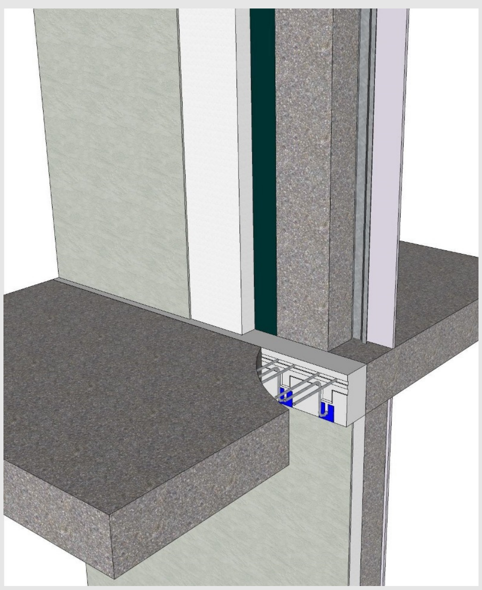
The Importance of Slab Edge & Balcony Thermal Bridges

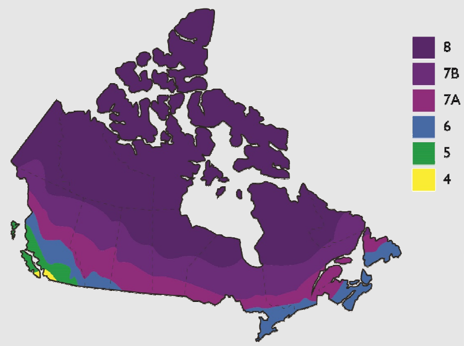
Report # 3: Energy Consumption and Cost Savings of Slab Thermal Breaks

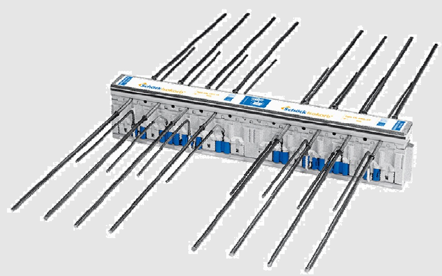
RDH

Making Buildings Better

rdhbe.com







Prepared by

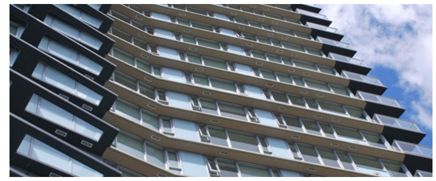
RDH Building Engineering Ltd.

Date

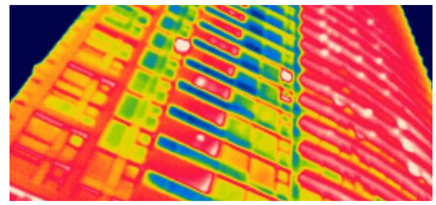
September 24, 2013

The Importance of Slab Edge & Balcony Thermal Bridges

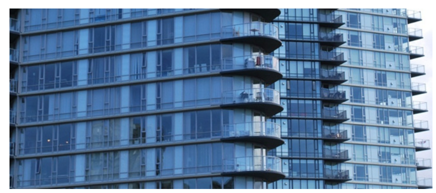
Report # 3 - Energy Consumption & Cost Savings of Slab Thermal Breaks



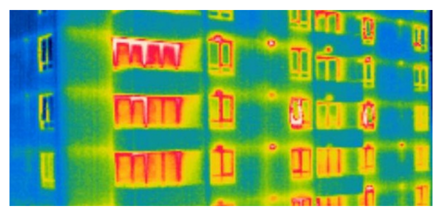
Thermal bridging occurs when heat flow bypasses the insulated elements of the building enclosure. Bridging occurs through structural components such as the studs/plates, framing, and cladding supports as well as the larger columns, shear walls, and exposed floor slab edges and protruding balconies. While thermal bridging occurs through the roofs, floors, and below-grade assemblies, it is often most pronounced in above-grade wall assemblies.



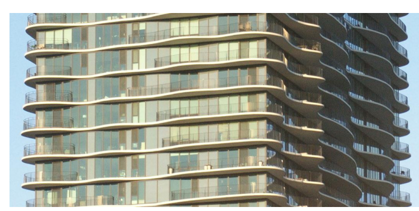
The heat flow through thermal bridges is significant and disproportionate to the overall enclosure area so that a seemingly well insulated building can often fail to meet energy code requirements, designer intent, or occupant expectations.



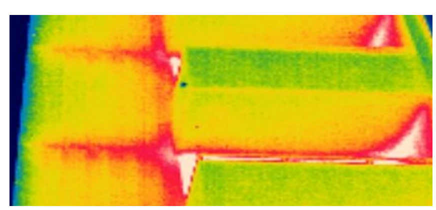
Windows are often seen as the largest thermal bridge in buildings, as the thermal performance is often quite low compared to the surrounding walls (i.e., an R-2 metal frame window within an R-20 insulated wall); however, exposed concrete slab edges and balconies can have almost as large of an influence having effective R-values of approximately R-1. After accounting for windows and doors, exposed concrete slab edges and balconies can account for the second greatest source of thermal bridging in a multi-storey building.



With a better understanding of the impacts of thermal bridging, the building industry has started to thermally improve 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. At the same time, the architectural look of exposed slab edges and protruding balconies or "eyebrow" elements is becoming more common. Many designers believe that these relatively small elements have a negligible impact on the overall performance of the building or see them as an unavoidable compromise to achieve a certain appearance. Unfortunately, the impact of exposed slab edges and balconies is very significant, as this report will demonstrate. The relative impact of these elements also increases as more highly insulated walls are required by upcoming building code changes or sustainable building programs.



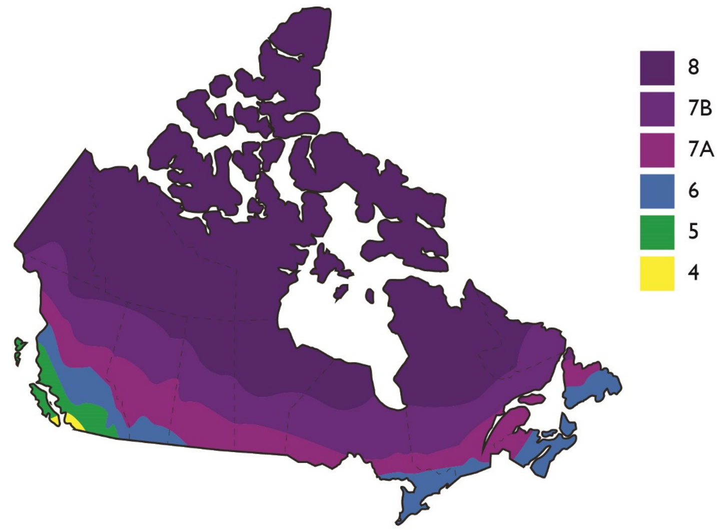
Fortunately, there are solutions available in the marketplace that help to minimize the thermal bridging impact at slab edges and balconies and allow for continued architectural design freedom under increasingly more stringent energy code requirements and occupant demands.

This research report addresses the thermal control, 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.

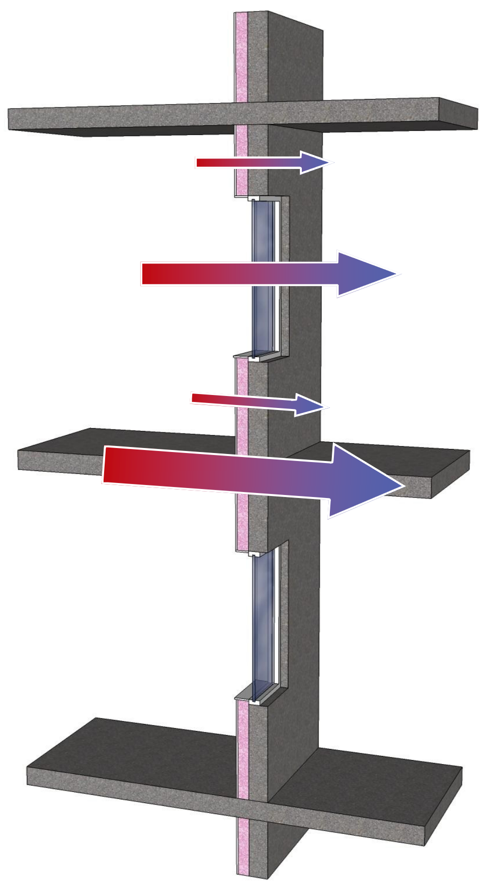
Exposed Slab Edge & Balcony Thermal Bridge Research Study

A research project was undertaken by RDH to quantify the thermal impact of exposed slab edges and balconies in mid- to high-rise residential buildings across climate zones in Canada.

The impact of exposed slab edges and balconies on the effective wall R-values, indoor temperatures, and indoor thermal comfort was assessed. Space heating and cooling loads were also modeled in each climate zone for an archetypal multi-unit residential building to quantify the energy loss through exposed slab edges and balconies and to determine the space conditioning savings that could be achieved in typical scenarios when balcony and slab edge thermal break products are used.



Canadian climate map showing Climate Zones 4 through 8 per the 2011 NECB. ASHRAE 90.1-2010 uses a similar climate zone map; however, Zone 4 is bumped into Zone 5 due to differences in reference climate data between NECB and ASHRAE.



Thermal bridging paths through the enclosure of a concrete multi-storey building with balconies

The study addresses the following topics:

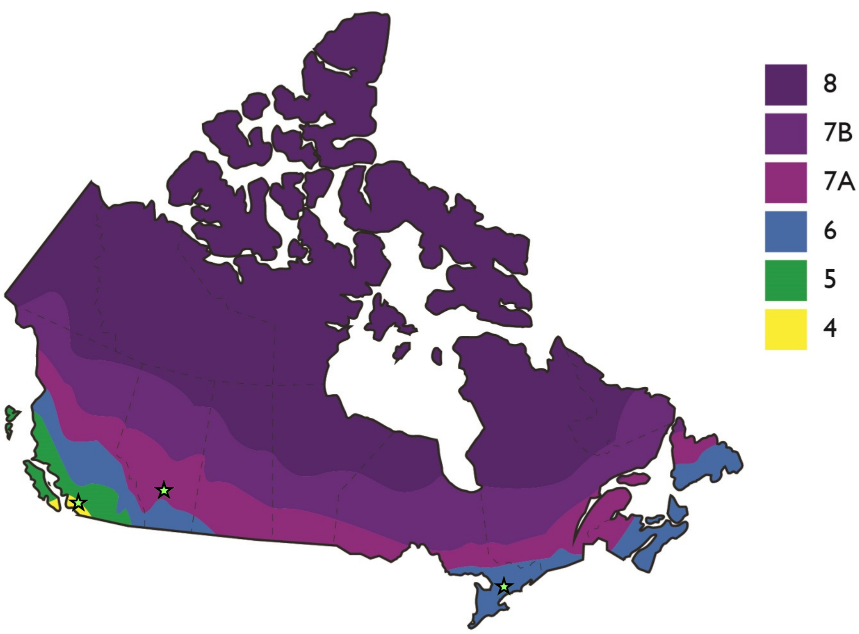
- Quantification of effective R-values, linear transmittance values (ψ), and indoor surface temperatures for various typical North American wall assemblies with and without exposed slab edges and balconies, and with various balcony thermal break solutions.
- Assessment of various thermal modeling parameters including floor finishes, in-slab heating and balcony depth.
- Comparison of the effective thermal performance of several alternate balcony thermal break solutions, insulation strategies, and manufactured thermal break products.
- Comparison of the space conditioning (heating and cooling) energy consumption for multi-unit residential buildings with exposed slab edges and balconies and with the various thermal break solutions.

This Report #3 of 4 specifically covers the impact of balcony and slab edge thermal break products on energy consumption and energy savings. Report #1 covers effective R-values and code compliance and Report #2 covers thermal comfort. Report #4 covers thermal modeling considerations and alternate systems.

Energy Consumption & Economic Impact of Exposed Slab Edges & Balconies

To determine the specific impact that exposed slab edges and balconies have on the energy consumption and operating cost of a building, the effective R-values for the various slab edge conditions were input into a whole-building energy model. Whole-building energy modeling was performed using DesignBuilder, which utilizes the EnergyPlus modeling engine. The use of this program has been validated by RDH against actual energy use within multi-unit residential buildings in North America.

For this report, a representative archetypical 20-storey 12,900 m^2 multi-unit residential building (MURB) containing 160 suites was built within the energy model and its energy consumption was simulated within selected Canadian cities. The building mechanical system consists of electric baseboard heating within the suites and a central pressurized corridor for suite ventilation, which is typical for most developer-constructed MURBs. Cooling is provided by a chiller with a COP of 2.8. Inputs for the building enclosure assemblies consist of ASHRAE 90.1-2010 prescriptive R-value minimums for the windows and roof. The wall effective R-values, as previously determined for different slab edge conditions, are the only variable in each case. For this set of results, the slab edge is assumed to be exposed along the entire perimeter (a common design in many newer MURBs). Results would vary, though not linearly, for less-exposed slab areas.



Canadian climate map showing Climate Zones 4 through 8 per the 2011 NECB. ASHRAE 90.1-2010 uses a similar climate zone map; however, Zone 4 is bumped into Zone 5 due to differences in reference climate data between NECB and ASHRAE.

The results of energy modeling for the archetypal MURB in three Canadian cities (Vancouver, Toronto, and Calgary) representing climate zones 4/5, 6, and 7 respectively are provided in the following tables. For each slab edge detail the total building space conditioning (heating and cooling) energy consumption (kWh/m^2/yr) and cost (\$/m^2/yr) is provided. In addition, the percent increase in space conditioning energy as a result of the detail as compared to a fully insulated case is provided.

Energy Consumption & Economic Impact of Exposed Slab Edges & Balconies

Vancouver, Climate Zone 5 (Zone 4 NECB)

20-Storey MURB in Vancouver, 9 ¢/kWh	Annual Space Conditioning Energy Consumption (kWh/m^2, \$/m^2) & Percent Increase in Energy Consumption over Exterior Insulated Wall (%)			
Wall R-Value / Slab Detail	R-2 Wall	R-5 Wall	R-10 Wall	R-20 Wall
Exterior-Insulated Slab Edge	87.7 kWh/m^2, \$7.70/m^2	75.0 kWh/m^2, \$6.59/m^2	68.8 kWh/m^2, \$6.04/m^2	65.1 kWh/m^2, \$5.72/m^2
	-	-	-	-
Exposed Slab Edge	91.0 kWh/m^2, \$7.95/m^2	80.2 kWh/m^2, \$7.04/m^2	74.9 kWh/m^2, \$6.58/m^2	71.8 kWh/m^2, \$6.31/m^2
	4% increase	7% increase	9% increase	10% increase
Eyebrow or Balcony Projection	92.8 kWh/m^2, \$8.15/m^2	81.6 kWh/m^2, \$7.16/m^2	76.0 kWh/m^2, \$6.68/m^2	72.8 kWh/m^2, \$6.39/m^2
	6% increase	9% increase	11% increase	12% increase

Toronto, Climate Zone 6

20-Storey MURB in Toronto, 14 ¢/kWh	Annual Space Conditioning Energy Consumption (kWh/m^2, \$/m^2) & Percent Increase in Energy Consumption over Exterior Insulated Wall (%)			
Wall R-Value / Slab Detail	R-2 Wall	R-5 Wall	R-10 Wall	R-20 Wall
Exterior-Insulated Slab Edge	126.1 kWh/m^2, \$16.64/m^2	108.7 kWh/m^2, \$14.75/m^2	100.1 kWh/m^2, \$13.58/m^2	95.0 kWh/m^2, \$12.89/m^2
	-	-	-	-
Exposed Slab Edge	130.5 kWh/m^2, \$17.70m^2	115.9 kWh/m^2, \$15.72/m^2	108.6 kWh/m^2, \$14.73/m^2	104.3 kWh/m^2, \$14.15/m^2
	3% increase	7% increase	8% increase	10% increase
Eyebrow or Balcony Projection	132.3 kWh/m^2, \$17.96/m^2	117.2 kWh/m^2, \$15.91/m^2	109.8 kWh/m^2, \$14.89/m^2	105.3 kWh/m^2, \$14.29/m^2
	5% increase	8% increase	10% increase	11% increase

Calgary, Climate Zone 7

20-Storey MURB in Calgary, Heat 14 ¢/kWh	Annual Space Conditioning Energy Consumption (kWh/m^2, \$/m^2) & Percent Increase in Energy Consumption over Exterior Insulated Wall (%)			
Wall R-Value / Slab Detail	R-2 Wall	R-5 Wall	R-10 Wall	R-20 Wall
Exterior-Insulated Slab Edge	139.1 kWh/m^2, \$19.32/m^2	119.1 kWh/m^2, \$16.54/m^2	109.0 kWh/m^2, \$15.14/m^2	103.0 kWh/m^2, \$14.30/m^2
	-	-	-	-
Exposed Slab Edge	144.2 kWh/m^2, \$20.03/m^2	127.4 kWh/m^2, \$17.69/m^2	119.0 kWh/m^2, \$16.52/m^2	114.0 kWh/m^2, \$15.83/m^2
	4% increase	7% increase	9% increase	11% increase
Eyebrow or Balcony Projection	146.1 kWh/m^2, \$20.29/m^2	128.7 kWh/m^2, \$17.88/m^2	120.1 kWh/m^2, \$16.67/m^2	114.9 kWh/m^2, \$15.95/m^2
	5% increase	8% increase	10% increase	12% increase

Energy Consumption & the Economic Impact of Balcony Thermal Breaks

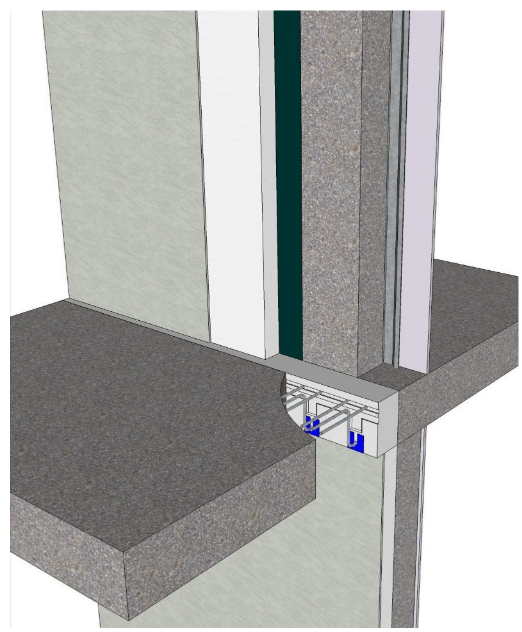
The energy consumption and space heating cost savings resulting from the integration of balcony thermal breaks is determined using whole-building energy modeling.

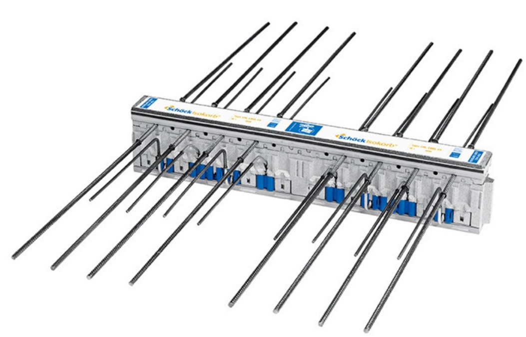
Similar to the previous analysis, a representative archetypical 20-storey 12,900 m^2 multi-unit residential building (MURB) containing 160 suites was built within the energy model and its energy consumption was simulated for Vancouver, Calgary and Toronto. The building mechanical system consists of electric baseboard heating within the suites and a central pressurized corridor for suite ventilation, which is typical for most developer-constructed MURBs. Cooling is provided by a chiller with a COP of 2.8.

Inputs for the building enclosure assemblies consist of ASHRAE 90.1-2010 prescriptive R-value minimums for the windows and roof. The wall effective R-values, as previously determined for thermally and non-thermally broken balconies, are the only variable in each case. To provide a range of potential energy savings, an R-3.4 and R-5.7 Schoeck Isokorb® thermal break were modeled compared to a non-thermally broken case. This provides a range in potential performance from this type of thermal break approach.

For this first analysis, the slab edge is assumed to be exposed along the entire perimeter of the building at each floor level. This is common in many MURB designs and is also representative of an interior-insulated building where the slab edge is uninsulated.

The results of energy modeling for the MURB in three Canadian cities (Vancouver, Toronto, and Calgary) representing climate zones 4/5, 6, and 7 respectively are summarized within the following tables. For each slab edge detail, the total building space conditioning (heating and cooling) energy consumption (kWh/m^2/yr) and cost ($/$m^2$/yr) is provided. In addition, the percent savings in space conditioning energy as a result of the thermal break as compared to a non-thermally broken (typical) detail is shown.





Energy Consumption Impact of Balcony Thermal Breaks

Vancouver, Climate Zone 5 (Zone 4 NECB)

20-storey MURB in Vancouver, 9 ¢/kWh	Annual Space Conditioning Energy Consumption (kWh/m², $/m²) & Percent Savings in Energy Consumption over Non-Thermally Broken Balcony (%)			
Slab Detail / Wall R-Value	R-2 Wall	R-5 Wall	R-10 Wall	R-20 Wall
Non thermally Broken 6' deep balcony	92.8 kWh/m², $8.15/m²	81.6 kWh/m², $7.16/m²	76.0 kWh/m², $6.68/m²	72.8 kWh/m², $6.39/m²
	-	-	-	-
Thermally Broken 6' Balcony, R-3.4 Isokorb	89.1 kWh/m², $7.82/m²	77.1 kWh/m², $6.77/m²	71.2 kWh/m², $6.25/m²	67.7 kWh/m², $5.94/m²
	4% savings	5% savings	6% savings	7% savings
Thermally Broken 6' Balcony, R-5.7 Isokorb	88.7 kWh/m², $7.79/m²	76.6 kWh/m², $6.72/m²	70.6 kWh/m², $6.20/m²	67.1 kWh/m², $5.89/m²
	4% savings	6% savings	7% savings	8% savings

Toronto, Climate Zone 6

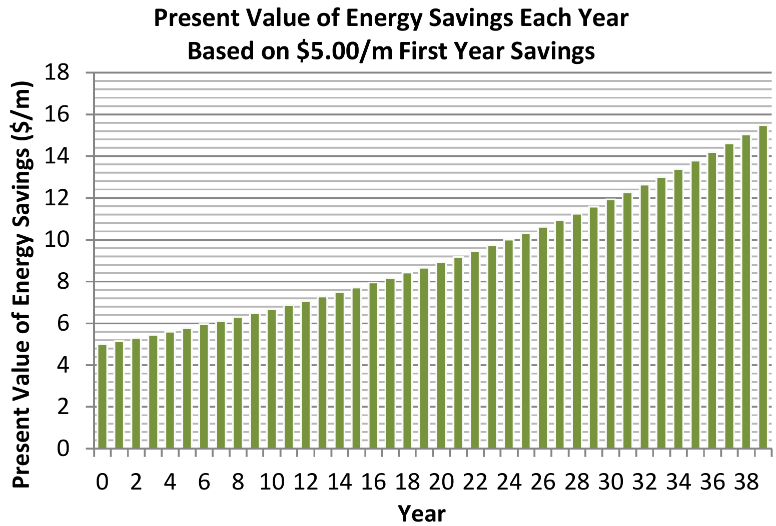
20-storey MURB in Toronto, 14 ¢/kWh	Annual Space Conditioning Energy Consumption (kWh/m², $/m²) & Percent Savings in Energy Consumption over Non-Thermally Broken Balcony (%)			
Slab Detail / Wall R-Value	R-2 Wall	R-5 Wall	R-10 Wall	R-20 Wall
Non-Thermally Broken 6' Deep Balcony	132.3 kWh/m², $17.96/m²	117.2 kWh/m², $15.91/m²	109.8 kWh/m², $14.89/m²	105.3 kWh/m², $14.29/m²
	-	-	-	-
Thermally Broken 6' Balcony, R-3.4 Isokorb	127.3 kWh/m², $17.28m²	111.2 kWh/m², $15.08/m²	103.1 kWh/m², $14.00/m²	98.4 kWh/m², $13.35/m²
	4% savings	5% savings	6% savings	7% savings
Thermally Broken 6' Balcony, R-5.7 Isokorb	126.9 kWh/m², $17.21/m²	110.5 kWh/m², $14.99/m²	102.3 kWh/m², $13.89/m²	97.53 kWh/m², $13.24/m²
	4% savings	6% savings	7% savings	7% savings

Calgary, Climate Zone 7

20-Storey MURB in Calgary, Heat 14 ¢/kWh	Annual Space Conditioning Energy Consumption (kWh/m², $/m²) & Percent Savings in Energy Consumption over Non-Thermally Broken Balcony (%)			
Slab Detail / Wall R-Value	R-2 Wall	R-5 Wall	R-10 Wall	R-20 Wall
Non-Thermally Broken 6' Deep Balcony	146.1 kWh/m², $20.29/m²	128.7 kWh/m², $17.88/m²	120.1 kWh/m², $16.67/m²	114.9 kWh/m², $15.95/m²
	-	-	-	-
Thermally Broken 6' Balcony, R-3.4 Isokorb	140.4 kWh/m², $19.50/m²	121.7 kWh/m², $16.90/m²	112.3 kWh/m², $15.60/m²	106.7 kWh/m², $14.82/m²
	4% savings	5% savings	6% savings	7% savings
Thermally Broken 6' Balcony, R-5.7 Isokorb	139.9 kWh/m², $19.43/m²	120.9 kWh/m², $16.79/m²	111.4 kWh/m², $15.47/m²	105.7 kWh/m², $14.68/m²
	4% savings	6% savings	7% savings	8% savings

Energy Cost Payback of Balcony Thermal Breaks

To evaluate the economic feasibility of using a slab edge or balcony thermal break, the energy savings per meter length of slab edge or balcony were determined. The current costs per meter length of slab edge thermal breaks in Canada with R-values of R-3.4 (3.25") and R-5.7 (5") are $217/m and $259/m respectively.



The tables below provide the value of energy savings per meter of slab edge or balcony length in the first year of building operation based on energy modeling of the archetypal MURB, the estimated discounted payback period, and the net present vale of the energy saving per meter in a 40 year period. These calculations assume that energy costs will increase at a rate of 5% per year and that inflation will be 2% per year.

Typically, the estimated payback period in colder climate zones indicates reasonable economic justification for use of a slab edge thermal break. As costs of the thermal breaks gradually decrease, the economic argument for their use will become more reasonable for warmer climate zones as well.

Vancouver, Climate Zone 5 (Zone 4 NECB)

20-Storey MURB in Vancouver 9 ¢/kWh	Space Heat Savings for Balcony/Slab Edge Thermal Break ($/m slab edge/year) & Discounted Payback Period (5% fuel escalation, 2% inflation), (# of years) & Savings in 40 years ($ in 40 years)			
Thermal Break\Wall R-Value	R-2 Wall	R-5 Wall	R-10 Wall	R-20 Wall
Thermally Broken 6' Balcony, R-3.4 Isokorb	$2.06/m savings 49 yrs ($153 in 40 yrs)	$2.48/m savings 44 yrs ($184 in 40 yrs)	$2.69/m savings 42 yrs ($200 in 40 yrs)	$2.84/m savings 41 yrs ($211 in 40 yrs)
Thermally Broken 6' Balcony, R-5.7 Isokorb	$2.25/m savings 52 yrs ($167 in 40 yrs)	$2.76/m savings 46 yrs ($206 in 40 yrs)	$3.02/m savings 44 yrs ($224 in 40 yrs)	$3.17/m savings 43 yrs ($236 in 40 yrs)

Toronto, Climate Zone 6

20-Storey MURB in Toronto 14 ¢/kWh	Space Heat Savings for Balcony/Slab Edge Thermal Break ($/m slab edge/year) & Discounted Payback Period (5% fuel escalation, 2% inflation), (# of years) & Savings in 40 years ($ in 40 years)			
Thermal Break\Wall R-Value	R-2 Wall	R-5 Wall	R-10 Wall	R-20 Wall
Thermally Broken 6' Balcony, R-3.4 Isokorb	$4.29/m savings 32 yrs ($319 in 40 yrs)	$5.19/m savings 28 yrs ($386 in 40 yrs)	$5.65/m savings 27 yrs ($421 in 40 yrs)	$5.95/m savings 26 yrs ($443 in 40 yrs)
Thermally Broken 6' Balcony, R-5.7 Isokorb	$4.68/m savings 34 yrs ($348 in 40 yrs)	$5.79/m savings 29 yrs ($431 in 40 yrs)	$6.34/m savings 28 yrs ($472 in 40 yrs)	$6.66/m savings 27 yrs ($495 in 40 yrs)

Calgary, Climate Zone 7

20-Storey MURB in Calgary 14 ¢/kWh	Space Heat Savings for Balcony/Slab Edge Thermal Break ($/m slab edge/year) & Discounted Payback Period (5% fuel escalation, 2% inflation), (# of years) & Savings in 40 years ($ in 40 years)			
Thermal Break\Wall R-Value	R-2 Wall	R-5 Wall	R-10 Wall	R-20 Wall
Thermally Broken 6' Balcony, R-3.4 Isokorb	$5.01/m savings 29 yrs ($373 in 40 yrs)	$6.17/m savings 25 yrs ($459 in 40 yrs)	$6.78/m savings 23 yrs ($504 in 40 yrs)	$7.17/m savings 22 yrs ($533 in 40 yrs)
Thermally Broken 6' Balcony, R-5.7 Isokorb	$5.45/m savings 31 yrs ($406 in 40 yrs)	$6.89/m savings 26 yrs ($513 in 40 yrs)	$7.60/m savings 24 yrs ($566 in 40 yrs)	$8.02/m savings 24 yrs ($597 in 40 yrs)

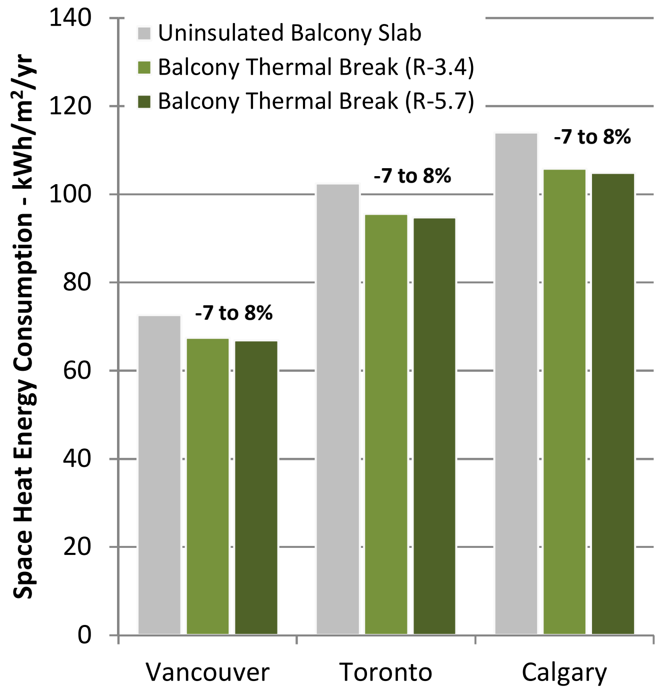
Conclusions

Thermal bridging in building enclosure systems often significantly reduces 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, the reduction of this thermal bridging will be necessary. In many buildings, exposed slab edges, balconies, and eyebrows are some of the most significant thermal bridging elements.

Use of these thermal break systems can significantly improve building enclosure thermal performance. The interior surface temperatures during winter conditions are increased, which reduces the potential for condensation and organic growth, and improves thermal comfort for building occupants. Additionally, as reduction of balcony slab edge thermal bridging improves the effective R-value of the building enclosure, energy savings can be realized, which in many climate zones will provide payback within the typical expected lifespan of a concrete building.

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

Space Heat Energy Savings from Balcony Thermal Breaks



Appendix: Additional Modeling Results

Impact of Exposed Slab Edges & Balconies on High-Performance Enclosures

In buildings where the high-performance, thermally efficient windows have been installed in combination with a relatively high R-value wall assembly, exposed slab edges and balconies are often the primary thermal bridge in the building enclosure system. Thus, once thermally efficient windows have been selected, slab edge and balcony thermal detailing becomes the priority enclosure element with respect to overall effective R-value of the building enclosure and building energy consumption. The following table shows results from modeling using the same archetypal MURB as in previous modeling, except with R-6 windows and R-20 walls to show the energy savings attributable to the use of slab edge thermal breaks in this type of design. The modeling was conducted for Toronto, which is in Climate Zone 6.

Toronto, Climate Zone 6

20-Storey MURB in Toronto 14 ¢/kWh R-6 Windows & R-20 Walls	Annual Space Conditioning Energy Consumption (kWh/m², $/m²) & Savings in Energy Consumption over Non-Thermally Broken Balcony (%, $/m slab edge)
Non-Thermally Broken 6' Deep Balcony	83.9 kWh/m², $11.39/m²
	-
Thermally Broken 6' Balcony R-3.4 Isokorb	77.4 kWh/m², $10.51/m²
	8% savings, $5.53/m
Thermally Broken 6' Balcony R-5.7 Isokorb	76.7 kWh/m², $10.40/m²
	9% savings, $6.18/m