Canadian Consulting Engineering Awards

Building Envelope
Thermal Bridging Guide

Project Sponsors:
BC Hydro Power Smart
Homeowner Protection Office
(a Branch of BC Housing)
Canadian Wood Council
FortisBC
FPInnovations
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2015

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PRESENTED BY

Morrison Hershfield

ASSOCIATION OF CONSULTING ENGINEERING COMPANIES | CANADA

CANADIAN CONSULTING ENGINEER
EXECUTIVE SUMMARY
BUILDING ENVELOPE THERMAL BRIDGING GUIDE

The *Building Envelope Thermal Bridging Guide* seeks to transform the building industry by facilitating the design and construction of more thermally efficient building envelopes. The Guide, developed by Morrison Hershfield in collaboration with sponsors BC Hydro Power Smart, Homeowner Protection Office (HPO) – a Branch of BC Housing, Canadian Wood Council, FortisBC and FPInnovations, aims to overcome obstacles confronting industry with respect to mitigating thermal bridging to reduce energy consumption in buildings.

A complex subject and set of problems was distilled into an easily understood and practical guide that fills a previous information gap, providing essential information for evaluating building envelope thermal performance, including easy-to-use methods for understanding, accurately calculating and mitigating thermal bridging.

The guide is of great interest to practitioners, researchers and regulators. It outlines how to effectively account for thermal bridging and provides an extensive catalog of common building envelope assemblies and interface details and their associated thermal performance. It contains a cost-benefit analysis and discussion on significance and further insights. Technically sophisticated and complex information is presented in a practical, user-friendly manner.

With its local and international significance, this groundbreaking reference tool has already begun to influence building design, construction, policy and the development of energy codes and standards in BC and beyond. When implemented, the guide will affect positive change in building envelope design and performance, resulting in more energy efficient buildings and a more sustainable future for generations to come.
INNOVATION

“Ever heard some old-timer describe what life was like before AutoCad? That might be exactly what today’s engineers sound like in a year or two, telling the youngsters how difficult it used to be to calculate energy performance in the days before the Building Envelope Thermal Bridging Guide.” - Robin J. Miller, Innovation Magazine

The thermal performance of a building’s envelope can be greatly affected by thermal bridging, or localized areas of high heat flow through walls, roofs and other insulated building envelope components. In the past, resources that allowed practitioners to accurately account for thermal bridging were limited and it was not effectively addressed in energy standards (either overlooked or exempted). Research and monitoring of buildings is increasingly showing the importance of mitigating the impact of thermal bridging which can be significant to building energy consumption, the risk of condensation on cold surfaces, and occupant comfort.

An earlier study carried out by Morrison Hershfield, ASHRAE 1365-RP “Thermal Performance of Building Envelope Details for Mid- and High-Rise Buildings”, put forward procedures and data that allowed practitioners to evaluate the impact of thermal bridging. This started a market transformation to better evaluate building performance but only scratched the surface in terms of identifying how to effectively mitigate thermal bridging in design and did not address the impact on energy consumption in buildings.

The Building Envelope Thermal Bridging (BETB) Guide, developed by Morrison Hershfield in collaboration with project sponsors, expands significantly on previous work, and identifies where opportunities exist to incentivize improving industry practice. Emerging technologies and construction practices that offer substantial improvements to current construction practice are also explored.

Morrison Hershfield used a “state of the art” high tech tool to analyze a complex set of problems to provide practical engineering solutions that industry can easily implement. Although the tools, expertise and software were available to provide solutions for every variable to multiple decimal places, it was recognized that industry needed engineering solutions rather than scientific explanations.

In developing the methodology for the Guide, Morrison Hershfield explored a myriad of variables in a manner that facilitates understanding of what is important and how to practically address thermal bridging in energy standards. Adjustments were made to the methodology to accommodate new information, new insights and validate against available lab measurements. The result is a robust methodology that industry can implement with confidence.

Although the introduction of new concepts and a call for change can sometimes be threatening, this groundbreaking reference tool has already begun to influence change. The overwhelming positive “buzz” regarding the BETB Guide received by industry across North America has resulted in a commitment from co-sponsors to making it a living document. The Guide has momentum for continued acceptance because of its technical excellence, the breadth of information within, and the way essential information is clearly communicated for a multitude of industry stakeholders.

COMPLEXITY

Before the BETB Guide, significant thermal bridges were often overlooked due to the complexity and time required to fully assess building envelope thermal performance. A “state of the art” high tech tool was used to analyze a complex set of problems and provide practical, implementable engineering solutions. Investment in resources,
software and staff facilitated not only the delivery
of this comprehensive assignment on time, but
exceeded client expectations for breadth and
quality of information.

In developing the guide, Morrison Hershfield
evaluated over 300 building envelope details (in
3D) that are directly relevant to construction in
North America. The thermal performance of
building envelope details was quantified using an
extensively calibrated and validated 3D heat
transfer model. This specialized heat transfer
software is not commonly used in the building
industry, but is relied on in other applications
where accuracy and the ability to evaluate many
design iterations is paramount (such as for the
design of the Mars rover, electronics and
automobiles.)

An extensive catalogue of details was developed,
allowing designers quick and straightforward
access to information intended to mitigate thermal
bridging, including some emerging technologies.
Costs associated with improving building envelope
thermal performance were examined, and the
energy impact was forecasted for several building
types and climates using whole building energy
models (EnergyPlus) of archetype buildings. Finally,
the energy cost benefit was evaluated for
improving the building envelope compared to
other strategies such as higher insulation levels
and high performance glazing.

The end result is a practical guide that is broken into
three stand-alone parts. Part 1, the “Building
Envelope Thermal Analysis (BETA) Guide”, is of great
value to practitioners as it outlines how to
effectively account for thermal bridging. Also for
practitioners, Appendices A & B provide a catalogue
of common building envelope assemblies and
interface details and their associated thermal
performance data. Part 2: Energy Savings and Cost
Benefit Analysis and Part 3: Significance, Insights and
Next Steps, along with Appendices C, D and E will
appeal to researchers and regulators, since they
contain the cost-benefit analysis and discussion on
the significance and further insights of using the
guide to mitigate thermal bridging in buildings.

SOCIAL AND/OR ECONOMIC BENEFITS

The BETB Guide will lead the way to constructive
changes in the building industry. For the first time,
modelers, architects, designers and others will
have a comprehensive catalogue of building
envelope details and a comprehensive guide that
will provide an easy to understand process to
account for major building envelope thermal
bridges.

The ability to more quickly, accurately and easily
account for the building envelope thermal
performance will help to transform the
marketplace so that new buildings are designed
and built to higher standards of energy efficiency.
Beyond reducing heating and cooling loads,
mitigating thermal bridging will also increase
comfort for building occupants and reduce
condensation which can extend the life of the
building envelope.

BC Hydro’s Gordon Monk is confident that the
BETB Guide is a critically important resource for
builders and industry professionals. “…it will
ultimately benefit the people who buy and live and
work in the units the new construction industry
builds. It’s also a great educational tool for up-
and-coming industry professionals.”

In a practical sense, the BETB Guide will make life a
lot easier for those involved in new building
design. “It used to take me two whole weeks to
calculate the performance of a building envelope,
with plans all over the floor, colour crayons
everywhere. Fast forward to today and BC
practitioners now have access to the latest in
modern technology to calculate energy
performance in far less time and with far greater
accuracy.” – Greg McCall, City of Vancouver
ENVIRONMENTAL BENEFITS

Because buildings consume a large percentage of electricity and natural gas, improved energy conservation in buildings is an important approach to reduce energy consumption and greenhouse gas emissions. In Canada, space conditioning (primarily heating) is one of the largest components of energy use in commercial, institutional, and residential buildings. 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.

The additional heat flow due to thermal bridging at interface details can add up to be a significant portion of the heat flow through the building. If major thermal bridges are not addressed then adding insulation to building envelope assemblies may not provide significant benefits and may go against energy standards where cost benefit must be a consideration. The BETB Guide hits this point squarely for policy makers to consider for future iterations of codes and standards.

If decisions are being made based on calculations that ignore significant heat loss paths then there is a high probability that materials are not being used efficiently, which does not fit well with the goal of truly sustainable buildings and reducing embodied energy. When implemented, the BETB Guide will affect positive change in building envelope design and performance, resulting in more energy efficient buildings and a more sustainable future for generations to come.

MEETING CLIENT’S NEEDS

The client’s primary goal was to provide information that makes it easier for thermal bridging to be comprehensively considered in building codes, design and whole building energy simulations. Adherence to a strict schedule and the creation of a legacy project were very important objectives.

The reaction from industry leaders has been excellent. “The work your team has produced is some of the clearest, most useful I have seen on the subject of thermal bridging in envelopes.” – Justin Pockar, City of Calgary.

This project was delivered on time and on budget. In the client’s own words “you guys went above and beyond in terms of both effort and quality.” This success can be partially attributed to the specialized technical expertise and state of the art software behind the analysis, but also to the determination of the team, good project management and a sensible investment in resources.

The BETB Guide is considered to be a significant energy efficiency initiative. It addresses a number of obstacles currently confronting industry and outlines why and how thermal bridging should be more comprehensively considered by industry.

Greg McCall from the City of Vancouver, summed it up well when he said: “The City of Vancouver recognizes the significance of the BETB Guide as a tool that could influence the industry and policy makers, and even those developing the next level of energy standards and codes. Its approach and accuracy lends itself to be a critically useful tool, not just in BC, but across the nation and even south of the border. In a world where energy performance is increasingly becoming a priority, this tool will undoubtedly affect positive change in building envelope design and performance wherever it is used.”
Photo 1: Building Envelope Thermal Bridging Guide.
Photo 2: From BETB Guide: example of common residential high-rise with extended concrete floor slabs around perimeter and building envelope of mainly floor to ceiling window-wall.

Photo 3: From BETB Guide: Sample 3D Model of a concrete balcony and window-wall as seen in Photo 2.
**Photo 4:** From BETB Guide: Example thermal image shows cold interior surfaces of concrete balcony and window-wall as seen in Photo 2.

**Photo 5:** Sample summary table of building envelope performance for evaluated wall assemblies per Insulation Level.

### Clear Wall Assemblies

<table>
<thead>
<tr>
<th>Description of Detail (Thermal Assembly)</th>
<th>Wall Assembly Description</th>
<th>Detailed Description</th>
<th>Reference</th>
<th>U-Value Insulation</th>
<th>Thermal Transmittance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal Clip</td>
<td>Exterior Insulated Steel Stud</td>
<td>Exterior Insulated Steel Frame Assembly with Insulated Vertical Z-Girts at 30° Supporting Metal Cladding</td>
<td>5.1.10</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Metal Clip</td>
<td>Exterior Insulated Steel Stud</td>
<td>Exterior Insulated Steel Frame Assembly with Insulated Vertical Z-Girts at 40° Supporting Metal Cladding</td>
<td>5.1.10</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Metal Clip</td>
<td>Exterior Insulated Steel Stud</td>
<td>Exterior Insulated Steel Frame Assembly with Insulated Vertical Z-Girts at 50° Supporting Metal Cladding</td>
<td>5.1.10</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Metal Clip</td>
<td>Exterior Insulated Steel Stud</td>
<td>Interior and Exterior Insulated Steel Frame Assembly with Vertical Clips Supporting Bracing Cladding</td>
<td>5.1.13</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Clips</td>
<td>Exterior Insulated Steel Stud</td>
<td>Exterior Insulated Steel Frame Assembly with Horizontal Clips Supporting Metal Cladding</td>
<td>5.1.11</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>
Table 1.3: Performance Categories and Default Transmittances for Floor and Balcony Slabs

<table>
<thead>
<tr>
<th>Performance Category</th>
<th>Description and Examples</th>
<th>Linear Transmittance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficient</td>
<td>Fully insulated with only small conductive bypasses Examples: exterior insulated wall and floor slab.</td>
<td>0.12 0.2</td>
</tr>
<tr>
<td>Improved</td>
<td>Thermally broken and intermittent structural connections Examples: structural thermal breaks, standoff shelf angles.</td>
<td>0.20 0.35</td>
</tr>
<tr>
<td>Regular</td>
<td>Under-insulated and continuous structural connections Examples: partial insulated floor (i.e. firestop), shelf angles attached directly to the floor slab.</td>
<td>0.29 0.5</td>
</tr>
<tr>
<td>Poor</td>
<td>Un-insulated and major conductive bypasses Examples: un-insulated balconies and exposed floor slabs.</td>
<td>0.58 1.0</td>
</tr>
</tbody>
</table>

Photo 6: Sample summary table of floor and balcony slab interface details. 64 Unique conditions are distilled to four (4) easy to use categories for designers.

Photo 7: Sample Archetype Building (low-rise residential) used in cost benefit analysis for evaluating how the building envelope can be improved with better details vs other strategies.