the three different main types of thermal bridging?
3. Name one or more effective strategies to mitigate structural thermal bridging.
4. Name a marginal or ineffective strategy to mitigate structural thermal bridging.





Recommendations

- Address ALL clear field thermal bridging.
- Address ALL linear thermal bridging.
- Minimize cross-sectional area of bridging elements, where structurally possible.
- Use stainless steel at bridging elements, when feasible.
- Architects and structural engineers need to collaborate to develop envelope details.
- Use FRP shims or pads when loads are low, MSTBA's for larger loads.
- Show foundation and slab edge insulation.
- **Consider, acknowledge, and address thermal bridging in your design practice!**

THANK YOU! FOR YOUR TIME AND CONSIDERATION

THERMAL BRIDGING ‘22:

NOW YOU KNOW. WHAT WILL YOU DO?

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Klepper, Hahn & Hyatt

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