THE IMPORTANCE OF BALCONY AND SLAB EDGE THERMAL BRIDGES IN CONCRETE CONSTRUCTION

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ABSTRACT

Exposed concrete slab edges, balconies, and eyebrows on multistorey buildings bridge the insulation provided by wall and window assemblies, which increases heat transfer between conditioned spaces and the exterior. This can also result in cold interior surface temperatures and condensation/fungal growth during the winter. These impacts are becoming more significant because balcony area is often considered a significant selling point in the condominium market, and many municipalities have been known to offer increased balcony area as an incentive for other variances.

Though solutions to reduce the impact of exposed concrete slab thermal bridging exist within the marketplace, they are seldom employed in North America—largely due to availability, cost, and a lack of data regarding their effects on energy use to offset the added expense. Cost-effective solutions exist but are often ruled out for reasons that relate to aesthetics and constructability or construction sequencing concerns. However, a few successful projects have now been completed in Canada that incorporate these products.

This paper examines the impact of concrete slab edges and balcony projections on annual heating and cooling energy consumption in Canadian climate zones. The individual assemblies are analyzed using 3D component thermal modeling to determine overall effective R-values/U-values and linear transmittance values and to assess thermal comfort impacts. Whole-building energy simulations are run to assess the impact on energy consumption. Several potential solutions are also assessed, comparing cost implications in relation to the anticipated energy savings.

BACKGROUND

Thermal bridging occurs when heat flow bypasses the insulated elements of the building enclosure through materials with high thermal transmittance. This can occur through structural components such as studs/plates, framing, and cladding supports as well as larger columns, shear walls, and exposed floor slab edges and protruding balconies. Thermal bridging can occur through all building enclosure assemblies including the roofs, floors, walls, windows, and below-grade assemblies.

Heat flow through thermal bridges can be significant and disproportionate to the overall enclosure area so that a seemingly well-insulated building may fail to meet energy code requirements, designer intent, or occupant expectations. Windows are often seen as the largest thermal bridge in buildings because the thermal performance is often quite low compared to the surrounding walls (e.g., an R-2 aluminum frame window within an R-20 insulated wall). Exposed concrete slab edges and balconies can have nearly as much influence, with effective R-values of approximately R-1. After windows and doors, exposed concrete slab edges and balconies often account for the second-greatest source of building enclosure heat loss in a multistorey building.

With a better understanding of the impacts of thermal bridging, the building industry has started to implement strategies to improve the thermal performance of building enclosures. For example, the use of exterior continuous insulation in walls is becoming more common. Unfortunately the impact of floor slab edges and balconies is still often overlooked, while the architectural aesthetic of exposed slab edges and protruding balconies or eyebrow elements is becoming more common. Some designers believe that these elements have a negligible impact on the overall performance of the building or see them as an unavoidable compromise to achieve a certain appearance or space. However, the impact of exposed slab edges and balconies is very significant, as this paper demonstrates. The significance of these elements also increases as more highly insulated walls are used. Fortunately, there are solutions available in the marketplace that help minimize thermal bridging impact at slab edges and balconies and allow for continued architectural design freedom under increasingly more stringent energy code requirements and occupant demands. A number of North American articles on the topic of thermal bridging at slab edges have highlighted the issue in the past few years (Lstiburek 2008, Lstiburek 2012, Ge et al. 2013), though the focus of those articles was not on quantifying the energy impacts beyond specific case studies.

Our firm undertook a research to quantify the thermal impact of exposed slab edges and balconies in mid- to high-rise residential buildings across climate zones in Canada. The project assessed the impact of exposed slab edges and balconies on the effective wall R-values and indoor surface temperatures. Space heating and cooling energy consumption was modeled in each climate zone for an archetypal multiunit residential building to quantify the energy loss through exposed slab edges and balconies and to determine the energy savings that could be achieved in typical scenarios when balcony and slab edge thermal break products are used. This paper summarizes the thermal comfort, energy, and cost impacts of exposed slab edges and balconies. It provides proven solutions and discussion of their implications with respect to these parameters.

Table 1 - Examples of Typical Exposed Concrete Slab Edges, Eyebrows, and Balconies in Reinforced Concrete Residential Buildings

REDUCTION IN R-VALUE DUE TO BALCONIES AND EXPOSED SLAB EDGES

The impact of balconies, eyebrows, and exposed slab edges on wall R-values was assessed with three-dimensional heat transfer simulations as part of this study. The effective R-values for these and other assemblies analyzed in this study were calculated using the three-dimensional finite element thermal modeling software, Heat3, Versions 5 and 6 (Blocon, 2014). This program has been validated to ISO 10211 standards and is widely used by researchers and consultants to perform 3D thermal simulations to calculate effective R-values of building enclosure assemblies and details.

Three levels of wall insulation were simulated as a clear wall with exterior insulation (no thermal bridging), an exposed slab edge, and various lengths of an eyebrow or balcony projection. The resulting overall effective R-values are shown in Figure 2 and Table 1. Effective R-values of R-2, R-5, R-10, and R-20 were selected for generic wall assemblies 4' above and 4' below the slab edge to represent a bounding range of potential wall assemblies. These effective R-values roughly corresponding to window wall/spandrel panels, to insulated steel studs, to exterior insulation with thermally improved cladding attachments, to EIFS, and to more specific assemblies are covered later within this paper.

Simulating the three slab edge configurations allows for comparison between the clear wall (unbridged) R-value and the effective R-value considering an exposed slab edge, eyebrow, or balcony. The overall effective R-value did not change significantly between simulations with different balcony/eyebrow projection lengths from exposed up to 8 feet.

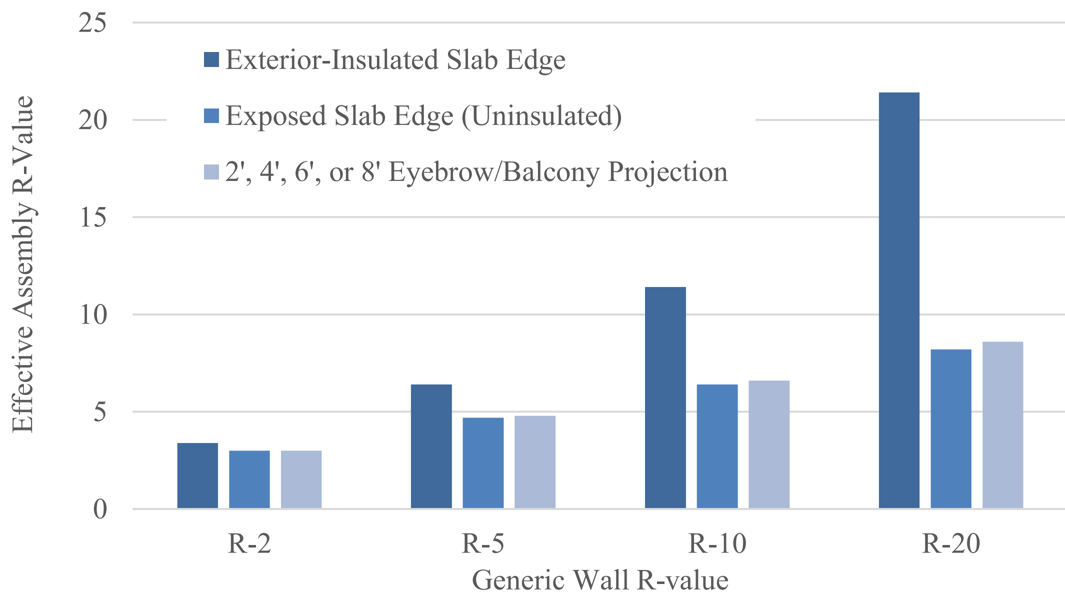


Figure 2 - Effective Assembly R-Values with Insulated Slab Edge, Exposed Slab Edge, and Balcony Projection

Table 1 - Effective Assembly R-Values with Slab Edge and Percent Reduction from Insulated Case

	Overall Effective Wall R-Value with Impact of Slab Edge			
Generic Wall R-Value	**R-2**	**R-5**	**R-10**	**R-20**
Exterior-Insulated Slab Edge (No Bridging)	3.4	6.4	11.4	21.4
Exposed Slab Edge (Uninsulated)	3.0	4.7	6.4	8.2
Percent reduction from insulated case	*12%*	*27%*	*44%*	*62%*
2', 4', 6', or 8' Eyebrow/Balcony Projection	3.0	4.8	6.6	8.6
Percent reduction from insulated case	*12%*	*25%*	*42%*	*60%*

The results in Figure 2 and Table 1 show that the exposed slab edge and balcony significantly reduces the overall R-value of the entire 8' 8" tall wall assembly. The R-value reductions range from of 12% to 62%; walls with more exterior insulation (e.g., the R-20 case) showing a greater percent reduction in overall R-value. This occurs due to the nonlinear nature of heat transfer: walls with more insulation will lose proportionally more heat through thermal bridges. The data also shows how, when more wall insulation is added, the overall effective R-value of an assembly with balconies or exposed slab edges improves only slightly. For example, moving from R-10 to R-20 exterior insulation (adding R-10) results in an effective

R-value improvement from R-6.4 to R-8.2 (addition of R-1.8) considering exposed slab edges. In other words, only an improvement of R-1.8 is seen from the addition of R-10 of insulation.

Building code requirements for wall insulation are typically between R-10 and R-20 effective as discussed later within this paper. The results shown above indicate that a balcony or exposed slab edge through this level of insulation results in a typical R-value reduction of 42% to 62%.

The thermal modeling results also demonstrate that, once the concrete slab edge is exposed to the exterior (as is common in interior-insulated wall assemblies), the effective R-value is already significantly reduced—and the addition of a 2' concrete eyebrow or 4' to 8' balcony does not reduce it significantly more. In fact, the extra concrete on the exterior actually provides a very small amount of insulation to the system, resulting in very slightly higher effective R-values in some cases. Additional heat flow from wind effects of a larger protrusion are not considered here, though in this study standard exterior surface films are applied over the entire surface, representing energy code design parameters. Further research in this area should be performed to determine in-service impacts of wind, though it would not necessarily change how code R-values are calculated.

BALCONY AND SLAB EDGE SOLUTIONS

Several concrete balcony and slab edge thermal break solutions were initially considered as part of this study, including the following potential solutions (Figure 3):

- Structural slab cut-outs with beam reinforcement
- Concentrated slab reinforcement with insulation inserts
- Full and partial balcony slab insulation wraps
- Manufactured purpose-built concrete slab thermal breaks

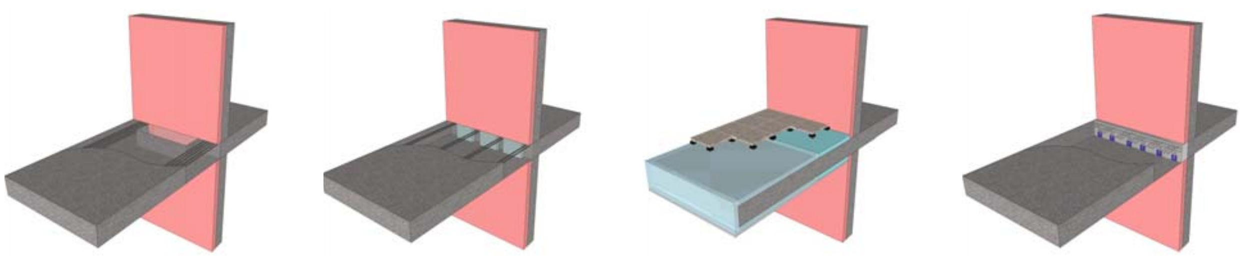


Figure 3 - Balcony Structural Slab Cut-Out, Concentrated Slab Reinforcement, Insulation Wrap, Manufactured Concrete Slab Thermal Breaks

The overall effective R-value of each of these assemblies was determined by three-dimensional heat transfer modeling. Costing was also completed for each assembly to estimate the increased cost of construction. This work showed that the first three solutions were either more expensive than the manufactured slab thermal break products or did not provide significant R-value improvements. The structural slab cut-outs and concentrated slab reinforcement options were both less expensive than a thermal break product but yielded only small improvements in the overall effective R-value. The full balcony insulation wrap resulted in a moderate R-value improvement that was less than the manufactured thermal break product but came at a much higher cost. As a result, these first three options were not investigated further within the study. Further information, including the comparative thermal analysis and costing of the various options, is provided in the full research report for this study (RDH, 2013).

A range of cast-in-place concrete balcony and slab edge thermal breaks are available on the market in Europe, with some products also available in North America. These products typically incorporate an expanded polystyrene insulation thermal break with stainless-steel tension reinforcing and special polymer concrete compression blocks. These products have a range of effective conductivity (or effective component R-value) depending on the structural reinforcing requirements and insulation thickness. To analyze a range of performance levels, two products were selected for this study: one with normal reinforcing (R-2.5 effective for a 3.25"-deep product) and one with light reinforcing (R-5.0 effective for a 5"-deep product, which provides better thermal performance).

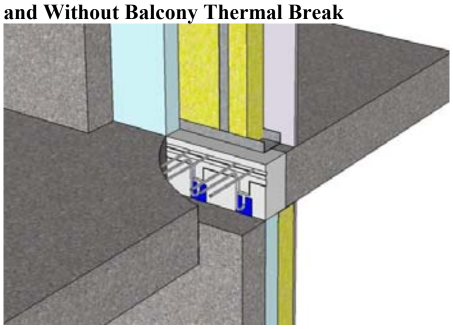
The thermal models were created using standard material properties and ASHRAE standard boundary conditions (-17.8°C and 34 W/m^2·K exterior, 21°C and 8.3 W/m^2·K interior). The program performs a finite difference calculation to determine heat flow through the assembly, which is then divided by the temperature difference to determine the U-value. Linear transmittance values were also calculated for each slab edge or balcony condition.

Effective R-values for the following wall assemblies with and without balconies and exposed slab edges are summarized in Table 2.

- Interior-Insulated Exposed Concrete
- Exterior-Insulated Cast-in-Place Concrete
- Exterior-Insulated (Girt and Clip–Supported Claddings)
- Insulated Steel Stud Infill Wall

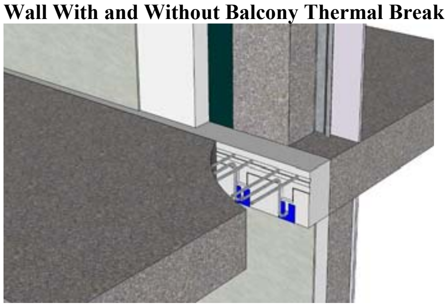
Table 2 - Summary of Effective R-Values for Various Typical High-Rise Wall Assemblies With and Without Balcony/Slab Edge Thermal Breaks

Interior-Insulated Exposed Concrete Wall With and Without Balcony Thermal Break



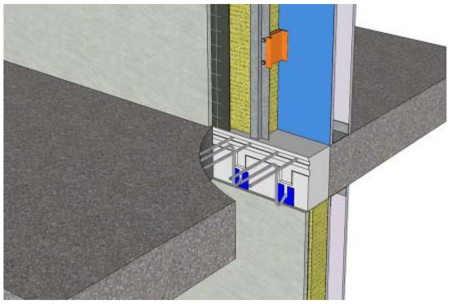
Interior Insulation Strategy	Effective R-Value (R_{SI}), No Thermal Break	Effective R-Values (R_{SI})	
		R-2.5 Thermal Break	R-5.0 Thermal Break
1" XPS (R-5) + R-12 batts/steel studs @ 16" o.c.	R-7.5 (R_{SI}–1.32)	R-11.0 (R_{SI} –1.94) (47% improvement)	R-12.1 (R_{SI} –2.13) (61% improvement)
2" XPS (R-10) + R-12 batts/steel studs @ 16" o.c.	R-8.9 (R_{SI}–1.56)	R-14.4 (R_{SI} –2.53) (62% improvement)	R-16.6 (R_{SI} –2.93) (87% improvement)
3" XPS (R-15) + R-12 batts/steel studs @ 16" o.c.	R-10.0 (R_{SI}–1.77)	R-17.0 (R_{SI} –2.99) (70% improvement)	R-19.5 (R_{SI} –3.44) (95% improvement)

Exterior-Insulated (EIFS) Exposed Concrete Wall With and Without Balcony Thermal Break



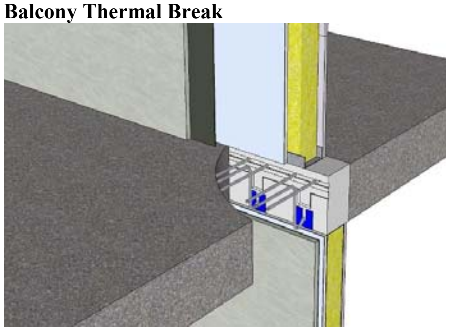
Exterior Insulation Strategy	Effective R-Value (R_{SI}), No Thermal Break	Effective R-Values (R_{SI})	
		R-2.5 Thermal Break	R-5.0 Thermal Break
3" EPS (R-12), Adhered EIFS	R-7.4 (R_{SI}–1.31)	R-11.5 (R_{SI} –2.02) (55% improvement)	R-12.6 (R_{SI} –2.22) (70% improvement)
4" EPS (R-16), Adhered EIFS	R-8.6 (R_{SI}–1.51)	R-13.8 (R_{SI} –2.43) (60% improvement)	R-15.7 (R_{SI} –2.76) (83% improvement)
6" EPS (R-24), Adhered EIFS	R-10.6 (R_{SI}–1.86)	R-17.7 (R_{SI} –3.12) (67% improvement)	R-20.9 (R_{SI} –3.68) (97% improvement)

Exterior-Insulated (Clip-Supported Cladding) Steel Stud Wall With and Without Balcony Thermal Break



Exterior Insulation Strategy	Effective R-Value (R_{SI}), No Thermal Break	Effective R-Values (R_{SI})	
		R-2.5 Thermal Break	R-5.0 Thermal Break
Nonconductive cladding clips 16"x24" spacing, 4" MW (R-16) exterior + no insulation in S.S. @ 16" o.c.	R-8.5 (R_{SI}– 1.50)	R-13.2 (R_{SI} –2.33) (55% improvement)	R-14.2 (R_{SI} –2.50) (67% improvement)
Horizontal Z-girts @ 24" vertically, 4" MW (R-16) exterior + no insulation in S.S. @ 16" o.c.	R-6.5 (R_{SI} – 1.15)	R-8.2 (R_{SI} –1.44) (26% improvement)	R-8.6 (R_{SI} –1.52) (32% improvement)

Steel Stud Insulated Wall With and Without Balcony Thermal Break



Exterior Insulation Strategy	Effective R-Value (R_{SI}), No Thermal Break	Effective R-Values (R_{SI})	
		R-2.5 Thermal Break	R-5.0 Thermal Break
3 5/8" steel studs with R-12 batt insulation	R-3.6 (R_{SI} –0.64)	R-4.1 (R_{SI} –0.72) (14% improvement)	R-4.2 (R_{SI} –0.74) (17% improvement)
6" steel studs with R-20 batt insulation	R-4.2 (R_{SI} –0.74)	R-4.7 (R_{SI} –0.82) (12% improvement)	R-4.8 (R_{SI} –0.85) (14% improvement)

ENERGY IMPACT OF BALCONIES, EXPOSED SLAB EDGES, AND THERMAL BREAK PRODUCTS

The thermal modeling of various thermal bridging cases has shown that the effective R-value of insulated wall assemblies bridged by exposed slab edges, eyebrows, or balconies are significantly reduced compared to the clear wall and nominal insulation R-values. Thermal modeling of potential solutions demonstrates that manufactured balcony thermal break products can create wall assemblies with balconies that have only a small reduction in R-value compared to the clear wall or insulation only R-value. To determine the impact that these scenarios have on the energy consumption and operating cost of a building, whole-building energy modeling was performed for a typical high-rise multiunit residential building with various slab edge and balcony conditions.

The thermal impact of the exposed slab edge was modeled by inputting the overall effective wall R-values as calculated by the 3D modeling in lieu of other energy modeling simplification methods such as separating the R-values for the walls above and below and the slab protrusion. Whole-building energy models are not sophisticated enough to account for actual geometries of protruding balconies and calculate actual effective R-values, so the impacts must be calculated separately. Research and development in this area is needed to improve the accuracy of energy modeling software.

This energy model uses a representative archetypical 20-storey, 12,900 m^2 multiunit residential building (MURB) containing 160 suites. The building mechanical system consists of a split system with forced-air heating and cooling within the suites. The building enclosure assemblies use ASHRAE 90.1-2010 prescriptive R-value minimums for the windows and roof. For this set of results, the slab edge or balcony was assumed to be exposed along the entire perimeter of the building, which is a common design in many newer MURBs. Results would vary, though not linearly, for buildings with less exposed slab area.

The program DesignBuilder, an interface for the EnergyPlus engine, was used to perform the energy modeling. To ensure the model provided realistic energy results, its output was compared to measured energy use within multiunit residential buildings from previous research studies (RDH, 2012). Within the model this also involved calibrating the heat output predicted by the model to reflect use within actual MURBs with similar design conditions.

Simulations were performed for locations across Canada. This report shows results for three cities (Vancouver, Toronto, and Calgary), representing climate zones 4/5, 6, and 7. Figure 4 shows a map of Canadian climate zones according to the 2011 National Energy Code for Buildings (NECB). Note that ASHRAE 90.1-2010 uses similar but slightly different climate zones where Canadian Zone 4 locations are part of ASHRAE Zone 5 due to the use of different climate data.

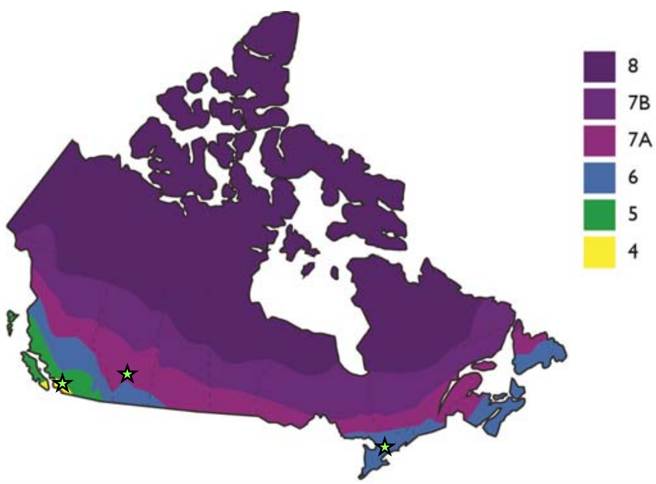


Figure 4 - Canadian climate map showing Climate Zones 4 through 8 per the 2011 NECB.

The overall wall effective R-values are the only variable that changes in each model scenario. Four wall assemblies were simulated with varying levels of exterior insulation using the same cases shown in the previous sections (R-2, R-5, R-10, and R-20), each with a cast-in-place concrete wall backup. Effective R-values that were used for the whole-building energy modeling are summarized in Table 3.

Table 3 - Effective Assembly R-Values of Different Slab Edge Details used for Energy Models

	Overall Effective Wall R-Value with Impact of Slab Edge & Thermal Breaks			
Generic Wall R-Value **Slab Detail**	**R-2**	**R-5**	**R-10**	**R-20**
Exterior-Insulated Slab Edge (No Bridging)	3.4	6.4	11.4	21.4
No Thermal Break, Exposed Slab	3.0	4.7	6.4	8.2
No Thermal Break, Eyebrow/Balcony	3.0	4.8	6.6	8.6
Balcony Thermal Break: R-3.4 product	3.4	6.2	10.1	16.3
Percent Improvement from Non-Thermally Broken Balcony (6' deep)	*14%*	*30%*	*53%*	*89%*
Balcony Thermal Break: R-5.7 product	3.5	6.4	10.8	18.2
Percent Improvement from Non-Thermally Broken Balcony (6' deep)	*15%*	*34%*	*63%*	*111%*

Figures 5, 6, and 7 show the annual energy use intensity for each scenario modeled in Vancouver, Toronto and Calgary, respectively. Tables 4, 5, and 6 show the numerical results, with the percent increase in heating and cooling energy consumption compared to the exterior-insulated case with no thermal bridging.

The energy modeling results show the energy consumption increase as a result of slab edges and balconies penetrating the exterior insulation. The resulting heating and cooling energy increase due to exposed slab edges or balconies is in the range of 4% to 12%, depending on the R-value of the wall. Walls with higher insulation R-values tend to have the greatest percent energy increase, which demonstrates the greater need to address this detail as energy code requirements for wall insulation increase.

The results also show that balcony thermal breaks result in only slight increase in heating energy compared to the fully insulated case, typically resulting in 1% to 4% increases in heating and cooling energy consumption. Comparing the cases with a balcony thermal break to the case with an uninsulated balcony shows that a thermal break results in space conditioning savings of between 4% and 8% depending on the effective R-value of the surrounding wall assembly. Higher savings are attained where walls are more highly insulated.

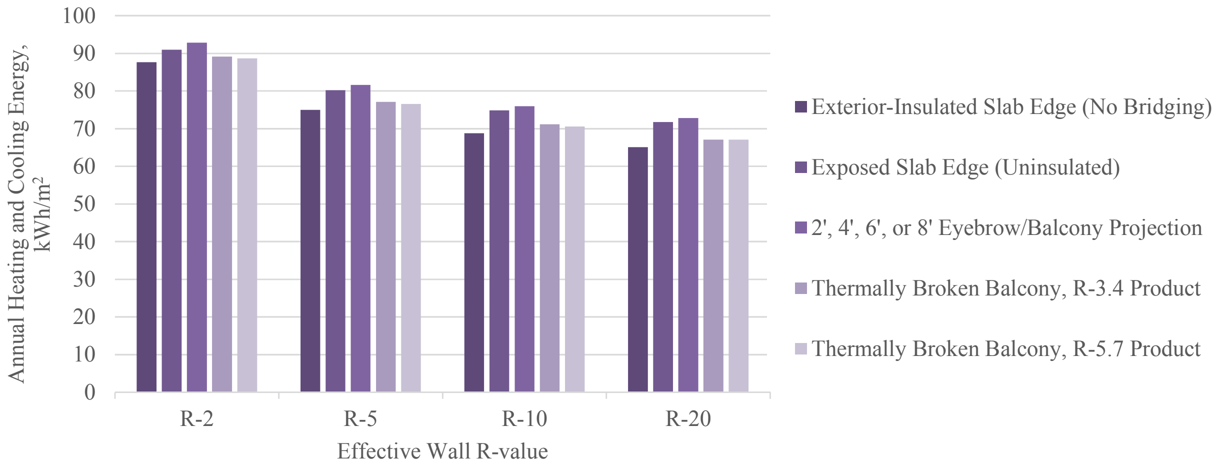


Figure 5 - Annual Energy Intensity of Slab Edge Configurations Modeled in Vancouver, kWh/m^2

Table 4 - Annual Energy Intensity of Slab Edge Configurations Modeled in Vancouver, kWh/m^2 and Percent Reduction from Insulated Case

	Insulation R-Value			
	R-2	**R-5**	**R-10**	**R-20**
Exterior-Insulated Slab Edge (No Bridging)	87.7	75	68.8	65.1
Exposed Slab Edge (Uninsulated)	91	80.2	74.9	71.8
Percent increase from insulated case	*-4%*	*-7%*	*-9%*	*-10%*
2', 4', 6', or 8' Eyebrow/Balcony Projection	92.8	81.6	76	72.8
Percent increase from insulated case	*-6%*	*-9%*	*-10%*	*-12%*
Thermally Broken Balcony, R-3.4 Product	89.1	77.1	71.2	67.1
Percent increase from insulated case	*-2%*	*-3%*	*-3%*	*-3%*
Thermally Broken Balcony, R-5.7 Product	88.70	76.6	70.6	67.1
Percent increase from insulated case	*-1%*	*-2%*	*-3%*	*-3%*

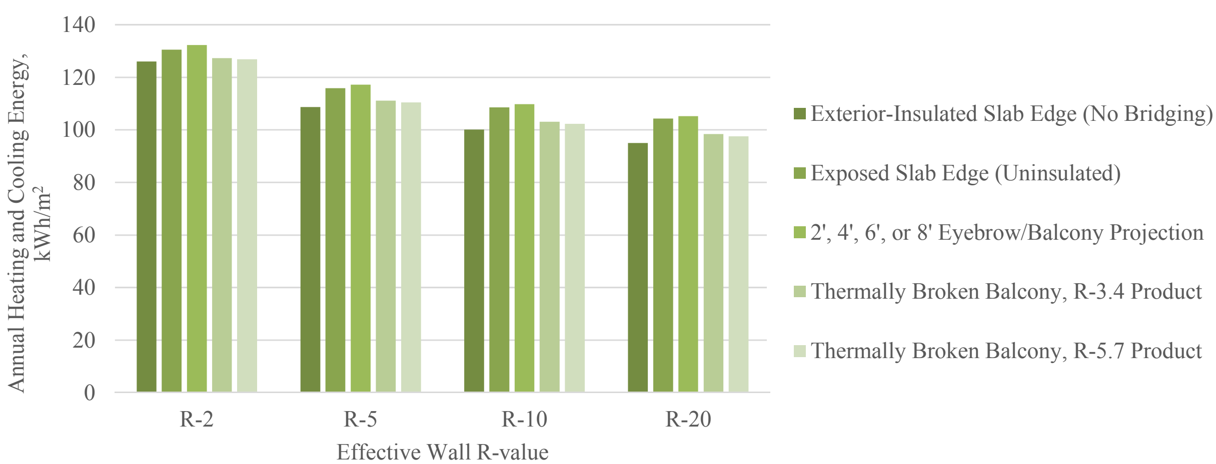


Figure 6 - Annual Energy Intensity of Slab Edge Configurations Modeled in Toronto, kWh/m^2

Table 5 - Annual Energy Intensity of Slab Edge Configurations Modeled in Toronto, kWh/m^2 and Percent Reduction from Insulated Case

	Insulation R-Value			
	R-2	**R-5**	**R-10**	**R-20**
Exterior-Insulated Slab Edge (No Bridging)	126.1	108.7	100.1	95.0
Exposed Slab Edge (Uninsulated)	130.5	115.9	108.6	104.3
Percent increase from insulated case	-3%	-7%	-8%	-10%
2', 4', 6', or 8' Eyebrow/Balcony Projection	132.3	117.2	109.8	105.3
Percent increase from insulated case	-5%	-8%	-10%	-11%
Thermally Broken Balcony, R-3.4 Product	127.3	111.2	103.1	98.4
Percent increase from insulated case	-1%	-2%	-3%	-4%
Thermally Broken Balcony, R-5.7 Product	126.9	110.5	102.3	97.5
Percent increase from insulated case	-1%	-2%	-2%	-3%

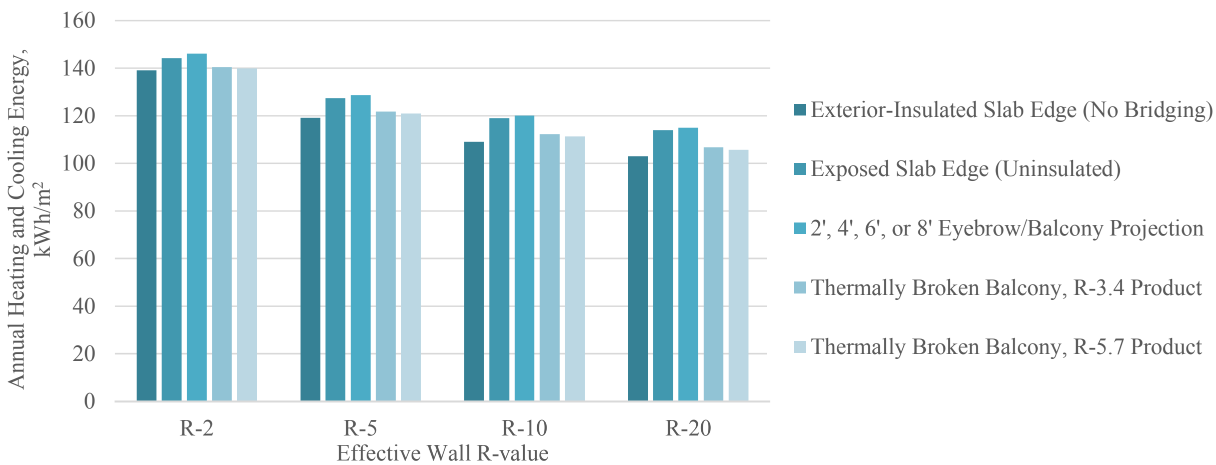


Figure 7 - Annual Energy Intensity of Slab Edge Configurations Modeled in Calgary, kWh/m^2

Table 6 - Annual Energy Intensity of Slab Edge Configurations Modeled in Calgary, kWh/m^2 and Percent Reduction from Insulated Case

	Insulation R-Value			
	R-2	**R-5**	**R-10**	**R-20**
Exterior-Insulated Slab Edge (No Bridging)	139.1	119.1	109.0	103.0
Exposed Slab Edge (Uninsulated)	144.2	127.4	119.0	114.0
Percent increase from insulated case	-4%	-7%	-9%	-11%
2', 4', 6', or 8' Eyebrow/Balcony Projection	146.1	128.7	120.1	114.9
Percent increase from insulated case	-5%	-8%	-10%	-12%
Thermally Broken Balcony, R-3.4 Product	140.4	121.7	112.3	106.7
Percent increase from insulated case	-1%	-2%	-3%	-4%
Thermally Broken Balcony, R-5.7 Product	139.9	120.9	111.4	105.7
Percent increase from insulated case	-1%	-2%	-2%	-3%

THERMAL COMFORT IMPACTS OF SLAB THERMAL BREAKS

The impact of balcony slab edge thermal breaks on thermal comfort was also assessed by thermal modeling to determine the interior floor and ceiling surface temperatures for each design scenario with and without a thermal break installed. For this analysis, a balcony penetrating the exterior wall was modeled for three wall types: an aluminum window wall system, an interior-insulated concrete wall, and an exterior-insulated concrete wall. Thermal modeling was performed using the program Heat3 (Blocon, 2013). The boundary conditions used for this analysis are at the 21°C at the interior and -10°C at the exterior, with standard floor, ceiling, and wall surface films.

Figure 8 shows the three wall assemblies modeled without (left) and with (right) a cast-in-place thermal break product (R-3.4 effective). The results show that the inclusion of a thermal break in these scenarios can significantly improve the indoor slab and wall/window frame surface temperatures. The amount of improvement depends on the wall assembly and details at the interface, though is in the range of 4°C to 7°C for the conditions modeled here. The improvements in surface temperature with a balcony thermal break reduce the potential for surface condensation and/or organic growth, and allow for a more comfortable indoor environment. There are certain details however, such as the window wall deflection head track as shown in Figure 8, that still bypass the thermal break and cannot be improved much by the incorporation of the slab thermal break. Improvements to this detail could be made by addressing the position of the deflection head (moving it inwards) or incorporating a more thermally efficient deflection header.

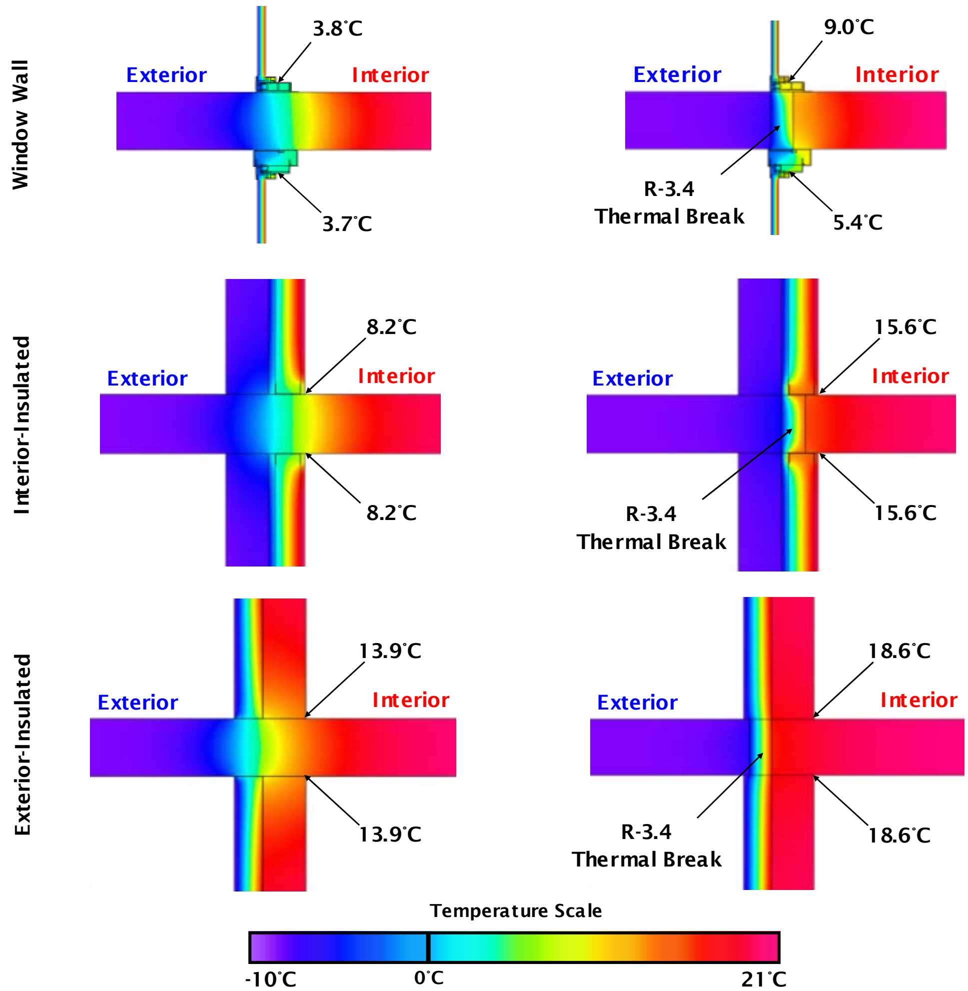


Figure 8 - Temperature Profiles and Minimum Surface Temperatures for Balcony Section With and Without Slab Thermal Breaks for Select Wall Assemblies.

CONCLUSIONS

Thermal bridging in building enclosure systems at slab edges can significantly reduce the effective R-value of wall assemblies. As the industry moves toward higher R-value assemblies to meet more stringent building codes, energy standards, and occupant expectations, it will be necessary to find solutions to reduce or eliminate thermal bridging, especially at exposed slab edges, balconies, and eyebrows. As shown here, thermal bridges caused by uninsulated concrete slab edges and balconies alone can reduce the effective R-value of full-height wall assemblies by over 60% and therefore have a profound impact on the performance of the building enclosure.

The use of cast-in-place concrete slab thermal break systems can significantly improve building enclosure thermal performance. Effective R-values of full-height wall assemblies can be improved significantly over non–thermally broken slabs. Typical interior-insulated wall assemblies can see overall effective R-value improvements of between 12% and 17%, and walls with additional interior continuous insulation can see between 47% and 95% improvement, depending on the wall insulation level and thermal break used. Exterior-insulated wall assemblies are shown to receive R-value improvements of between 26% and 32% for walls with continuous Z-girts and between 55% and 97% for walls with continuous exterior insulation. As discussed, the thermal improvement of wall assemblies using thermally broken slab edges compared to non–thermally broken slabs is more significant for walls with higher initial effective R-values, due to the increased heat loss through the slab edge. Interior surface temperatures during cold periods are also increased, which reduces the potential for condensation and organic growth and improves thermal comfort for building occupants. Where the exterior temperature is -10°C, interior surface temperatures are shown to be increased by up to 5.2°C for window wall assemblies, up to 7.4°C for interior-insulated wall assemblies, and up to 4.4°C for exterior-insulated wall assemblies.

Additionally, as reduction of balcony slab edge thermal bridging improves the effective R-value of the building enclosure, energy savings can be realized. Within all cases modeled, buildings using thermally broken slab edges see between 4% and 8% improvement in total heating and cooling energy, compared to buildings without thermally broken slab edges, which in many climate zones will provide payback within the typical expected life span of a concrete building.

Overall, balcony slab edge thermal break systems provide architectural freedom to designers while maintaining good thermal performance characteristics of a building to reduce building energy consumption, improve thermal comfort, and meet increasingly stringent energy code requirements. While these systems are currently uncommon in typical North American construction, as the industry develops, the incorporation of these systems into building design will likely become more common.

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REFERENCES

ASHRAE. 2010. "ASHRAE Standard 90.1-2010 Energy Standard for Buildings except Low-Rise Residential Buildings". Available at www.ashrae.org.

Blocon. 2014. HEAT 3 v.5 and v.6 Three-Dimensional Finite Element Thermal Modeling Software. Available at www.buildingphysics.com.

Ge, H., McClung, R., Zhang, S. 2013. Impact of Balcony Thermal Bridges on Overall Thermal Performance of Multi-Unit Residential Buildings: A Case Study. Energy and Buildings Volume 60, May 2013, Pages 163-173.

Lstiburek. J. 2008. Building Science Insights – BSI-005: A Bridge Too Far. Building Science Corporation Publication. Available at www.buildingscience.com

Lstiburek, J. 2012. Building Science Insights – BSI-062: Thermal Bridges Redux. Building Science Corporation Publication. Available at www.buildingscience.com.

National Energy Code of Canada for Buildings (NECB) 2011. Canadian Commission on Building and Fire Codes. National Research Council of Canada, Ottawa, Ontario.

RDH Building Engineering. 2012. Energy Consumption and Conservation in Mid- and High-Rise Residential Buildings. Available at www.rdhbe.com.

RDH Building Engineering. 2013. The Importance of Slab Edge and Balcony Thermal Bridges, Reports #1 through #4. Available at www.rdh.com.