BEST6

Optimizing Renovation:

Unveiling Thermal Bridging in Existing Buildings Through Modeling

SGH

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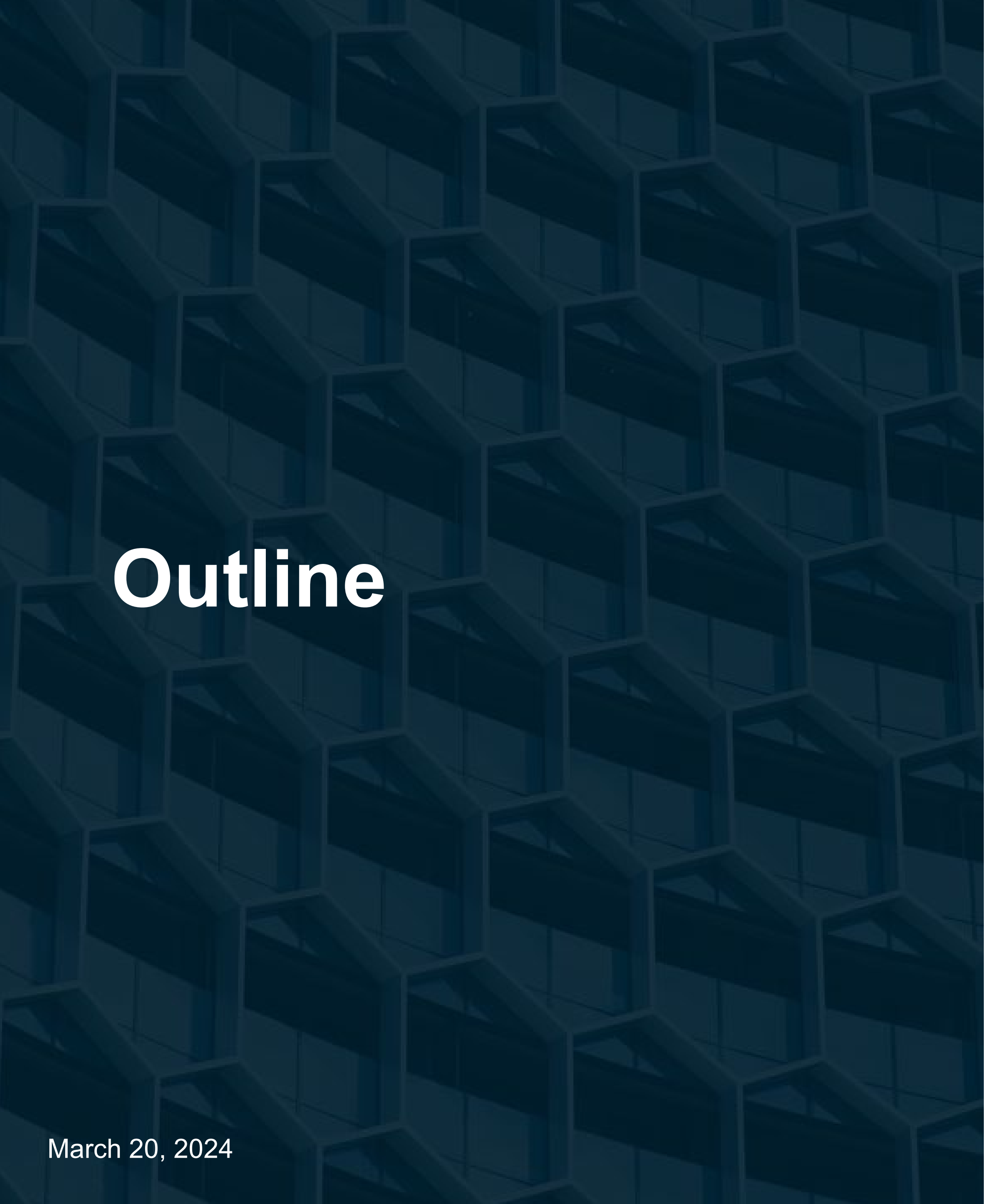


Outline

- Building Enclosure Thermal Performance
- Thermal Bridging
- Thermal Modeling
- Modeling Examples
- Conclusion

Enclosure Thermal Performance

Table 5.5-2 Building Envelope Requirements for Climate Zone 2 (A,B)*

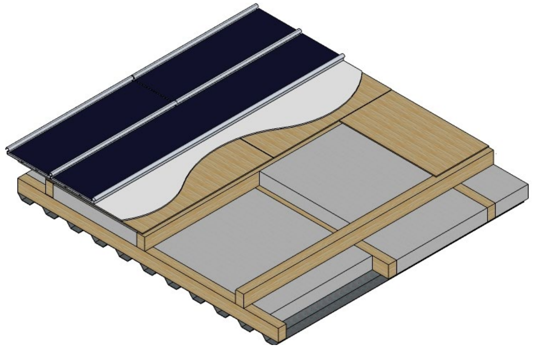
Excerpt from ASHRAE 90.1-2022

Opaque Elements	Nonresidential Assembly Maximum	Nonresidential Insulation Min. R-Value	Res Assembly Maximum
			Roofs
Insulation entirely above deck	U-0.039	R-25 *c.i.*	U-0.039
Metal building [a]	U-0.041	R-10 + R-19 FC	U-0.041
Attic and other	U-0.027	R-38	U-0.027
			Walls, above Grade
Mass	U-0.151 [b]	R-5.7 *c.i.* [b]	U-0.123
Metal building	U-0.094	R-0 + R-9.8 *c.i.*	U-0.094
Steel-framed	U-0.084	R-13 + R-3.8 *c.i.*	U-0.064
Wood-framed and other	U-0.089	R-13	U-0.089

Fenestration	Assembly Max. U	Assembly Max. SHGC	Assembly Min. VT/SHGC	Assembly Max. U	Assembly Max. SHGC	Assembly Min. VT/SHGC
			Vertical Fenestration, 0% to 40% of Wall			
Fixed	0.45	0.25	1.10 (for all types)	0.45	0.25	1.10 (for all types)
Operable	0.60	0.23		0.60	0.23	
Entrance door	0.77	0.23		0.77	0.23	
			Skylight, 0% to 3% of Roof			
All types	0.65	0.30	NR	0.65	0.30	NR

WALL SYSTEMS

ROOF SYSTEMS

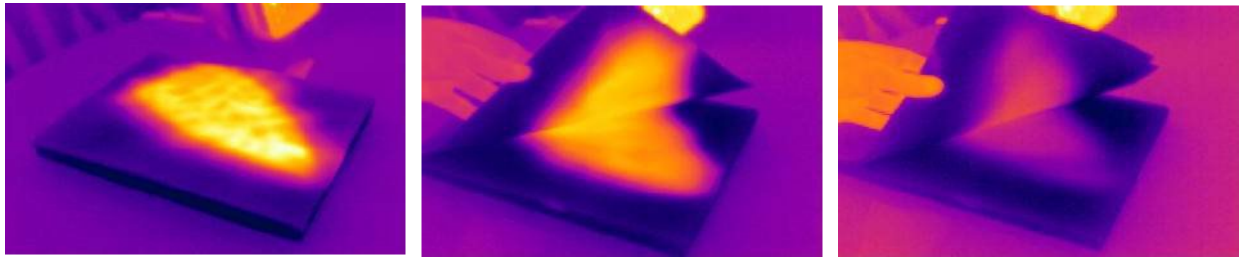


WINDOW SYSTEMS

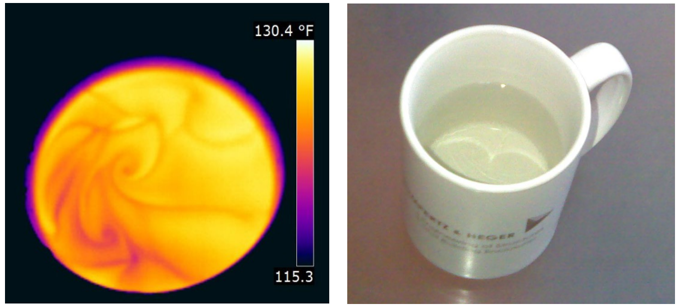
Thermal Bridging

Heat Flow Basics

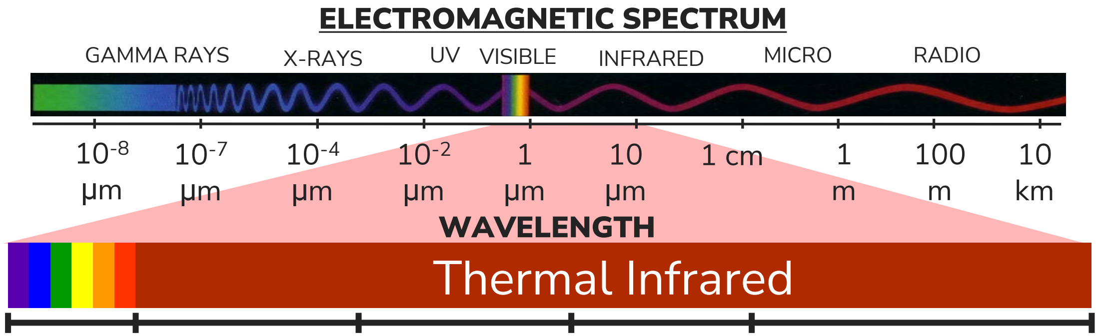
1. **Conduction** – heat transfer through a solid material from one molecule to another



2. **Convection** – heat transfer by movement of circulating fluids (liquids or gases)



3. **Radiation** – heat transfer in the form of electromagnetic waves



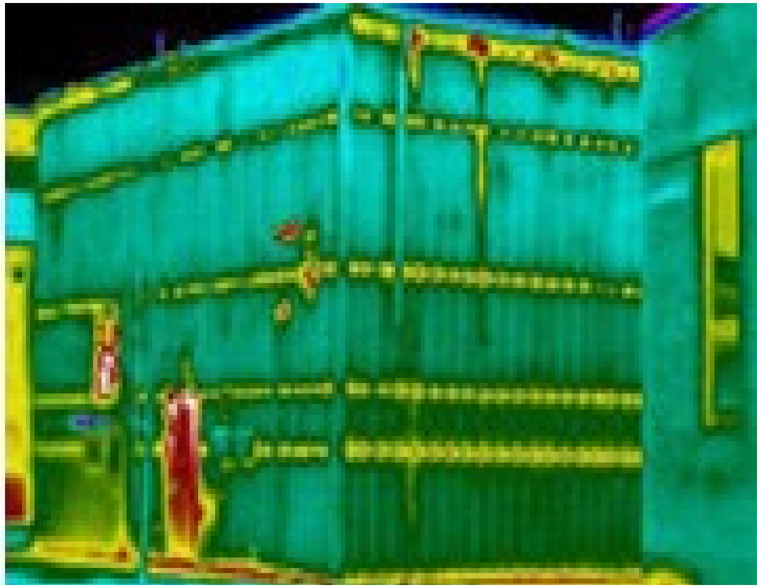
Thermal Bridging

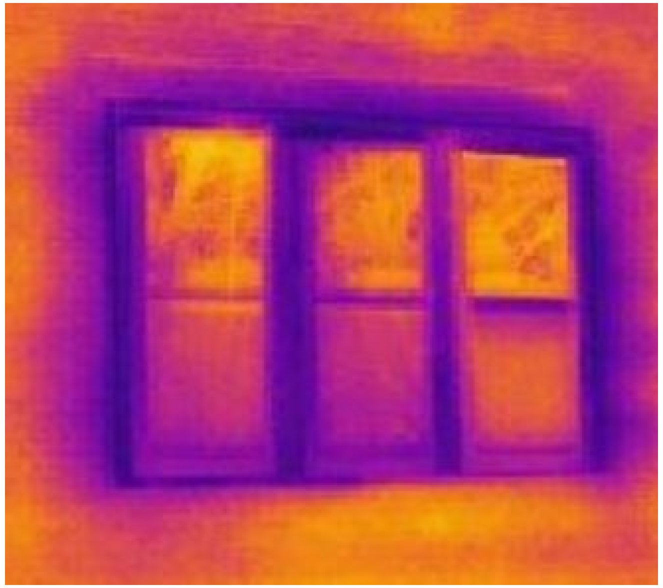
Definition

Thermal Bridge – Any place in the building envelope where heat flows through one material at a much higher rate than adjacent materials.

It can occur due to:

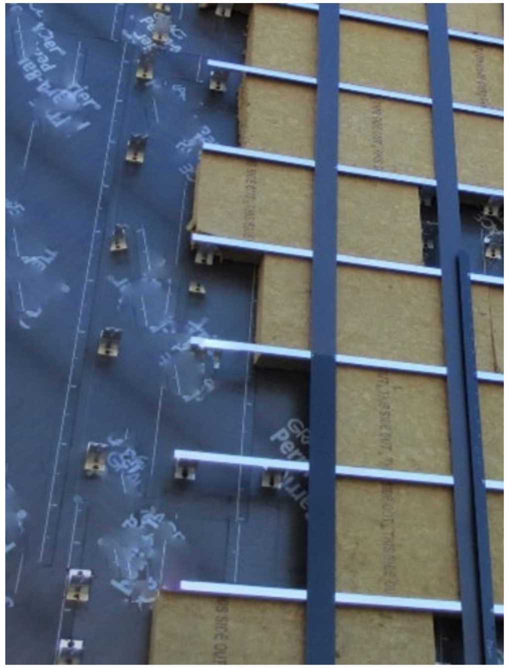
- Penetrations
- Change in Thickness
- Change in Geometry





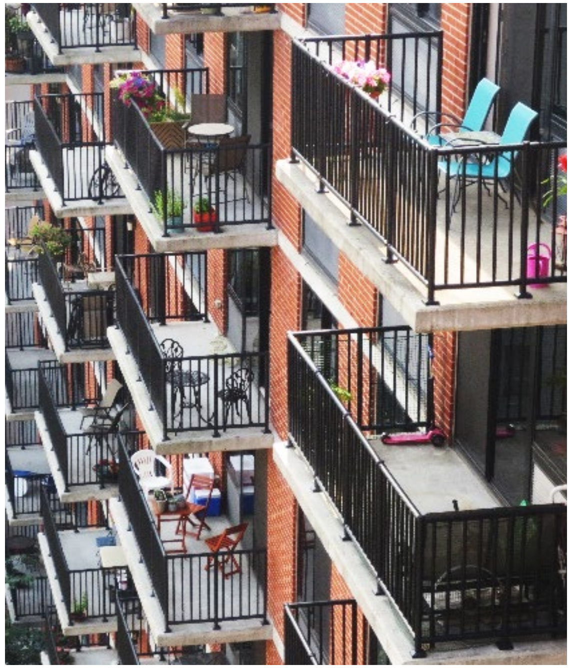
Thermal Bridging

Classification



Clear-Field (Assembly)

Continuous and/or repeating planer elements such as metal framing or regularly spaced cladding anchor clips



Linear

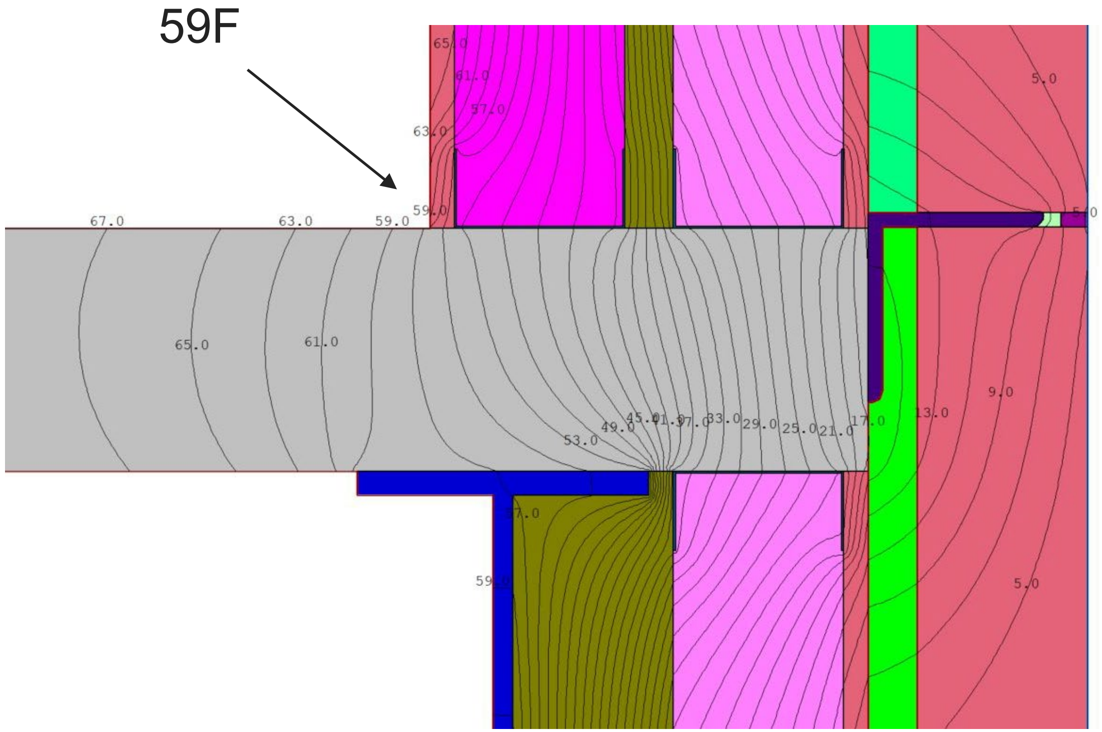
Interfaces where two parts of a building intersect (interfaces), such as floor-to-wall and roof-to-wall interfaces, projecting balcony slabs, or parapets

Point

Localized penetrations through the building envelope (non-continuous across the plane of the enclosure assembly)

Thermal Bridging

Importance and Consequences

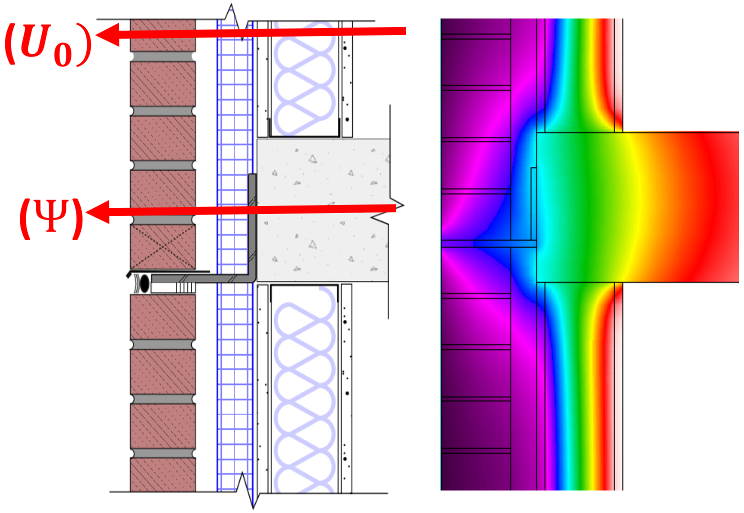


Thermal Bridging

Code Requirements

- ASHRAE 90.1-2022
  - Requirements to address thermal bridging
  - New Normative Appendix K
- NYC, DC, Seattle, MA

$$U_T = \frac{\sum(\Psi * L) + \sum(\chi)}{A_{Total}} + U_0$$



Where:

- U_T = total effective assembly thermal transmittance (Btu/hr·ft^2·°F or W/m^{2}K)
- U_o = clear field thermal transmittance (Btu/hr·ft^2·°F or W/m^{2}K)
- A_{total} = the total opaque wall area (ft^2 or m^2)
- Ψ = heat flow from linear thermal bridge (Btu/hr·ft °F or W/mK)
- L = length of linear thermal bridge, i.e. slab width (ft or m)
- χ = heat flow from point thermal bridge (Btu/hr· °F or W/K)

Thermal Bridging

Resources

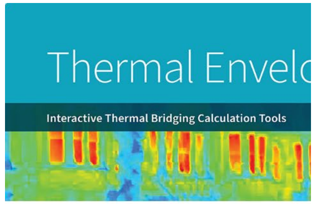


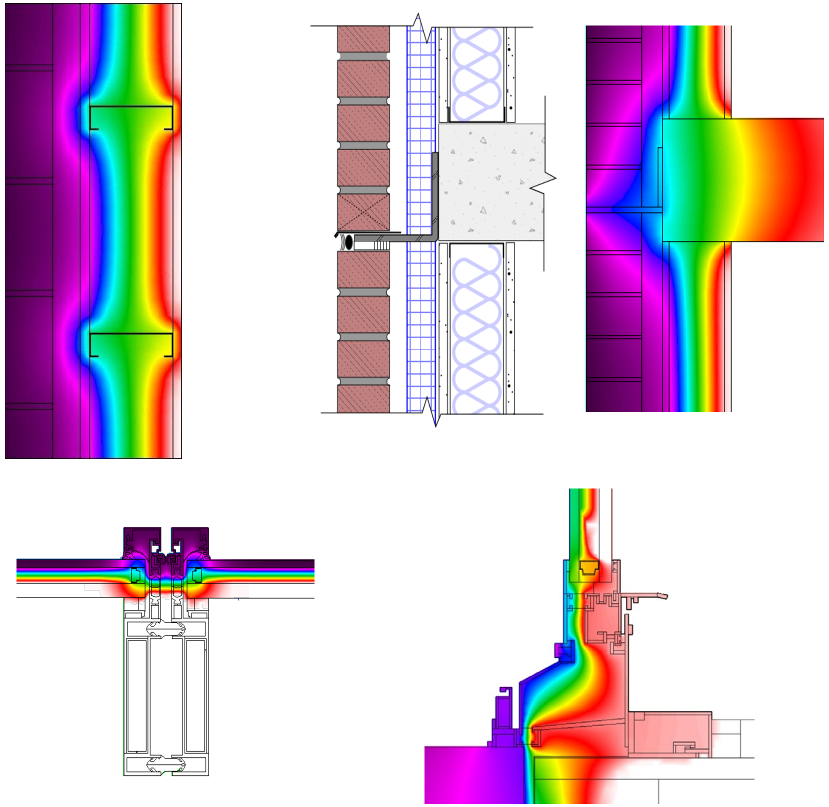
Table A10.1 Thermal Bridging Psi-Factors and Chi-Factors for Thermal Bridges

			Unmitigated		Default	
Class of Construction—Wall, above Grade	Thermal Bridge Type	Section	Psi-Factor, Btu/(h·ft·°F)	Chi-Factor, Btu/(h·°F)	Psi-Factor, Btu/(h·ft·°F)	Chi-Factor, Btu/(h·°F)
Steel framed and *metal buildings*	*Roof* edge	5.5.5.1.1	0.450	N/A	0.140	N/A
	Parapet	5.5.5.1.2	0.289		0.151	
	Intermediate floor to *wall* intersection	5.5.5.2.1	0.487		0.177	
	Intermediate floor balcony or overhang to opaque *wall* intersection	5.5.5.2.2	0.487		0.177	
	Intermediate floor balcony in contact with *vertical fenestration*	5.5.5.2.2	0.974		0.177	
	Cladding support	5.5.5.3	0.314		0.217	
	Wall to *vertical fenestration* intersection	5.5.5.4	0.262		0.112	
	Other element and assembly intersections	5.5.5.5	N/A	1.73	N/A	0.91
Mass (exterior or integral)	*Roof* edge	5.5.5.1.1	0.500	N/A	0.100	N/A
	Parapet	5.5.5.1.2	0.238		0.125	
	Intermediate floor to *wall* intersection	5.5.5.2	0.476		0.179	
	Intermediate floor balcony or overhang to opaque *wall* intersection	5.5.5.2.2	0.476		0.179	
	Intermediate floor balcony in contact with *vertical fenestration*	5.5.5.2	0.974		0.177	
	Cladding support	5.5.5.3	0.270		0.186	
	Wall to *vertical fenestration* intersection	5.5.5.4	0.188		0.131	
	Other element and assembly intersections	5.5.5.5	N/A	0.91	N/A	0.19

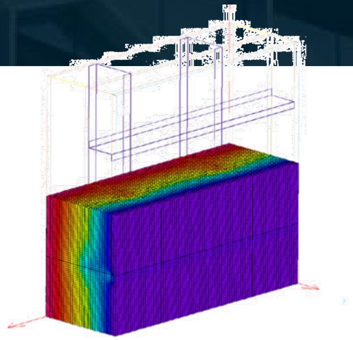
N/A = not applicable

Thermal Bridging

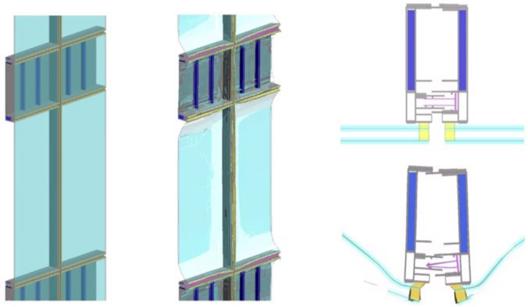
Analysis Tools



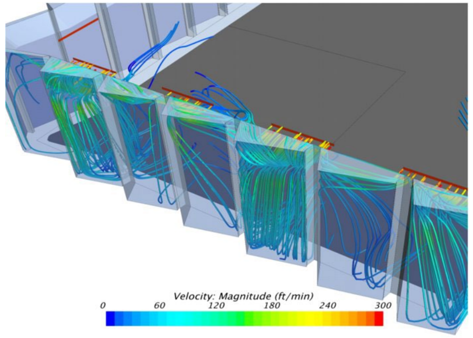
THERM
2D Finite Element
Analysis
(Steady State)



Heat 2 / Heat 3
3D Finite Difference
(Steady State / Transient)



ANSYS
3D Finite Element Analysis
(Steady State / Transient)

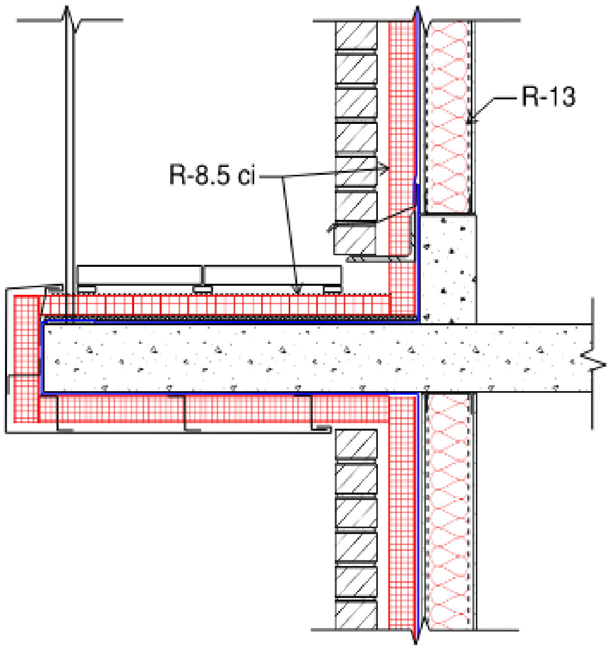


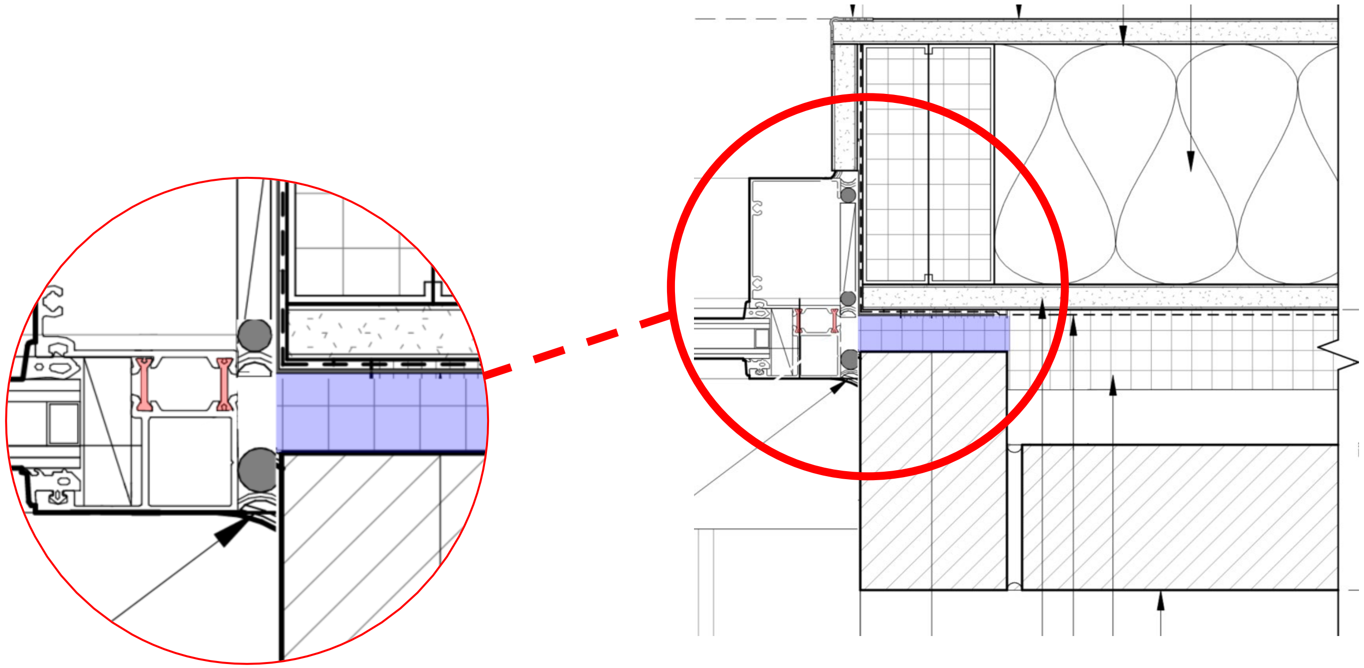
StarCCM+
Computational Fluid Dynamics
(Finite Volume Method – Steady State / Transient)

Thermal Bridging

Mitigation Strategies

- Maintain Continuity
- Align thermal barrier elements

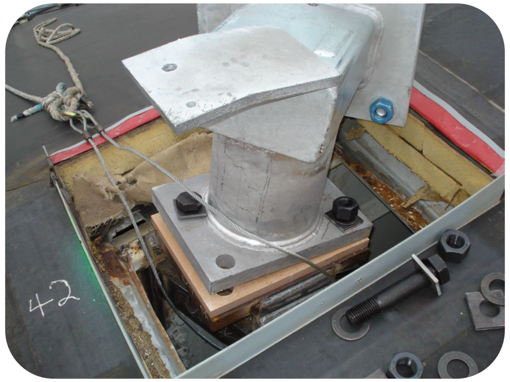


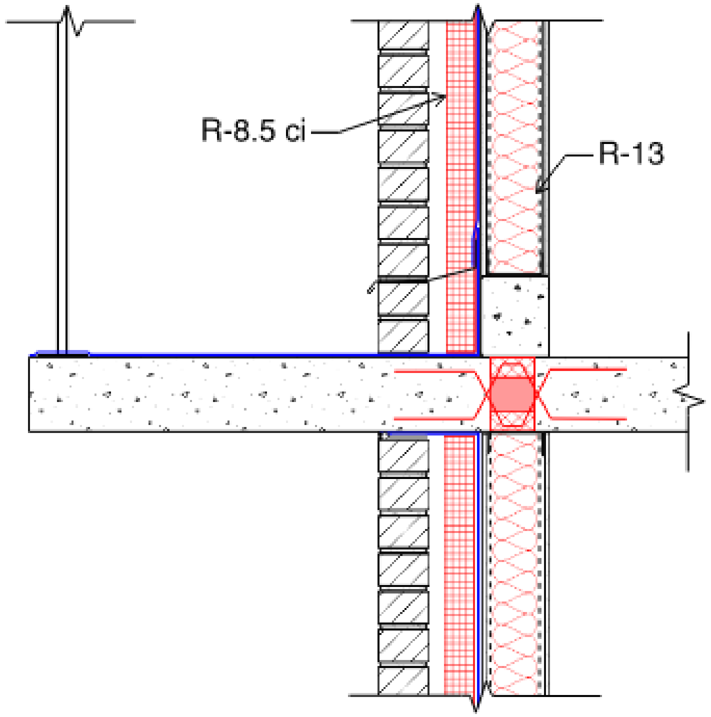


Thermal Bridging

Mitigation Strategies

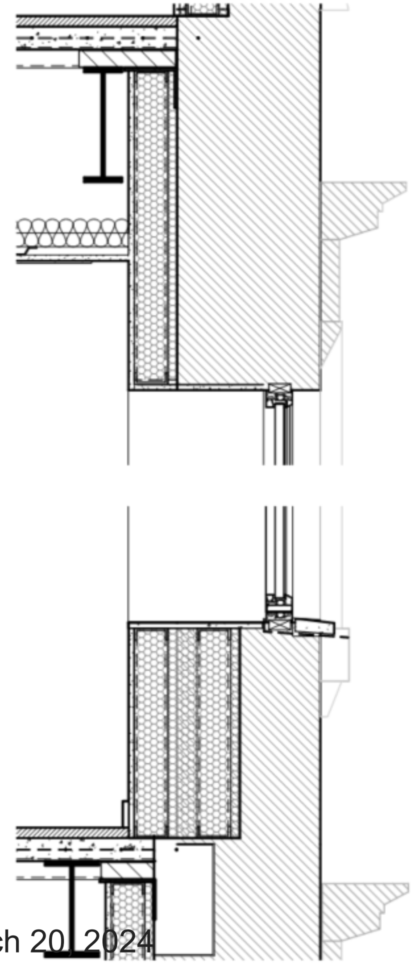
- Reduce Thermal Bridges
- Consider thermal break/separator

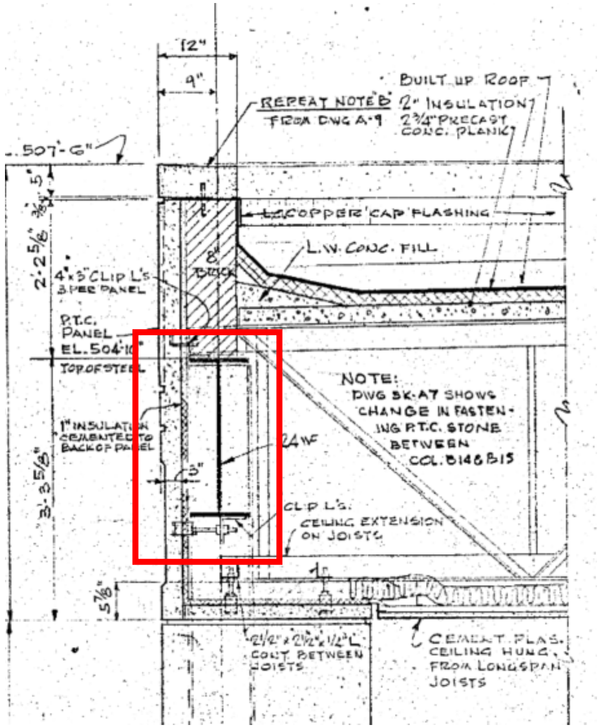


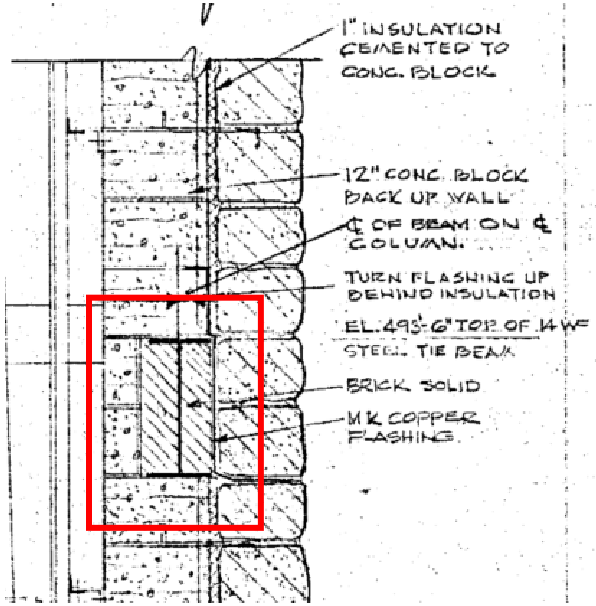


Thermal Bridging

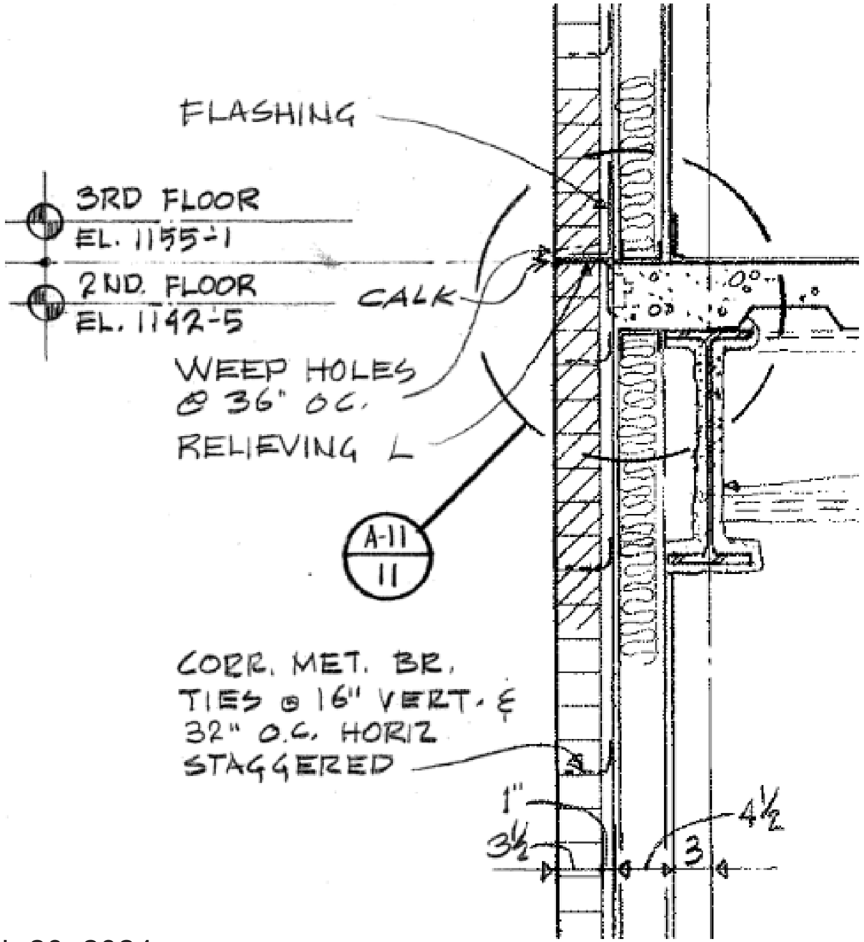
Mitigation Strategies – Existing Buildings





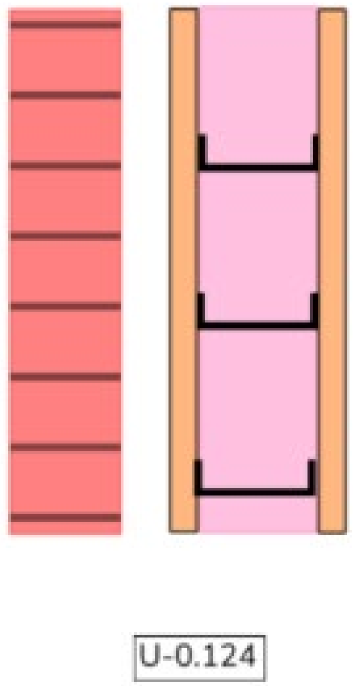


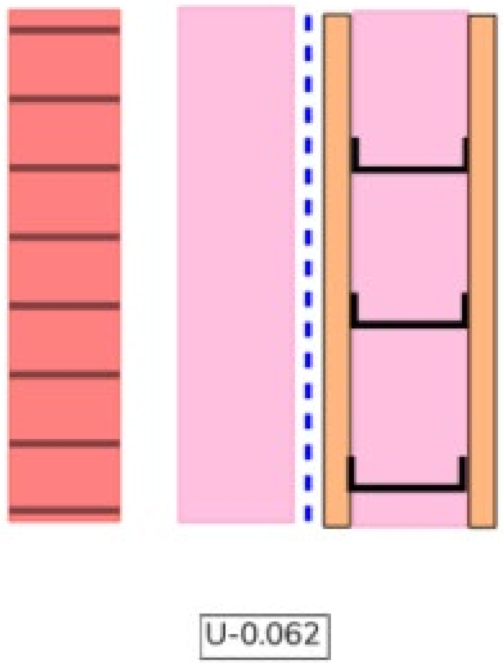
Project Example No. 1 - University Building Renovation

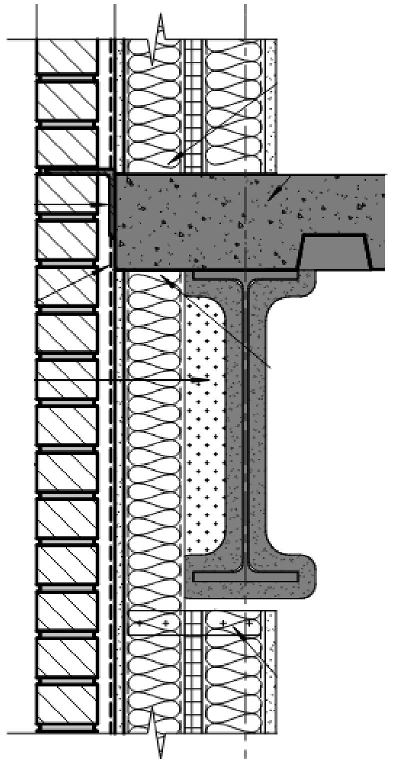


Project Example No. 1 - University Building Renovation

- 2018 IECC
  - R13 + R7.5 ci or U-0.064
- Thermal Bridging
  - Clear-Wall (Field) at metal stud framing
  - Linear at floor lines







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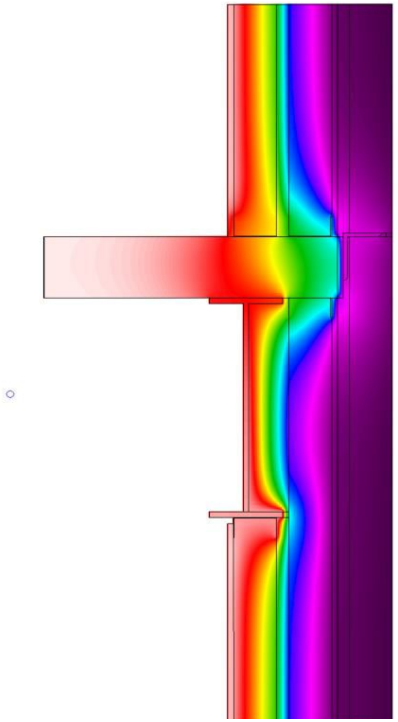

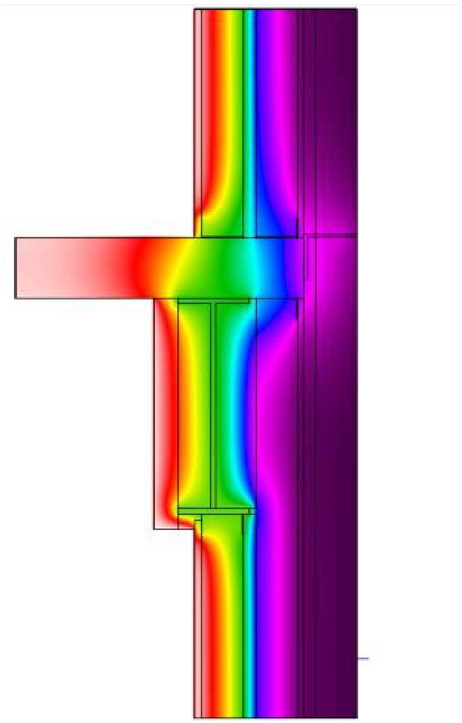

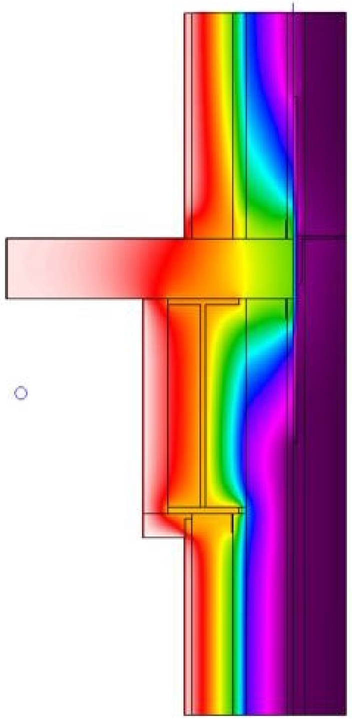

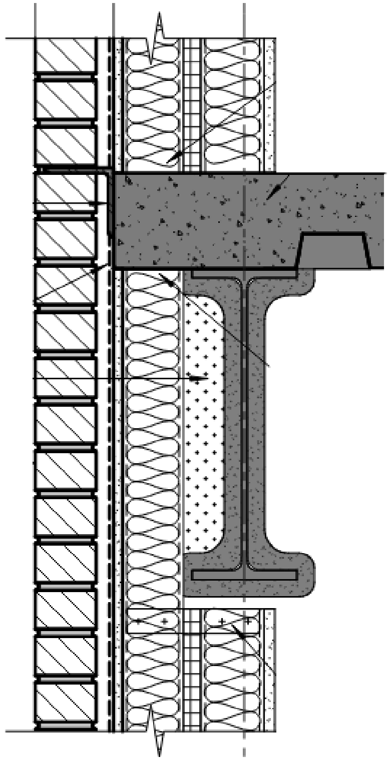

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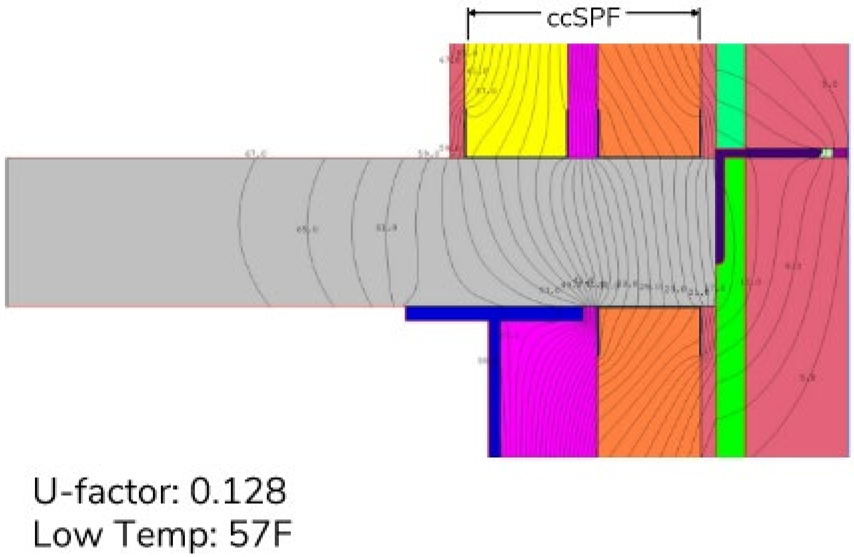

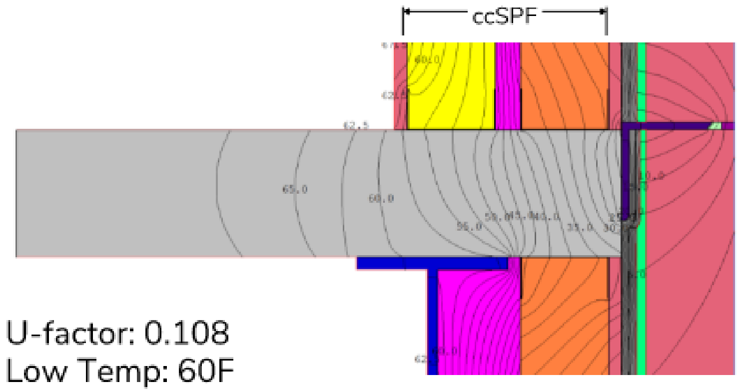

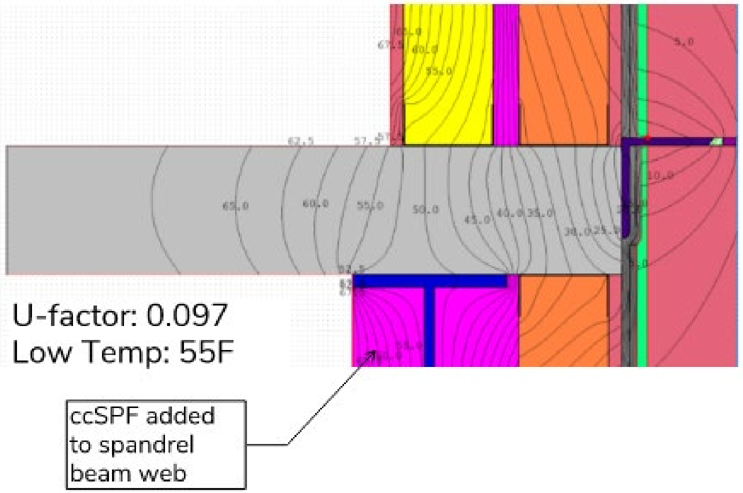

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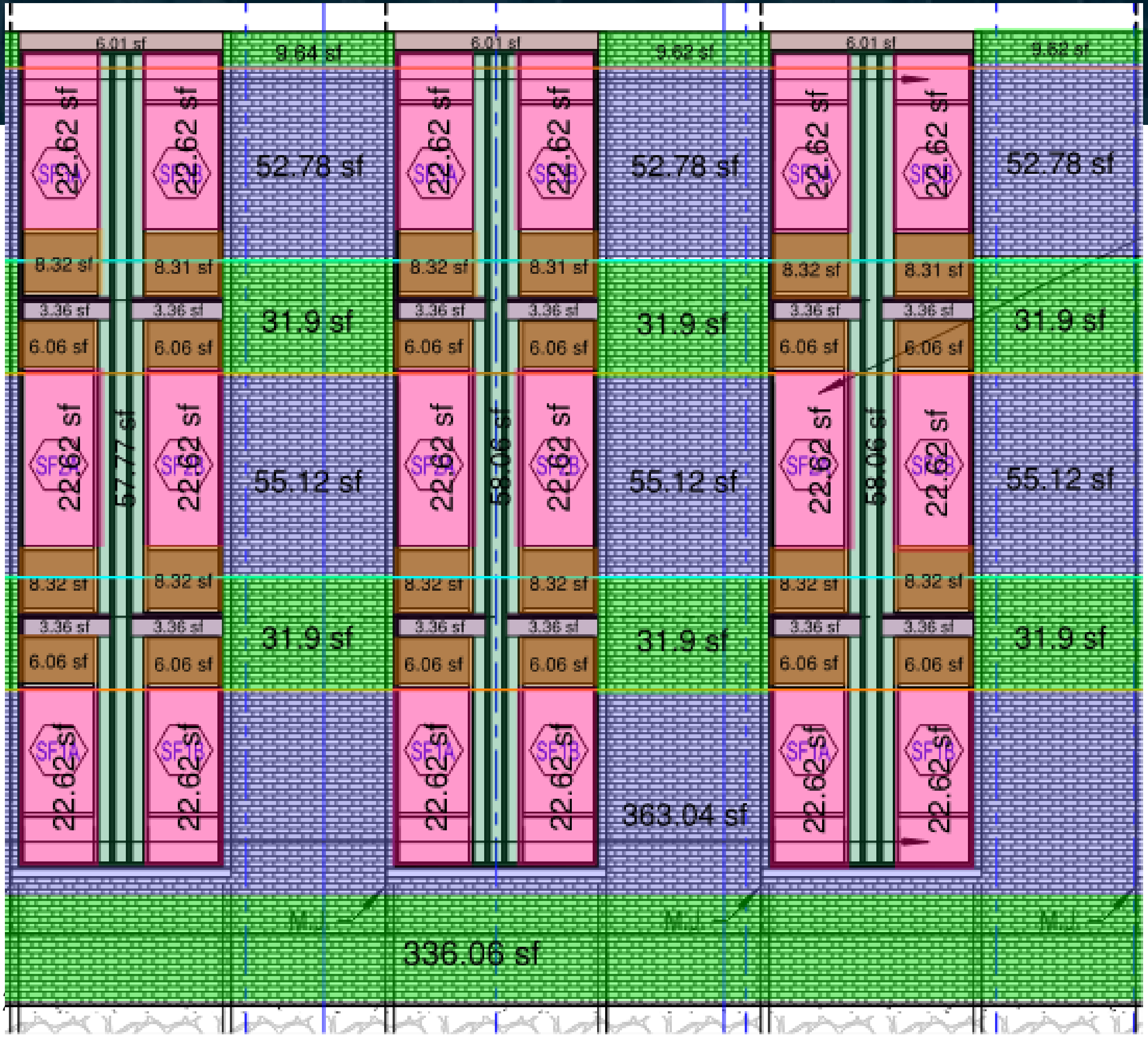
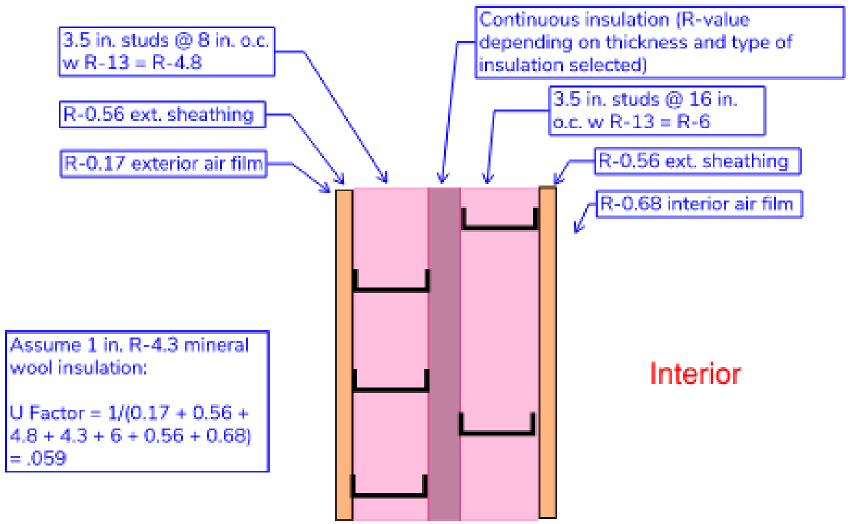
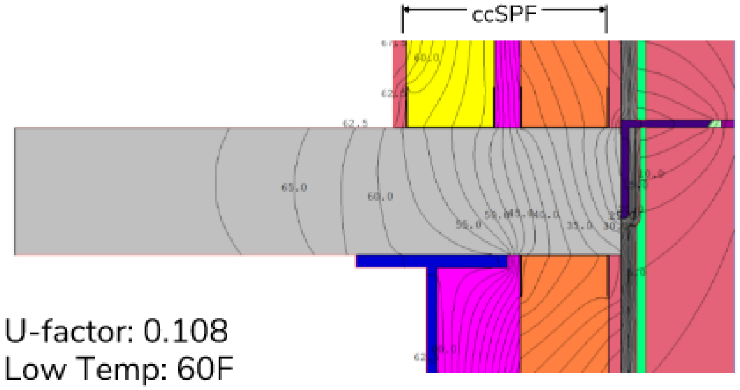
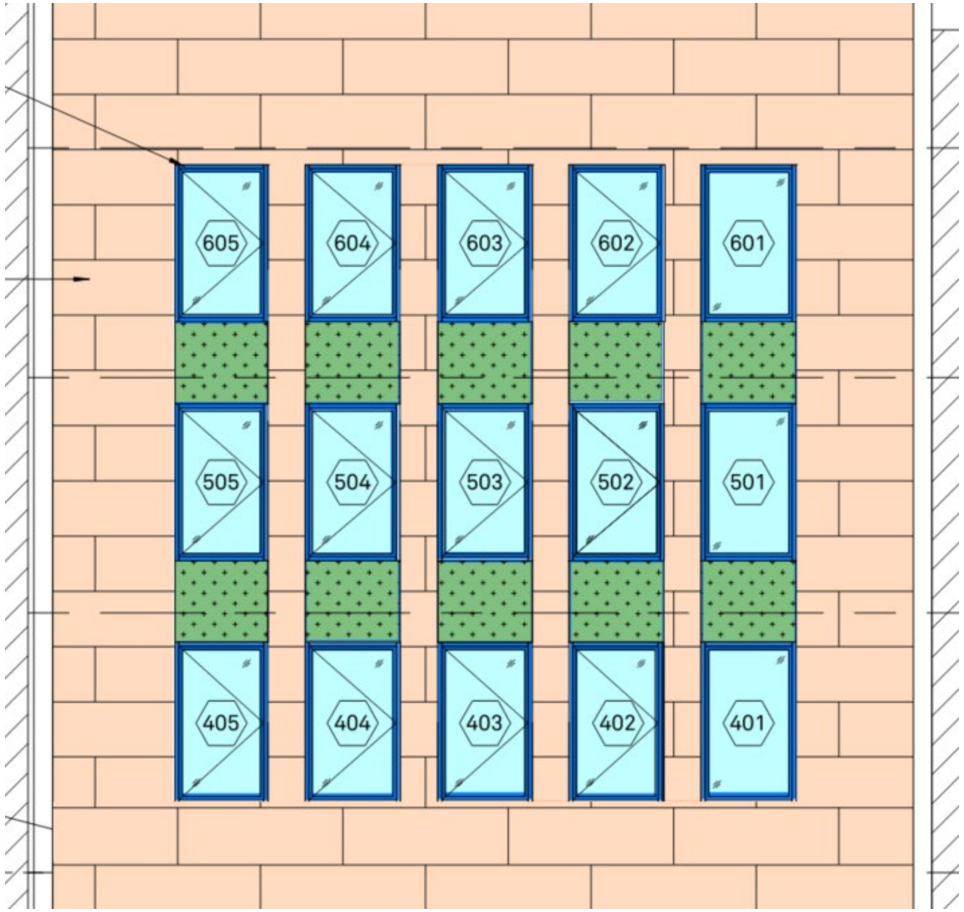


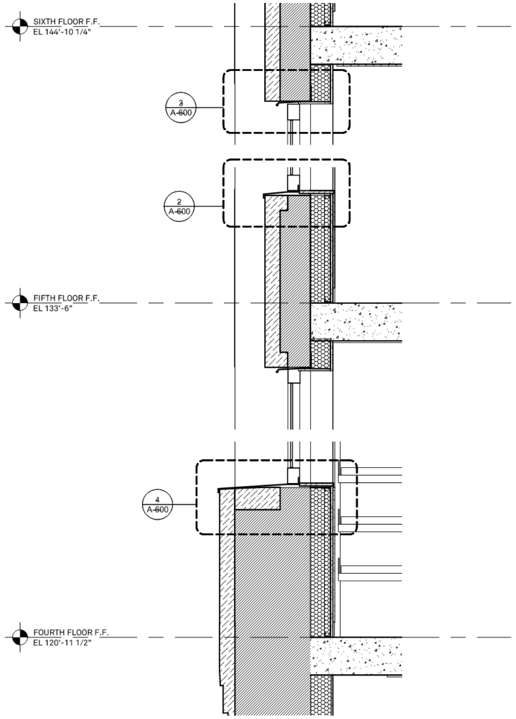




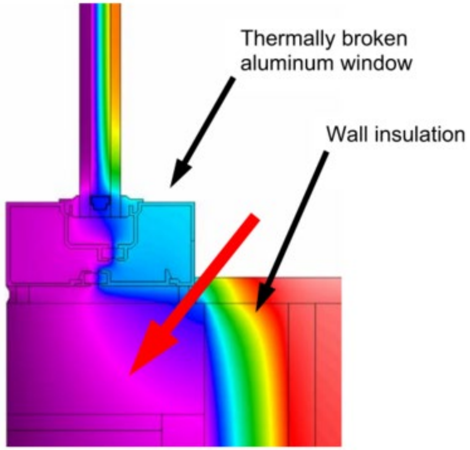
U-factor: 0.108
Low Temp: 60F

Project Example No. 2 – Existing Building Window Replacement





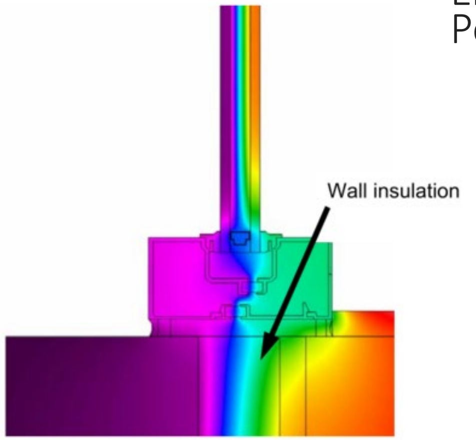
Window Product Performance = U-0.45



THERM model results showing heat flow path between insulation and window frame (red arrow)

$T_{interior}$ = 70°F
$T_{exterior}$ = 0°F

Effective Thermal Performance = U-0.55



Alignment of the window with the wall insulation provides better continuity between insulating components and lowers heat loss at the window perimeter

$T_{interior}$ = 70°F
$T_{exterior}$ = 0°F

Conclusions

- Thermal bridging can have a significant impact on the overall thermal performance of the building enclosure.
- Improper or incomplete evaluation often results in a combination of increased condensation risk, inefficient mechanical system operation, high energy costs, and occupant thermal comfort problems.
- Existing buildings present greater challenges that are outside of the designer’s control when compared to new design projects.
- Selecting the appropriate method of analysis is influenced by the project location, certifications, owner-driven performance requirements, and/or building geometry.

Thank You