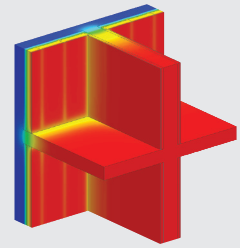

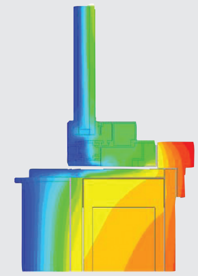

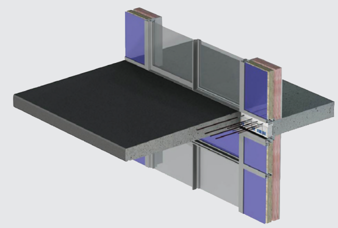

Building Envelope Thermal Bridging Guide

ANALYSIS, APPLICATIONS & INSIGHTS

BC hydro powersmart
Homeowner Protection Office Branch of BC Housing
Canadian Wood Council / Conseil canadien du bois
FORTIS BC
FPInnovations
Morrison Hershfield

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DISCLAIMER

This publication is provided to inform the practice of applying the Building Envelope Thermal Analysis (BETA) methodology for determining the effective thermal performance of building envelope assembly and interface details, as well as to guide BETA's application in overall building design. The greatest care has been taken to confirm the accuracy of the information contained herein. However, the authors, co-sponsors, industry advisors, industry partners and other contributors assume no liability for any damage, injury, loss or expense that may be incurred or suffered as result of the use of this publication, building envelope design methodology or energy modeling practices. The views expressed herein do not necessarily represent those of any individual contributor. Nothing in this publication is an endorsement of any proprietary building envelope system or particular assembly product.

In addition to using this publication, readers are encouraged to consult applicable up-to-date technical publications on building envelope science, practices and products. Retain consultants with appropriate architectural and/ or engineering qualifications and speak with appropriate municipal and other authorities with respect to issues of envelope design, assembly fabrication and construction practices. It is also advisable to seek specific information on the use of envelope-related products and consult the instructions of envelope assembly manufacturers. Always review and comply with the specific requirements of the applicable building codes for any construction project.

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Table of Contents

INTRODUCTION

In British Columbia, a large percentage of electricity and natural gas is consumed in commercial, institutional, and residential buildings. Improved energy conservation in buildings has long been recognized as an important approach to reduce energy consumption and greenhouse gas emissions in BC. Government and utilities have a mandate to encourage energy conversation in buildings and BC jurisdictions have been adopting increasingly more stringent building energy efficiency standards. Space conditioning, primarily heating, is one of the largest components of energy use in commercial, institutional, and residential buildings in BC. Building envelope thermal performance is a critical consideration for reducing space heating loads and will be an increasingly important factor as authorities strive for lower energy consumption in buildings.

It has become more and more evident that the thermal performance of the building envelope can be greatly affected by thermal bridging. Thermal bridges are localized areas of high heat flow through walls, roofs and other insulated building envelope components. Thermal bridging is caused by highly conductive elements that penetrate the thermal insulation and/or misaligned planes of thermal insulation. These paths allow heat flow to bypass the insulating layer, and reduce the effectiveness of the insulation.

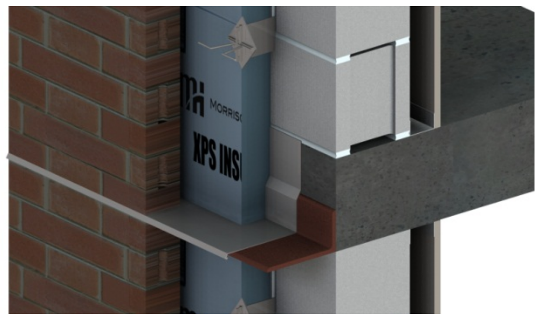

Figure 1: Thermal Bridging due to a Shelf Angle that supports Brick Veneer

Research and monitoring of buildings is increasingly showing the importance of reducing thermal bridging in new construction and mitigating the impact in existing buildings. The impact can be significant to whole building energy use, the risk of condensation on cold surfaces, and occupant comfort. The traditional approach of building codes to reducing space heating loads in buildings was to introduce progressively higher levels of thermal insulation and more stringent glazing performance requirements. This was a logical approach in the past because standard practice was to largely overlook thermally bridging. The effects of thermal bridging were assumed to be negligible if the cross-sectional areas of these conductive components were small, relative to the rest of the building envelope or they were purposely ignored due to the difficulty in assessing the impact. However, the additional heat flow due to major thermal bridges, including ones with small cross sectional areas such as shelf angles or flashing around windows, can add up to be a significant portion of the heat flow through opaque envelope assemblies. For example, the contribution of details that are typically disregarded can result in the underestimation of 20% to 70% of the total heat flow through walls. If major thermal bridges are not addressed then adding insulation to the assemblies may not provide significant benefits in reducing the overall heat flow because heat will flow through the path of least resistance. The cost of adding extra insulation, not just additional materials but also potentially reduced useable floor space, is not justified if no substantial energy savings are realized in practice.

Energy standards and codes in BC jurisdictions (BCBC, VBBL, ASHRAE 90.1and NECB) do not currently effectively address, or explicitly allow designers to ignore, major thermal bridges such as slab edges, shelf angles, parapets, window perimeters, etc. These codes and standards have steadily increased their insulation requirements but the development and implementation of procedures to effectively address thermal bridging in these codes has been slow. Some reasons for the slow response include: absence of data, the complexity of some prevailing procedures to account for thermal bridging, and a lack of clear information demonstrating that thermal bridging needs to be more thoroughly addressed. Moreover, reaching agreement for how to implement significant changes to codes and standards can be challenging for committees comprised of a wide range of interests, backgrounds and perspectives.

With this context in mind, this guide explores how the building industry in BC can realistically meet the challenges of reducing energy use in buildings, in part by effectively accounting for the impact of thermal bridging. The goal of the co-sponsors of this guide is to help transform the BC construction sector to realize more energy efficient buildings. To help meet this goal, the primary objective of this guide is to address the obstacles currently confronting our industry, with regard to thermal bridging, by:

1. Providing a catalogue of the thermal performance of common envelope assemblies and interface details directly relevant to construction in BC.
2. Providing information that makes it easier for industry to comprehensively consider thermal bridging in building codes and bylaws, design, and whole building energy simulations.
3. Examining the costs associated with improving the thermal performance of opaque building envelope assemblies and interface details, and forecasting the energy impact for several building types and BC climates.
4. Evaluating the cost effectiveness of improving the building envelope through more thermally efficient assemblies, interface details, and increasing insulation levels.

Scope

It is important to recognize that this guide is deliberately narrow in scope. The focus is on the thermal performance of the opaque building envelope. A wide range of opaque assemblies were evaluated in preparation of this guide; however, the thermal performance of the opaque building envelope is only one of many considerations for reducing energy use in buildings and its relative impact changes as other building energy uses are reduced. The building archetypes selected for the whole building energy analysis in this guide were chosen to cover the typical energy end use distributions in the current BC building market, with performance characteristics based on current market practice.

Audience

The target audiences for this guide are broad: committees for energy standards, policy and government, utilities, architects, mechanical designers, building envelope consultants, energy modellers, developers and contractors, manufacturers and trade organizations. Not all the information contained in the guide will be of direct interest to all these industry stakeholders. To provide easy access to information, the guide is broken up into three stand-alone main sections:

- **Part 1:** Building Envelope Thermal Analysis (BETA) Guide
- **Part 2**: Energy Savings and Cost Benefit Analysis
- **Part 3**: Significance, Insights and Next Steps

Each section begins with an overview, highlighting important information for the various target audiences, a summary of analysis completed in preparation of each section and a discussion of how to use the information in practice.

Glossary Of Terms

Term	Symbol	Units Imperial	Units SI	Description
Conductivity	K	$\frac{(BTU\ in)}{(hr\ ft^2\ {}^oF)}$	$\frac{W}{(m\,{}^oK)}$	The ability of a material to transmit heat in terms of energy per unit area per unit thickness for each degree of temperature difference.
Equivalent Conductivity	K_{eq}	$\frac{(BTU\ in)}{(hr\ ft^2\ {}^oF)}$	$\frac{W}{(m\,{}^oK)}$	The averaged or equivalent thermal conductivity of a component consisting of several building materials, effectively treating the component as a homogeneous material that provides the same thermal characteristics.
Heat Flow	Q	BTU/hr	W	The amount of energy per unit time that passes through an assembly under a specific temperature drive of ΔT.
Thermal Transmission Coefficient	U	$\frac{(BTU)}{(hr\ ft^2\ {}^oF)}$	$\frac{W}{(m^2\,{}^oK)}$	Heat flow per unit time through a unit area of an assembly per temperature degree difference. The convention is to include the impact of air films
Thermal Resistance of a Material	R	$\frac{(hr\ ft^2\ {}^oF)}{(BTU)}$	$\frac{(m^2\,{}^oK)}{W}$	A measure of a material's resistance to heat flow.
Effective Thermal Resistance	R_{eff}	$\frac{(hr\ ft^2\ {}^oF)}{(BTU)}$	$\frac{(m^2\,{}^oK)}{W}$	A measure of an assembly's resistance to heat flow, including the effects of thermal bridging. The inverse of the assembly U-value.
Clear field Assembly Thermal Transmittance	U_0	$\frac{(BTU)}{(hr\ ft^2\ {}^oF)}$	$\frac{W}{(m^2\,{}^oK)}$	Heat flow coefficient for an assembly with uniformly distributed thermal bridges, which are not practical to account for on an individual basis for U-value calculations. Examples of thermal bridging included in U_o are brick ties, girts supporting cladding, and structural studs.
Linear Heat Transmittance Coefficient	Ψ	$\frac{(BTU)}{(hr\ ft\ {}^oF)}$	$\frac{W}{(m\,{}^oK)}$	Heat flow coefficient representing the added heat flow associated with linear thermal bridges that are not included in the clear field U_o. Linear thermal bridges typically occur at interface details. Examples are shelf angles, slab edges, balconies, corner framing, parapets, and window interfaces.
Point Heat Transmittance Coefficient	χ	$\frac{(BTU)}{(hr\ {}^oF)}$	$\frac{W}{({}^oK)}$	Heat flow coefficient representing the added heat flow associated with a point thermal bridge that is not included in the clear field U_o. Point thermal bridges are countable points and are considered feasible to account for on an individual basis for U-value calculations. An example is a structural beam penetration through insulation.
Length of a Linear Transmittance	L	ft	m	The length of a linear thermal bridge, i.e. height of a corner or width of a slab.

Term	Description
Air Films	An approximation of the combined radiative and conductive-convective heat exchange at air boundary surfaces.
Area of Influence	The area that heat flow through an assembly is affected by a thermal bridge by lateral heat flows.
Area Weighted Method	The method by which an average U-value is determined by summing the Area multiplied by U-Value of each component and then dividing by total Area. This method assumes parallel heat flow paths.
At-Grade Interface Detail	An interface detail at the transition between the above-grade wall assembly intersections with either an at-grade floor slab or below grade assemblies.
Building Elevation	A view of a building seen from one side, a flat representation of one façade. Elevations drawings typically show views of the exterior of a building by orientation (North, East, South or West).
Building Envelope	The elements of a building that separate the conditioned space from unconditioned space of a building. This includes walls, roofs, windows and doors.
Clear Field Assembly	Wall, floor and roof assemblies of a building. (see definition of U_0 above).
Corner Interface Detail	Where walls meet at a corner of the building. Interface details can have additional heat flow than compared to the clear field assembly because of additional framing and related to the geometry (increased exterior surface area).
Curtain Wall	A non-load bearing building façade that sits outboard of the main building structure made up of metal framing, vision glass and spandrel sections. The curtain wall only carries its own dead-load and lateral loads (wind).
Dynamic Thermal Response	The time variant heat flows through the building envelope that result in delayed heat gain or loss depending on the amount of energy that is stored within the building envelope. The amount of energy that is stored within the building envelope at any given time is related to the mass of all the combined components of the building envelope (thermal mass).
Eyebrow	An architectural feature where the floor slab projects beyond the walls. Eyebrows often provide overhead protection from rain for fenestration and are similar in construction to a balcony.
Fenestration	All areas (including the frames) in the building envelope that let in light, including windows, plastic panels, clerestories, skylights, doors that are more than one-half glass, and glass block walls.
Firestop	A fire protection system made of various components used to seal openings and joints in fire-resistance rated wall and floor assemblies.
Floor Space Ratio	Ratio of gross floor area of a building to the area of land on which it is built.
Glazing	See definition of fenestration. Examples of glazing are windows, window-wall, and curtain-wall.
Glazing Interface Detail	Linear thermal bridges that occur at the intersection of glazing and opaque assemblies.

Term	Description
Insulating Glass Unit (IGU)	Double or triple glass planes separated by air or other gas filled space. The space between the panes is glass is created by a physical spacer that is also adhered to the glass. Sealant is provided at the perimeter of the unit as a gas and moisture barrier.
Interface Details	Thermal bridging related to the details at the intersection of building envelope assemblies and/or structural components. Interface details interrupt the uniformity of a clear field assembly and the additional heat loss associated with interface details is accounted for by linear and point thermal transmittances.
Lateral Heat Flow	Heat flow in multiple directions through an assembly as a result of conductive components bypassing the thermal insulation in multiple dimensions.
Linear Thermal Bridge	An interface detail that can be defined by a linear length along a plane of the building envelope.
MURB	Multi-unit residential building.
Opaque Assembly	All areas in the building envelope, except fenestration and building services openings such as vents and grilles.
Parallel Path	The assumption that the heat flow paths through an assembly are perpendicular to the plane of the assembly and there is no lateral heat flow.
Parapet	An interface detail that joins the walls to the roof.
Point Thermal Bridge	Points of heat loss that are considered feasible to account for on an individual basis for U-value calculations. An example is a structural beam penetrations through insulation.
Poured-in-Place Concrete Wall	An architectural exposed concrete wall that is formed at the location of installation and is part of the building structural support.
Precast Concrete Wall	An architectural concrete cladding that is formed off site and shipped to the location of installation.
Plane of Heat Transfer	The theoretical projected area between the interior and exterior environment where the net heat flow through the building envelope is calculated.
Plug Loads	Any system that draws electrical power through the building, but is not explicitly used to operate the building. This includes appliances, computers and other items that are dependent on the occupants use.
Setpoint Temperature	The desired operating temperature that a heating system works to maintain, ie: the interior space temperature set by a thermostat.
Shelf Angle	A structural support that transfers the dead load of brick veneer to the building structure at the floor slab.
Floor Slab	A concrete floor that partially or fully penetrates the building envelope at the exterior.
Slab Bypass	A portion of window-wall that covers the floor slab edge to give the appearance of uninterrupted glazing across the entire façade of a building.
Spandrel Section	An opaque section of curtain wall or window wall with insulation between the system framing.

Term	Description
Stick Built Curtain Wall	A site installed and glazed curtain-wall system that is assembled by running long pieces of framing between floors vertically and between vertical members horizontally.
Structural Beam	A steel beam that penetrates through the building envelope to support an exterior element, such as a canopy.
Quantity Takeoff	A quantity measurement that determines the areas and lengths needed for U-value calculations. The quantities are determined using architectural drawings.
Thermal Break	A non-conductive material that interrupts a conductive heat flow path. For example, aluminum framing for glazing in cold climates typically utilizes a low conductivity material to join an exterior and interior portion of the metal framing.
Thermal Bridge	Part of the building envelope where otherwise uniform thermal resistance is changed by full or partial penetration of the thermal insulation by materials with lower thermal conductivities and/or when the interior and exterior areas of the envelope are different, such as what occurs at parapets and corners.
Thermal Modeling	The process by which the thermal performance of assemblies is determined through computer simulations utilizing heat transfer models. Assemblies can be modeled two- or three- dimensions (2D and 3D).
Thermal Performance	A broad term to describe performance indicators related to the heat transfer through an assembly. The performance indicators include thermal transmittances, effective R-values, and metrics to evaluate condensation resistance related to surface temperatures.
Thermal Zone	A grouping of the interior building spaces that experience similar heating and cooling requirements.
Total Energy Use	The amount of annual energy use of a building, including space heating/cooling, ventilation, lighting, plug loads, domestic hot water, pumps, fans etc.
Unitized Curtain Wall	A curtain-wall system that is assembled in modules that is glazed before arriving at site.
Vision Section	The section of curtain-wall or window-wall that contains transparent or translucent elements.
Window to Wall Ratio/ Glazing Ratio	The percentage of glazing to the wall area of a building.
Window-wall	A factory built modular façade system installed from floor to ceiling that is supported by the floor slab. This could include a vision and a spandrel section.
Whole Building Energy Use	The amount of energy a building uses, typically on a yearly basis. This includes, but is not limited to energy for space and ventilation heating and cooling, domestic hot water heating, lighting, miscellaneous electrical loads and auxiliary HVAC equipment such as pumps and fans.