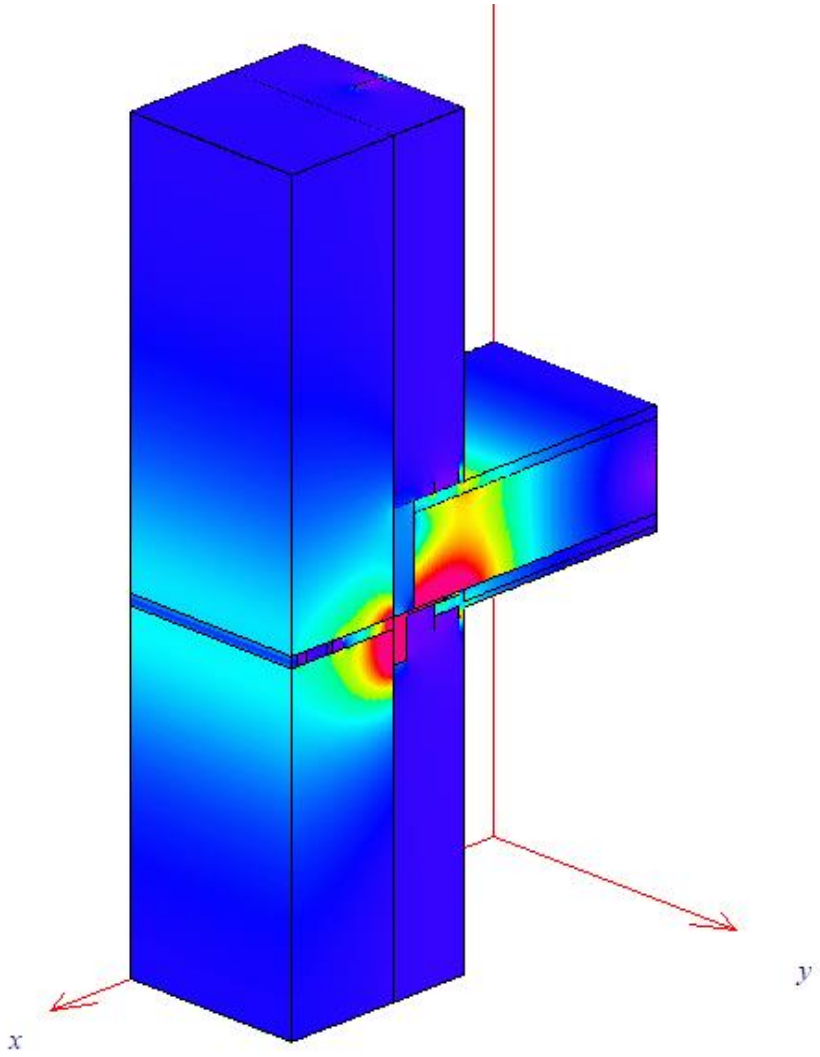
RDH BUILDING SCIENCE LABORATORIES

Thermal Analysis of Total Precast Concrete MURB Walls

Project 10393.007



To M. Mike Singleton
Sustainable Buildings Canada

Submitted December 2020 by
Dr. Randy Van Straaten P.Eng &
Dimuth Kurukula, M.Sc
RDH Building Science Laboratories
167 Lexington Court #5
Waterloo ON N2J 4R9

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1 Introduction

This guide stems from Enbridge Natural Gas's Saving-By-Design[1] design workshops where experts assist project team in finding solutions achieve high energy efficiency in building projects. Mid and high-rise multi-unit residential building project teams are common participants in these Ontario based workshops. *Total precast* concrete buildings are a popular construction approach for these buildings. The main structure of these buildings are thick interior and exterior precast concrete wall panels. Thinner non-structural precast concrete exterior panels walls are installed where enclosure but not support is needed. This approach can support towers up to 30 or 40 storeys and are often built on top of cast-in-place concrete parking garages or podiums. This approach of shorter erection times at a competitive cost with cast-in-place concrete systems.

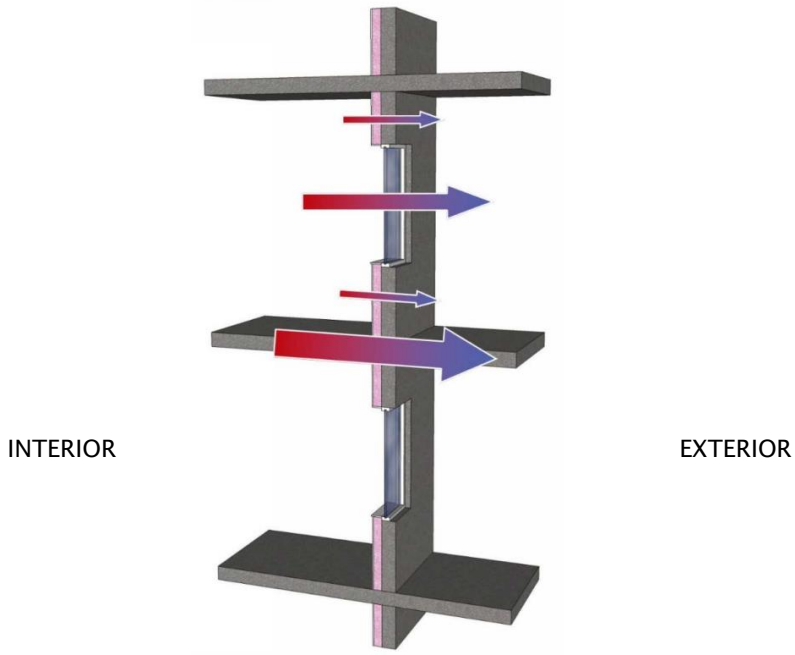

Figure 1-1 Heat flow paths through centre of wall, floor slab, and windows (arrow size is relative to magnitude of heat flow).

Both total precast and cast-in-place systems can provide concrete exterior finishes. Concrete is perceived to have less repair and maintenance costs and resilience advantages[2] over other claddings. Total precast further has an advantage over cast-in-place concrete buildings in its potential to address thermal bridging illustrated in Figure 1-1. A previous Canadian Precast/Prestressed Concrete Institute (CPCI) guide[3] is available with simplified calculation methods to estimate thermal performance. The CPCI guide is suitable for preliminary analysis of thermal bridges but is less precise than required by current codes and does not address a number of important thermal bridges.

[1] www.savingsbydesign.ca

[2] Van Straaten, R., Straube, J., Lukachko, A., (2016) "Increasing the durability and resilience of tall buildings with precast concrete enclosure systems" *Annual Conference of the Canadian Society for Civil Engineering*. London, Canada.

[3] Canadian Precast/Prestressed Concrete Institute (CPCI) (2017). *Meeting and Exceeding Building Code Thermal Performance Requirements.* Guide Written by RDH Building Science (Retrieved from cpci.org).

This guide illustrates thermal performance calculations for opaque wall areas suitable for demonstrating compliance to National Energy Code for Building (NECB) 2017[4], Enbridge Gas's Savings-by-Design Commercial program[5], and Toronto Green Standard v3[6] Tier 2 or higher. This publication is timely for several reasons:

- → Ontario is expected to soon adopt NECB 2017 (or NECB 2020) which will require accounting for thermal bridging as detailed in this guide;
- → As of January 1, 2021, the current HFC blowing agent used in most closed-cell polyurethane spray foam (ccSPF) products will be banned in Canada. ccSPF is the predominant insulation used in total precast building walls due to its ability to limit risk of condensation on the inside face of the panels. The thermal performance of the new HFO blowing agent based ccSPF vary between manufacturers and the long-term thermal resistance (LTTR) will be significantly lower that those for HFC blowing agent based ccSPF insulation.
- → The upcoming CSA Z5010 publication of a national standard for the simulation and calculation of thermal bridges in building enclosure assemblies by the Canadian Standards Association; and
- → A growing interest in reducing thermal bridging for improving energy efficiency (through programs such as Savings By Design and Passive House) and to minimize condensation risks (which may grow from elevated interior winter-time humidity levels demanded for infectious aerosol risk mitigation[7] (ASHRAE 2020)).

It is noted that building materials and construction practices change and improve over time. It is advisable to regularly consult up-to-date technical publications on building science, products, and practices, rather than relying solely on this publication. For instance, it does not address sandwich precast assemblies which are currently uncommon for total precast applications due to high cost implications. It is also advisable to seek specific information on the use of products, the requirements of good design and construction practices, and the requirements of the applicable building codes before undertaking a construction project. Retain consultants with appropriate engineering or architectural qualifications, including airtightness testing agencies, and appropriate municipal and other authorities, regarding issues of design and construction practices, airtightness testing, and compliance with the Ontario Building Code (OBC) and municipal bylaws. The use of this guide does not guarantee compliance with code requirements, nor does the use of systems not covered by this guide preclude compliance.

[4] NRC-CNRC (2017). *National Energy Code of Canada for Buildings (NECB) 2017*. Government of Canada.

[5] Sustainable Buildings Canada (2020) *Savings by Design (SBD) – Part 3 Buildings Energy Modelling Guide – 2020*, Sustainable Buildings Canada, Toronto.

[6] City of Toronto (2019). *Energy Efficiency Report Submission & Modelling Guidelines for the Toronto Green Standard (TGS) Version 3 February 1*, 2019. (Retrieved from www.toronto.ca).

[7] ASHRAE (2020) *ASHRAE Position Document on Infectious Aerosols* April 14, 2020 (retrieved from ASHRAE.org).

1.1 Thermal Requirements for Walls in Ontario

The energy performance of new building designs in Ontario is governed by Supplementary Standard SB-10[8], for which an updated version took effect January 1, 2017. Within the SB-10 requirements, projects can choose from one of three compliance paths based on three energy performance standards:

- National Energy Code for Building (NECB) 2015[9] with amendments;
- ASHRAE 90.1 *Energy Standard for Buildings Except Low-Rise Residential Buildings* 2013[10] with amendments; or
- ASHRAE 189.1 *Standard for the Design of High-Performance, Green Buildings Except Low-Rise Residential Buildings* 2014[11].

NECB 2015 maximum thermal transmittance requirements are listed in Table 1-1 which include calculated thermal resistance values and colour coding to match the climate zone map in Figure 1-2. NECB 2017 and NECB 2020 have the same maximum thermal transmittance required for walls as NECB 2015. SB-10 includes amendments including a thermal resistance value of 5.46 RSI (R-31) to be used across Ontario for electrically heated buildings regardless of climate zone. Projects can follow one of three paths within NECB:

- prescriptive requirements;
- trade-off enclosure thermal performance requirements between walls, roofs, windows, etc.;
- performance path based on energy modelling in effect allowing trade-off between mechanical, lighting, and enclosure elements (e.g. required for projects with high glazing ratios).

The SB-10 amendments for ASHRAE 90.1-2013 are significant and result in a rough alignment of the building enclosure requirements with those for NECB 2015. ASHRAE 189.1 compliance is not commonly pursued because the standard involves a wide scope of green building requirements beyond energy performance. This guide is based on NECB prescriptive compliance path because this is a common approach for total precast concrete MURBs in Ontario.

[8] Ontario Building Code *Supplemental Standard SB-10* "Energy Efficiency Requirements" Amended on December 22, 2016 (retrieved from mah.gov.on.ca).

[9] NRC-CNRC (2015). *National Energy Code of Canada for Buildings (NECB) 2015*. Government of Canada.

[10] ASHRAE (2013). Standard 90.1-2013 *Energy Standard for Buildings Except Low-Rise Residential Buildings*. ASHRAE, Atlanta, GA.

[11] ASHRAE (2014). Standard 189.1-2014 *Standard for the Design of High-Performance Green Buildings*. ASHRAE, Atlanta, GA.

TABLE 1-1 NECB 2015 ABOVE-GRADE OPAQUE WALL THERMAL PERFORMANCE REQUIREMENTS – SI (IP) FROM TABLE 3.2.2.2 Note: NECB 2015 and NECB 2017 have the same requirements as listed in this table		
Climate Zone	Maximum Thermal Transmittance	Minimum Thermal Resistance
	$W/m^2 \cdot ^\circ C$ (Btu/ h ft^2 $^\circ F$)	$m^2 \cdot ^\circ C/W$ (h ft^2 $^\circ F$/Btu)
4	0.315 (0.055)	3.2 (R-18.2)
5	0.278 (0.049)	3.6 (R-20.4)
6	0.247 (0.044)	4.0 (R-22.7)
7	0.210 (0.037)	4.8 (R-27.0)
8	0.183 (0.032)	5.5 (R-31.3)

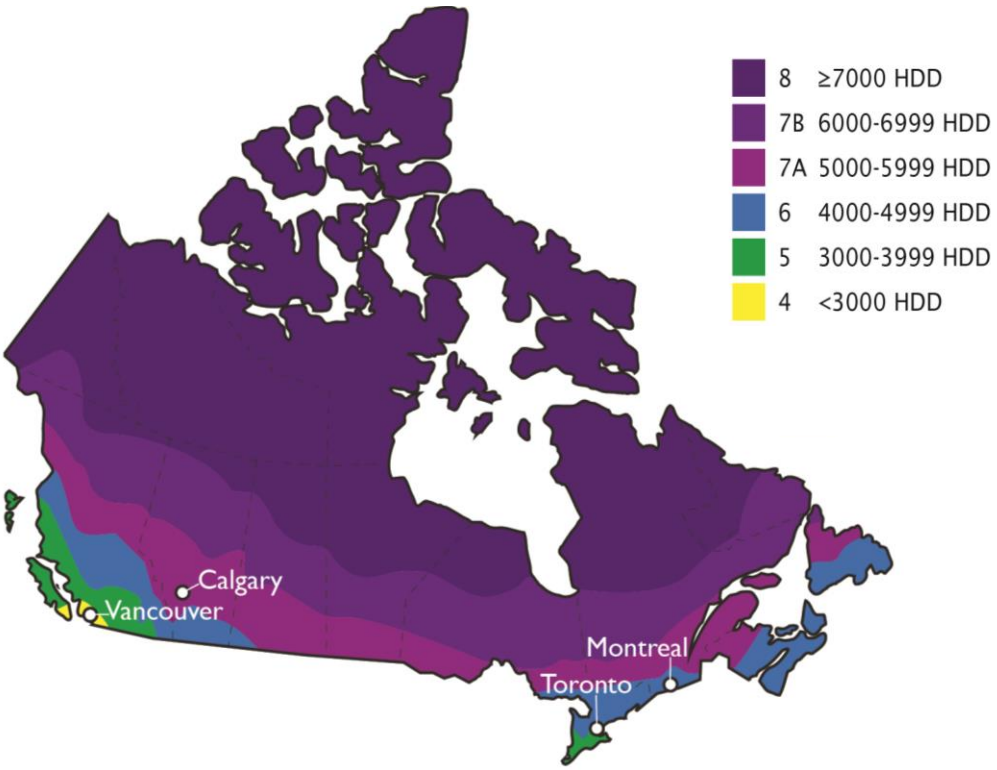

Figure 1-2: Study cities on NECB 2015 Heating Degree Day (HDD) climate zone map.

Thermal bridging allowance are reduced and clarified in NECB 2017. The differences between NECB 2015 and NECB 2017 are summarized in Table 1-2.

The next chapter of the guide details thermal performance calculations and explains the various thermal bridges and performance data suitable for analysis of total precast concrete wall assemblies. The final chapter documents a case study total precast MURB tower and includes several design options for addressing thermal bridging.

TABLE 1-2 REQUIRED THERMAL PERFORMANCE ADJUSTMENTS FOR THERMAL BRIDGING IN VARIOUS ENERGY CODES AND PROGRAMS		
Thermal Bridge	**NECB 2015**	**NECB 2017***
Closely spaced repetitive structural members (e.g. studs and joists)	Yes	Yes
Closely spaced ancillary members (e.g. lintels, sills and plates)	Yes	Yes
Structural wall penetrations (e.g. floor slabs, beams, girders, columns, curbs)	See note**	Yes
Structural roof penetrations and ornamentation or appendages that substantially or completely penetrate the insulation layer	See note**	Yes
Interface junctions between building envelope assemblies (e.g. roof-to-wall junctions and glazing to wall/roof junctions)	No	Yes
Cladding structural attachments (e.g. shelf angles, girts, clips, fasteners and brick ties)	No	Yes
The edge of walls/floors that intersect the building enclosure and substantially or completely penetrate the insulation layer	See note***	Yes
Mechanical penetrations (e.g. pipes, ducts, through-the-wall equipment venting, packaged terminal air conditioners or heat pumps)	No	No
Minor thermal bridge elements with an expected cumulative impact of less than 10% if they were included in the calculation	No	No

Notes

* NECB 2017 has similar thermal bridging allowances as Enbridge Gas's Savings-By-Design Commercial Project and Toronto Green Standard requirements for Tier 2, 3 and 4 buildings. Also note that no additional changes to the thermal bridging allowances or calculations have yet been proposed for NECB 2020.

** per NECB 2015 3.1.1.7. 2) *"… the thermal bridging of major structural elements, such as columns and spandrel beams, that are parallel to the plane of the building envelope and partly penetrate that building envelope assembly need not be taken into account, provided they do not increase the overall thermal transmittance at the projected area of the member to more that twice the permitted in Section 3.2"*

*** per NECB 2015 3.1.1.7. 4) *"… major structural penetration, such as balcony slabs, beams, girders, columns, and ornamentation or appendages that must completely penetrate the building envelope to perform their intended function need not be taken into account, provided that the sum of the cross -sectional areas at such major structural penetrations is limited to a maximum of 2% of the above-ground building enclosure area"*

2 Thermal Performance

Effective thermal transmittance calculations for opaque wall assemblies are described in Section 3 of BC Hydro's Building Envelope Thermal Bridging Guide (BETBG)[12]. This guide uses BETBG and alternate performance data including the following:

- → ISO 14683[13];
- → ASHRAE Handbook of Fundamentals (HOF)[14] calculations; and
- → Two- or three-dimensional thermal simulations.

There are two steps to thermal performance calculations for enclosure elements 1) calculation of clear wall (or clear field) thermal transmittance U_{cw} or resistance, R_{cw}, and 2) accounting for linear and point thermal bridges. The calculations are summarized in terms of R-values in this guide because the Ontario building industry is more familiar with these terms.

2.1 Clear Wall R-value

Clear Wall (or Clear Field) **R-value** ($\mathbf{R_{cw}}$) is the air-to-air thermal resistance of an opaque assembly with uniformly distributed thermal bridges (e.g., framing, clips, etc.). A sketch of the typical wall assembly layers within a total precast wall is illustrated in Figure 2-1 along with example basic isothermal plane thermal resistance R-value calculation.

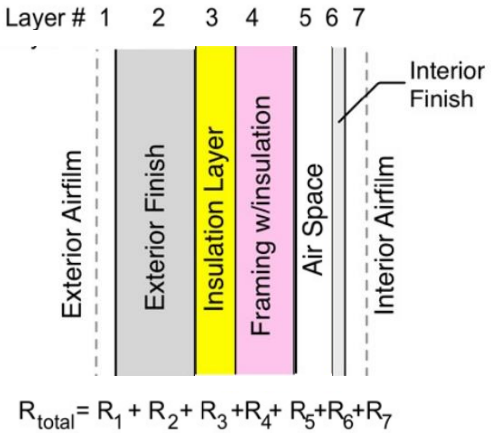

Figure 2-1 Typical Total Precast Wall Component in Clear Field of Wall

Using isothermal planes analysis to calculate R_{cw} is challenging for total precast wall assemblies because insulation is commonly installed between metal studs and the resulting performance varies depending on the thickness of continuous insulation separating the studs from the inside surface of the precast concrete panels.

[12] BC Hydro's Building Envelope Thermal Bridging Guide (BETBG) version 1.4 (2020) (retrieved from www.bchydro.com).

[13] ISO 14683 (2007) *Thermal Bridges in Building Construction: Linear Thermal Transmittance: Simplified Methods and Default Values*. International Organization for Standardization. Geneva, Switzerland.

[14] ASHRAE (2017) *Handbook of Fundamentals* ASHRAE, Atlanta, GA.

Two-dimensional thermal modelling using the THERM 7.7 software[15] was used to calculation clear wall thermal performance. The material properties and thicknesses used in the modelling and further three dimensional modelling presented later in the report are listed in Table 2-1.

Table 2-1 Total Precast Wall Assembly Materials and Component Thermal Properties

Material	Thickness mm (inches)	Conductivity W/mK (Btu/hr·ft·˚F)	Resistance RSI (IP)	Sources
Outside Air Film	-	-	0.029 (R-0.165)	ASHRAE HOF
Concrete	152 (6")	1.8 (1.04)	0.06 (R-0.36)	ASHRAE HOF
Concrete Topping	25 (1")	1.15 (0.664)		NFRC[16] Medium Density
ccSPF (HFO)	51 (2")	0.0275 (0.0159)	1.90 (R-10.8)	BASF[17]
Mineral Wool Insulation	25 (1") & 51 (2")	0.040 (0.0231)	0.64 (R-3.6) & 1.27 (R-7.2)	ASHRAE HOF
Structural Thermal Break	25 (1")	0.20 (0.116)		Armatherm FFR[18]
Galvanized Sheet Steel	25 Gauge 102 (4") Stud	62 (35.8)		NFRC
Steel (Angle)	102x102x6 (4"x4"x0.25")	50 (28.9)		NFRC
Silicone Sealant	13 (0.5")	0.35 (0.202)		NFRC
Air Space	≥13 (1/2")	-	0.16 (R-0.91)	CSA Z5010[19]
Gypsum Board	13 (1/2")	0.16 (0.0924)	0.08 (R-0.45)	ASHRAE HOF
Inside Air Film *Vertical* *Floor* *Ceiling*	-	-	 0.121 (R-0.687) 0.108 (R-0.613) 0.163 (R-0.926)	ASHRAE HOF

[15] Lawrence Berkeley National Labs THERM 7.7 software (see windows.lbl.gov/software/therm).

[16] NFRC 101 (2017) *Procedure for Determining Thermophysical Properties of Materials for Use in NFRC-Approved Software* National Fenestration Rating Council Incorporated Greenbelt, MD.

[17] BASF (2019) *Technical Data Sheet Walltite CM10 CCMS 14100-L* April 2019.

[18] Armatherm (2017) *Thermal Break Material Armatherm™ Grade FRR For Structural Steel Connections* (downloaded from armatherm.com).

[19] Communication with Daniel Haaland (2020) regarding CSA Z5010 *Calculation of Thermal Bridges in Building Enclosure Assemblies* (not yet released).

Table 2-2 provides clear wall thermal performance results for 152 mm (6") precast wall panel assembly with varying levels of c.i. ccSPF and ccSPF between the metal studs found through thermal modelling. The models account for vertical steel framing at 406 mm (16") on centre. The results are colour coded by climate zone based on the highest NECB 2015 prescriptive target which is met. Illustrations of a sample THERM model and isothermal planes and temperature contour results is given below in Figure 2-2.

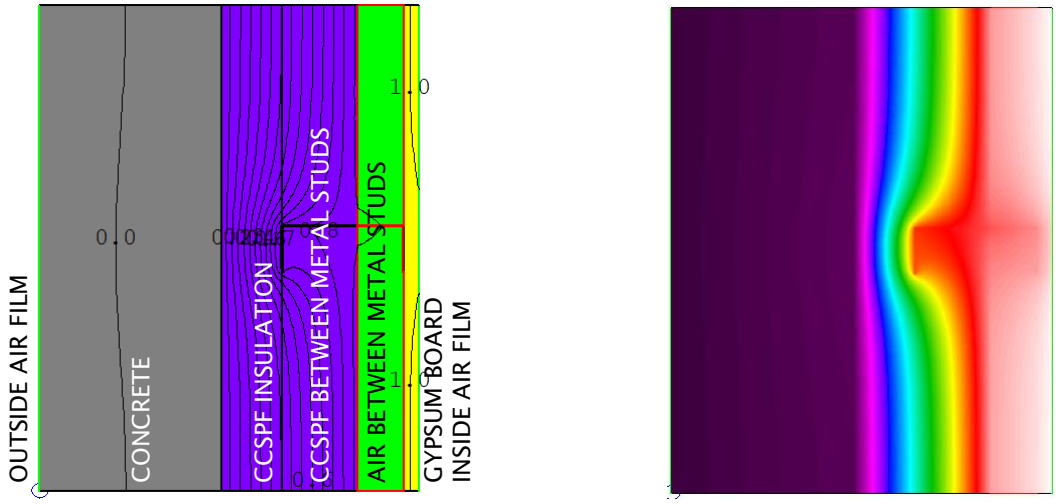

Figure 2-2 Example 2D model isothermal planes (left) and temperature contour (right) results for 4" metal stud offset 2" from concrete panel and with a total of 5.5" closed cell spray foam insulation

When using Table 2-2 thicker concrete panels will slightly improve thermal performance (e.g. using a 305 mm (12") thickness structural precast panel in lieu of a 152 mm (6") panel will add 0.06 RSI (R-0.36) to overall thermal resistance) and different densities and steel reinforcing will affect performance. The use of solid concrete to represent hollow-core concrete floors and precast panels with steel reinforcing is a common thermal modelling approach and used in this analysis.

The impacts of linear thermal bridges are illustrated in the case study section in the next chapter of this guide. In practice, walls will required greater insulation thicknesses than given in Table 2-2 where thermal bridging must to accounted for in design to meet building code.

Table 2-2 Clear Wall R-values for Precast Walls						
ccSPF c.i. Thickness		ccSPF Between Studs		Clear Wall R-value Result		NECB 2015 Zone
(inch)	(mm)	(inch)	(mm)	(IP)	(RSI)	
64 mm (2.5") metal stud						
3.5	89	-	-	22.2	3.92	5
4	102	-	-	24.9	4.39	6
4.5	114	-	-	27.7	4.87	7
5	127	-	-	30.4	5.35	7
5.5	140	-	-	33.1	5.83	8
6	152	-	-	35.8	6.31	8
3	76	1	25	23.5	4.15	6
3.5	89	1	25	26.3	4.62	6
4	102	1	25	29.0	5.10	7
4.5	114	1	25	31.7	5.58	8
5	127	1	25	34.4	6.06	8
5.5	140	1	25	37.1	6.54	8
2	51	2.5	64	22.1	3.89	5
2.5	64	2.5	64	24.9	4.38	6
3	76	2.5	64	27.6	4.87	7
3.5	89	2.5	64	30.4	5.35	7
4	102	2.5	64	33.1	5.83	8
4.5	114	2.5	64	35.8	6.31	8
6	152	2.5	64	43.9	7.83	8
102 mm (4") metal stud						
2	51	2.5	64	22.6	3.98	5
2.5	64	2.5	64	25.4	4.47	6
3	76	2.5	64	27.6	4.87	7
3.5	89	2.5	64	30.4	5.35	7
4	102	2.5	64	33.1	5.83	8
4.5	114	2.5	64	36.4	6.41	8
1	25	4	102	20.1	3.54	4
1.5	38	4	102	23.2	4.08	5
2	51	4	102	26.1	4.60	6
2.5	64	4	102	28.9	5.10	7
3	76	4	102	31.7	5.59	8

2.2 Accounting for Linear Thermal Transmittances

Linear Thermal Transmittances (***Ψ)*** is a quantity describing the influence of a linear thermal bridge on the total heat flow (i.e. additional to the heat transfer taken into account by the area-based clear field thermal transmittances). Linear thermal transmittance is steady-state heat flow rate divided by length and by the temperature difference between the environments on either side of a thermal bridge (IS0 14683)).

Effective thermal transmittance (U_{eff}) can be calculated as follows:

$$U_{eff} = \frac{\sum U_{o,j} \cdot A_j + \sum \Psi_k \cdot l_k + \sum \mathrm{X}_l \cdot n_l}{\sum A_j}$$

where,

$\sum U_{o,j} \cdot A_j$, is the sum product of clear-wall U-values and their areas, W/K [Btu/(hr·˚F)]

$\sum \Psi_k \cdot l_k$, is the sum product of linear transmittances and their lengths, W/K [Btu/(hr·˚F)]

$\sum \mathrm{X}_l \cdot n_l$, is the sum product of point transmittances and their quantity, W/K [Btu/(hr·˚F)]

$\sum A_j$, is the sum of clear-wall assembly areas, m² [ft²]

Similarly, **effective whole wall R-value**, (R_{ww}), can be calculated as follows:

$$R_{ww} = \frac{\sum A_j}{\sum A_j / R_{cw,j} + \sum \Psi_k \cdot l_k + \sum \mathrm{X}_l \cdot n_l}$$

where,

$\sum A_j / R_{cw,j}$, is the sum product of clear-wall areas divided by their clear wall R-values, W/K [Btu/(hr·˚F)]

The linear transmittance values can be based on interior or exterior dimensions of assemblies for either calculation approach. BETGB linear transmittance values are based on *exterior* enclosure areas and lengths. The ISO 14683 values quoted in this guide are all based on exterior dimensions. Where interior dimensions will be used for energy modelling or other applications, precise analysis will require adjustment of Ψ values and is not addressed in this guide.

Potential linear thermal transmittance values available for analysis of total precast wall systems are given in Table 2-3. The values are organized into three sources: 1) default values taken from ISO 14683, 2) default values taken from BETBG, and 3) 3D simulation results documented in the CPCI guide or performed for this guide (indicated as RDH in the table). The table is further divided into assemblies with no thermal break, assemblies with 1", 2", and 4" mineral wool thermal breaks, and high and reduced window and door flanking values. The various thermal bridges which that should be considered in analysis and recommended linear transmittance values are detailed in the following subsection along with discussion of the variations in values from the different sources and limitations.

ISO 14683 values are based on walls with R_{cw} values of 2.9 RSI (R-16.6) and the BETBG values are often presented for walls with 2.64 RSI (R-15) insulation. These insulation amounts are less than typically used in total precast concrete MURBs in Ontario. Linear transmittance values can be significantly affected by the R-value and thickness of

surrounding wall insulation. Hence, the precision of thermal bridging calculations using these sources are limited but often used as a reasonable way of conducting this analysis to approximate thermal performance of wall assemblies without having to conduct a large scope of custom thermal modelling.

TABLE 2-3 LINEAR TRANSMITTANCE SOURCES AND VALUES AVAILABLE FOR TOTAL PRECAST WALL ASSEMBLIES

Note that the space filed with grey did not have a suitable value for the calculation and that values recommended for use are bolded. See Section 2.3 through 2.8 for description of assembly details considered in this table.

Wall Interface	ISO 14683		Simulation		BETBG	
	W/K m	Detail	W/K m	Source	W/K m	Detail
Assemblies with no Thermal Break						
Floor-to-wall & Balconies	0.90	IF3	0.913	CPCI	0.797	7.2.4
Internal Wall & Outrigger	0.90	IW3			0.710	7.2.4
Roof-to-wall	0.65	R6			0.579	7.5.6
Over Unheated Space	0.55	GF11			0.674	7.7.1
Assemblies with 1" Mineral Wool Thermal Breaks						
Floor-to-wall & Anchors Including Balconies			0.328	CPCI	0.377	7.2.7
Floor set on Shelf Angle			0.581	RDH		
Internal to Exterior Wall	0.45	IF8	0.195-0.211	CPCI	0.454	7.2.3
Roof-to-wall					0.216	7.5.7 B
Assemblies with 2" Mineral Wool Thermal Breaks						
Floor-to-wall & Anchors including Balconies			0.247	CPCI		
Floor set on Shelf Angle			0.522	RDH		
Floor set on Shelf Angle with Thermal Break			0.366	RDH		
Internal Wall			0.089-0.109	CPCI		
Assemblies with 4" Mineral Wool Thermal Breaks						
Floor-to-wall & Anchors including Balconies			0.192	CPCI		
High Window and Door Flanking						
Header	0.45	W7			0.225	7.3.3 D
Jamb	0.45	W7			0.388	7.3.3 D
Sill	0.45	W7			0.333	7.3.3 D
Reduced Window and Door Flanking						
Header	0	W1			0.139	7.3.11 D
Jamb	0	W1			0.051	7.3.11 D
Sill	0	W1			-0.040	7.3.11 D

Point transmittances such as canopies, outriggers, pipes, clips, etc. have been excluded from this guide and only linear thermal bridges are considered. This approach is assumed to captures the significant building heat loss contributions although individual zones in the building may be significantly affected by such losses.

2.3 Floor Slab to Wall Interface

Floor slabs commonly connect directly to exterior concrete walls in cast-in-place construction. Insulation is often installed on the interior of the wall in lieu of the exterior to allow the concrete to serve as the exterior finish. A similar approach is used with precast concrete panel walls which can result in similar thermal losses.

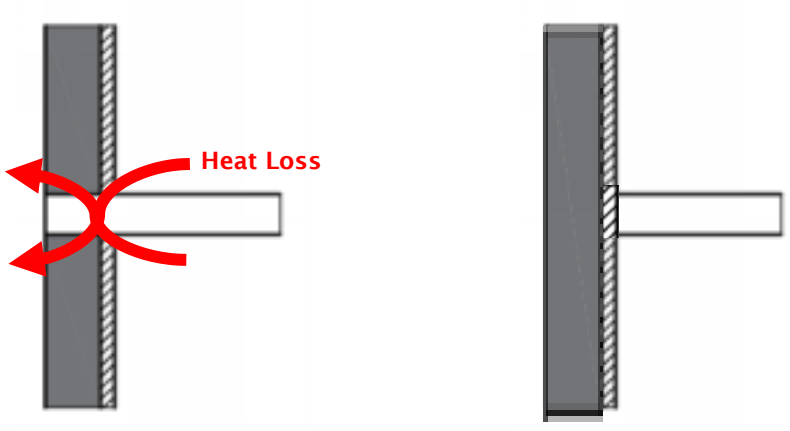

Figure 2-3: Illustration of floor-to-wall interface with internal insulation showing the major resulting thermal bridge through the floor slab and the thermal break possible with total precast concrete assemblies (base illustrations from ISO 14683)

Floor Slab

The use of interior insulation allows significant heat loss through the edge of the floor slab and high resulting linear transmittance values. ISO 14683 gives a value of 0.90 W/mK and BETBG gives a value of 0.797 W/mK. However, these values are for walls with low R_{cw} values which were shown in the CPCI guide to underpredict Ψ values.

Linear thermal transmittance can be calculated from R_{cw} value of 5.28 RSI (R-30.0) and floor-to-floor height (h) of 2.94 m (9.66 ft) and resulting slab thermal resistance (R_{slab}) value of 2.0 RSI (R11.4) in Table 13 of the CPCI guide as follows:

$$\Psi = h/R_{cw} - h/R_{slab} = 2.94\text{m}/5.28\text{RSI} - 2.94\text{m}/2.0\text{RSI} = \mathbf{0.913\ W/K\ m}$$

Floor Slab with Thermal Break

Non-structural precast panels present an opportunity to add a thermal break where a gap between floor slabs and wall panels that can be filled with non-combustible mineral wool insulation as shown in Figure 2-4. The gap between the panel and floor slab tends to be narrow due to the anchoring costs. A ¼" to ½" smoke seal and firestop is included at the top of the mineral wool thermal break and it is assumed to have a negligible effect on heat loss.

Table B1 in the CPCI guide provides linear transmittance values of 0.211, 0.109, and 0.041 W/mK for 25 mm (1”), 51 mm (2”), and 102 mm (4”) mineral wool firestopping gap thicknesses, respectively for a wall with 6.34 RSI (R-36) continuous insulation. Table B1 also provides point thermal transmittance values of 0.143, 0.168, and 0.184 W/mK for anchors for these same wall system scenarios. Precast anchors are typically spaced every 1.219 m (4’) to 1.829 m (6’)[20]. The point and linear transmittance can be combined into an equivalent linear transmittance as follows:

$$\Psi' = \Psi + \frac{X}{w}$$

This calculation results in equivalent Ψ' values of **0.328**, **0.247,** and **0.192 W/mK** for an anchor spacing, w, of 1.219 m (4’) for 25 mm (1”), 51 mm (2”), and 102 mm (4”) mineral wool firestopping gap thicknesses, respectively.

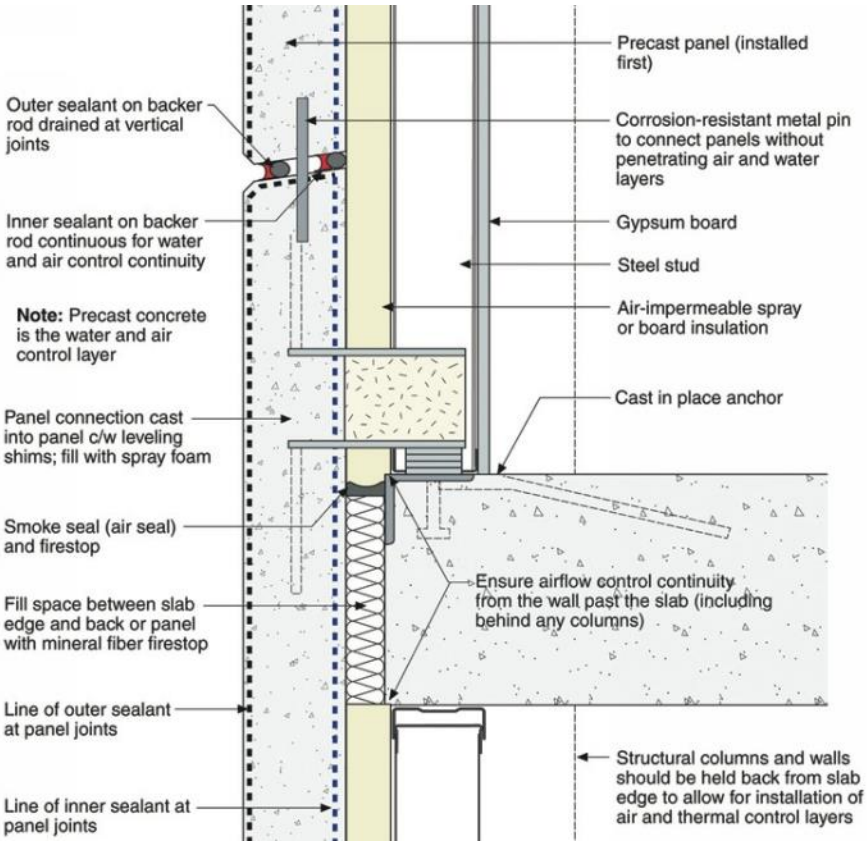

Figure 2-4: Section at floor of a non-structural precast concrete panel showing mineral wool insulation filling gap between floor slab and wall acting as a thermal break and anchor to support the precast concrete panel (taken from CPCI 2017)

BETBG includes the performance of a similar detail to Figure 2-4 in their detail 7.2.7. Their modelling found a Ψ value of 0.377 W/K m. The BETBG linear transmittance value includes heat loss through anchors. These values were not used in this guide because the models had minimum insulation (R_{cw} of 2.26 RSI (R-12.9)), the gap had excessive ~1 ¼” silicone seal at the top and bottom of the mineral wool firestop, and the anchor space was considered excessively narrow at a spacing of 813 mm (2’ 8”).

[20] Communication with Albert Meyer, Stubbes Precast Inc (2020).

Floor set on Shelf Angle

The CPCI guide includes an alternative design for floor-to-wall interface for structural precast walls including an interior corbel added to the panels to support the floor. This allows insulation between the ends of the floor slab and wall. However, the floor slab sits in direct contact with the corbel resulting in a degree of thermal bridging. Linear thermal transmittance can be calculated from their reported R_{cw} value of 5.28 RSI (R-30.0) and floor-to-floor height (h) of 3.05 m (10 ft) and resulting slab thermal resistance (R_{slab}) value of 2.88 RSI (R-16.4) in Table 13 of the CPCI guide as follows:

$$\Psi = h/R_{cw} - h/R_{slab} = 3.05\text{m}/2.88\text{RSI} - 3.05\text{m}/5.28\text{RSI} = 0.481 \text{ W/K m}$$

The addition of corbels is not a common practice for total precast building. An alternative approach is to mount the floor slab on a steel angle anchored to the inside of the structural precast wall. In order to determine the effectiveness of this approach a 3D model was created using Heat3 v9.01 modelling software[21] as shown in Figure 2-5. Material properties from Table 2-1 were used in the analysis. The floor slab is mounted on a 102 mm x 102 mm x 6 mm (4"x4"x0.25")" shelf angle.

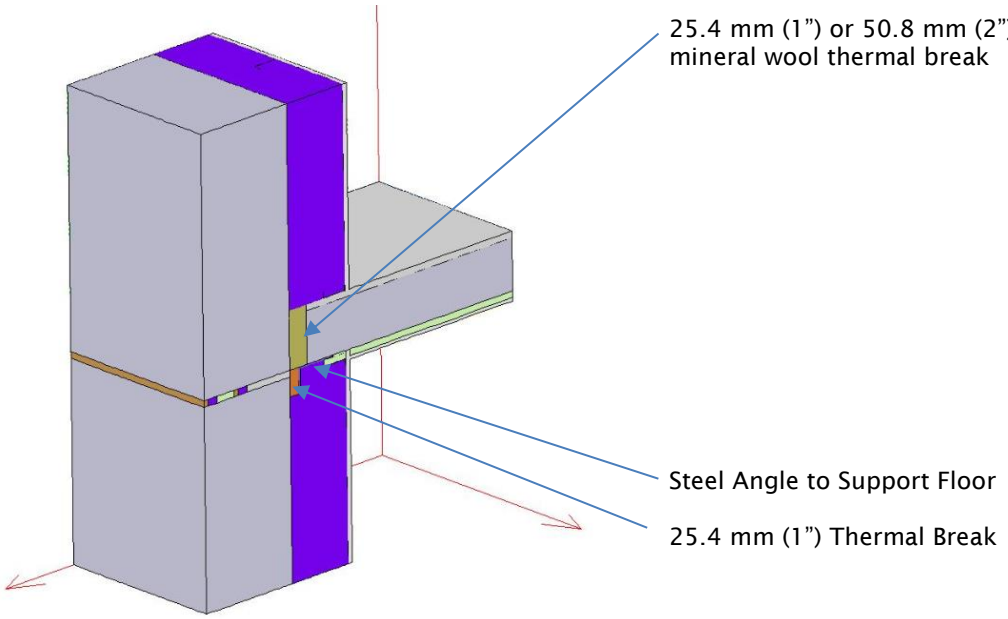

Figure 2-5: 3D model illustration showing the model setup

The simulation was conducted with three variations as follows

1. 25 mm (1") thermal break at the floor and the wall interface. The resulting temperature profile for this model is given in Figure 2-6 showing the warm indoor temperature reaching well into the wall at the angle indicating significant thermal bridging. The model resulted in a Ψ value of **0.581 W/K m**.

2. 51 mm (2") thermal break at the floor and the wall interface. The resulting temperature profile for this model is given in Figure 2-6 showing the warm indoor temperature reaching a similar depth into the wall at the angle indicating significant thermal bridging. The model resulted in a Ψ value of **0.522 W/K m** which is a 10% improvement over the 25 mm (1") thermal break.

[21] Blocon HEAT3 three dimensional heat transfer software v9.01 (see www.buildingphysics.com).

3. 51 mm (2”) thermal break at the floor and the wall interface and a 25 mm (1”) thermal break plate separating the angle and wall. The resulting temperature profile for this model is given in Figure 2-7 showing minimal warm indoor temperature reaching into the wall demonstrating the effectiveness of the thermal break. The model resulted in a Ψ value of **0.366 W/K m** which is a significant improvement but still about 50% greater than values for the interfaces with the non-structural panels.

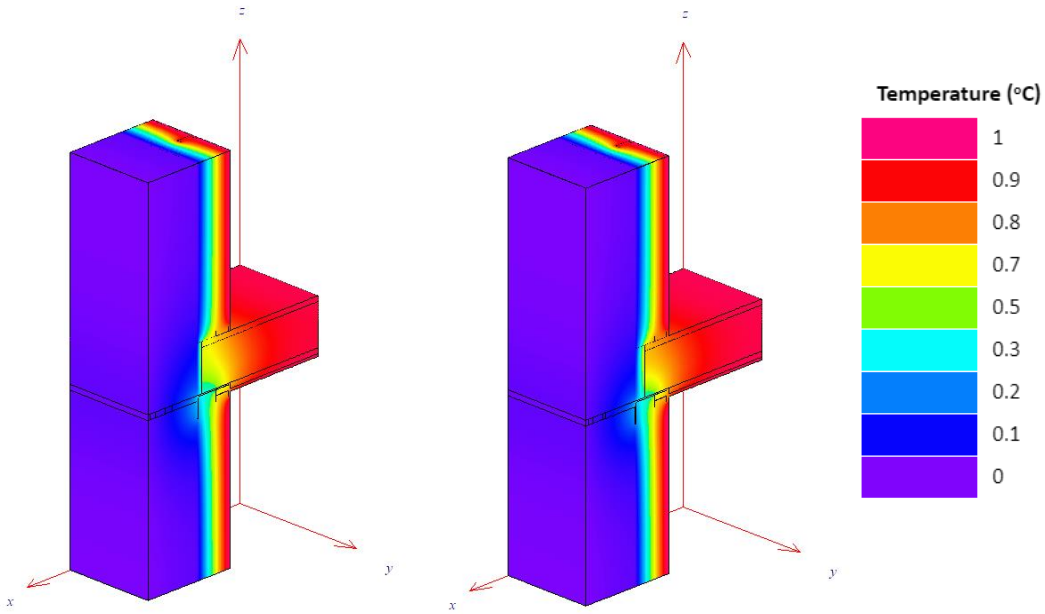

Figure 2-6: 3D model result temperature for 25 mm (1”) and 51 mm (2”) mineral wool thermal break at the floor and the wall interface with interior set to 1˚C and exterior set to 0˚C

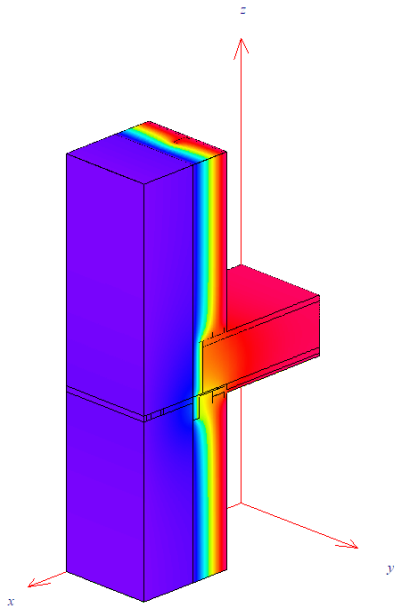

Figure 2-7: 3D model result temperature a 51 mm (2”) mineral wool thermal break at the floor and the wall interface and a 25 mm (1”) thermal break plate separating the angle and wall with interior set to 1°C and exterior set to 0°C

2.4 Balcony

Projecting balconies are common for cast-in-place and precast concrete balconies. The projecting slab carries the momentum load of the balcony. Unfortunately, the projecting concrete is a significant thermal bridge. A previous RDH report[22] demonstrated the effectiveness of thermal break designs for projecting balconies. An alternative is to install balconies within alcoves providing support on two opposing sides or providing perimeter columns to carry the moment load. Eliminating the moment load allows precast concrete balconies to be use with similar insulated separations as for floor-slab-to-wall interfaces presented in section 2.3.

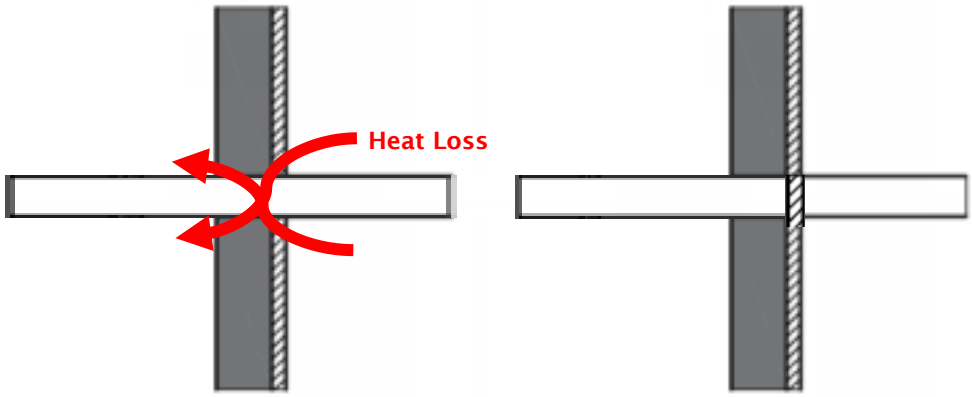

Figure 2-8: Illustration of floor-to-wall interface with internal insulation showing the major resulting thermal bridge through the floor slab and the thermal break possible with total precast concrete assemblies (base illustrations from ISO 14683)

Projecting Balcony

RDH found that thermal heat loss through projecting balconies of was similar to that of exposed floor slab edges.

Balcony with Thermal Break

RDH provided simulations for including and 0.6 RSI (R-3.4) Isokorb type thermal break between the balcony and floor slab. This approach is a potential, albeit expensive, thermal break option for cast-in-place concrete structures. Furthermore, the full insulating value would not be achieved due to a point losses at anchors.

For simplicity, users are recommended to use the value presented in section 2.3 for both projecting balconies and balconies with thermal breaks.

[22] Finch, G., Higgins, J., Hanam, B., (2014) "The Importance of Balcony and Slab Edge Thermal Bridges in Concrete Construction" CCBST 2014.

2.5 Internal Wall and Outrigger

Load-bearing interior walls are anchored to exterior walls in total precast building to provide support. Limited insulation at these interfaces can be a significant thermal bridge. Furthermore, when balconies cannot be supported by three adjacent walls, one method for support is to use outriggers which are an extension of precast internal support walls which results in a significant thermal bridge.

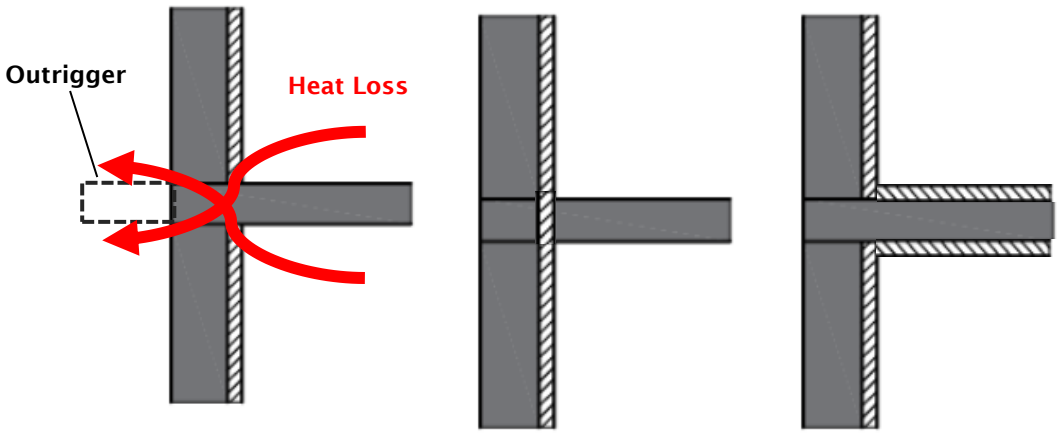

Figure 2-9: Illustration of floor-to-wall interface with internal insulation showing the major resulting thermal bridge through the floor slab, the thermal break possible with total precast concrete assemblies, and an alternative approach involving insulation on interior walls (base illustrations from ISO 14683)

Internal Wall and Outriggers

ISO 14683 provides similar Ψ values for internal wall interfaces of 0.90 W/K m as that for floor slabs (shown on the right above). BETBG demonstrated that the metal track and drywall typical for these internal wall finishes reduces heat loss and resultant Ψ values (**0.797 W/K m** for the BETBG case).

As shown for balconies in section 2.4, the heat loss from concrete thermal bridges with ends exposed to the outdoors is similar to that of project elements. Hence, the same **0.797 W/K m** used for exposed internal wall ends is also use for the vertical length of outrigger.

Internal Wall with Insulation

ISO 14683 provides a Ψ value for internal wall with insulation run along the internal wall of 0.45 W/K m which is similar to that found in BETBG of 0.454 W/K m. However, this is quite different from the mineral wool firestopping and anchors used in precast construction. Hence, users are recommended to use the Ψ values for floor-to-wall interfaces of **0.211** and **0.109** W/mK for 25 mm (1") and 50 mm (2") mineral wool thermal breaks

2.6 Window and Door Flanking

Window and door flanking loss are losses around the framing, typically through the structural wall components they are installed in. These are losses additional to those captured by clear wall R-value for the opaque wall and the U-Value of the window or door system.

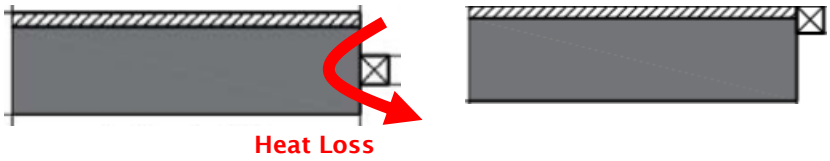

Figure 2-10: Illustration of window and door flanking with frame misaligned with insulation showing the major resulting thermal bridge through the floor slab and alignment with insulation (base illustrations from ISO 14683)

Window and Doors Not Aligned with Insulation

When windows are installed out of alignment with insulation, heat "flanks" around the window through the wall structure as shown in the illustration above on the right. The example in ISO 14863 has **0.45** W/K m linear transmittance. BETBG details 7.3.2 and 7.3.3 provide Ψ values for aluminum windows installed to the exterior of the opening and not aligned with the insulation. Detail 7.3.2 provides Ψ values of 0.273 and 0.322 W/mK for installation with and without metal flashing connected with interior metal studs. Detail 7.3.3 provides Ψ values of **0.388** and **0.224** W/mK for the jamb and header and 0.163 and **0.333** W/mK for sill with and without sheet metal subsill. The clear wall R-values used in these simulations is 3.05 RSI (R-17.3) which may partly explain the lower values than ISO 14863.

Where windowsills are set at floor level and for door sills it is important to avoid double counting the thermal bridging through the floor-to-wall interface. BETBG detail 9.1.7 C provides a thermal transmittance value for the base of a curbless sliding door on top of a penetrating concrete slab of 0.992 W/K m. This value is similar to that for floor-to-wall interface and hence, it is recommended for simplification to ignore flanking for windowsill set at floor level and for door sills.

Window and Doors Aligned with Insulation

ISO 14863 illustrated by providing a psi value **0.00** W/K m for windows aligned with insulation (as shown on the illustration above on the left). The negligible Ψ value indicates that the heat loss is adequately captured by clear wall R-values and window U-values.

Window installation aligned with insulation is illustrated in Figure 2-4. BETBG includes detail 7.3.11 with aluminum windows aligned with insulation including Ψ values of **0.051** and **0.139** W/K m for the jamb and header. For sills with and without sill shim insulation and 0.106 and **-0.040** W/K m (heat loss be less than that captured in R_{cw} and window U-values).

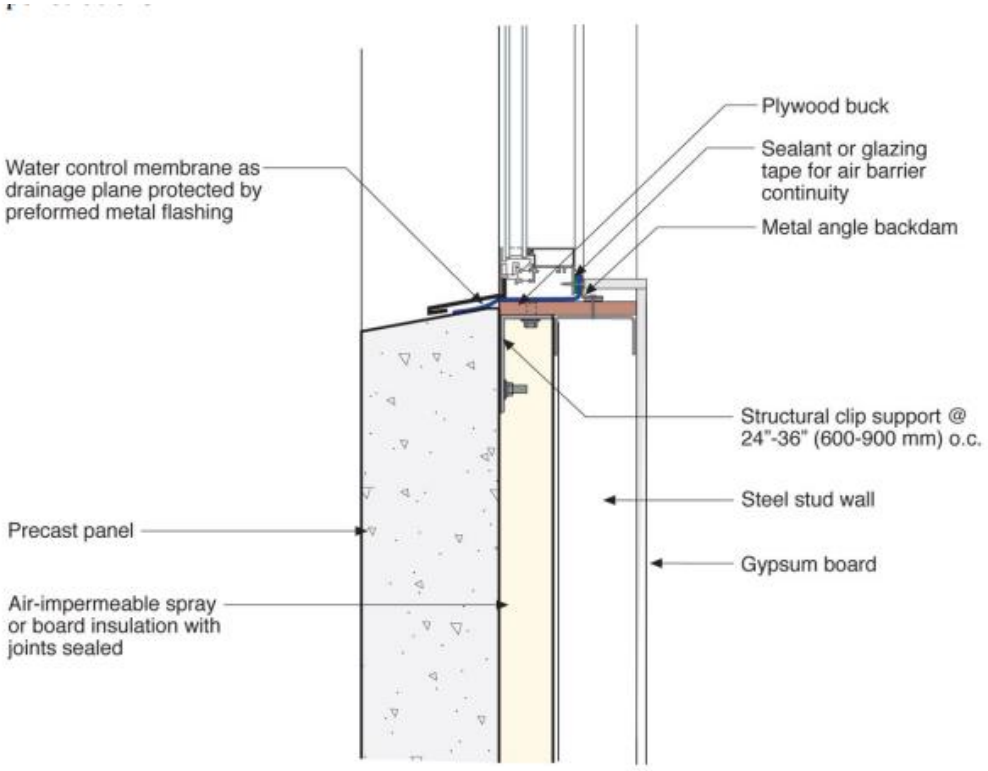

Figure 2-11: Section at window wall to a non-structural precast concrete panel showing window alignment with continuous insulation (taken from CPCI Rain Control Guide[23])

BETBG detail 9.1.7 A shows that when an 0.63 RSI (R-3.5) thermal break is included at the floor-to-wall interface inline with the door frame, that the linear thermal transmittance value lowers to 0.246 W/K m. This value is similar to that for floor-to-wall interface and hence, it is recommended for simplification to ignore flanking for windowsill set at floor level and for door sills.

[23] Canadian Precast/Prestressed Concrete Institute (CPCI) (2016). *High Performing Precast Concrete Building Enclosures: Rain Control*. Guide Written by RDH Building Science (retrieved from cpci.org).

2.7 Roof Parapet

Roof parapet losses are losses through minimally insulated paths through roof-to-wall interfaces with parapets. They are losses additional to those captured by clear wall and roof R-values.

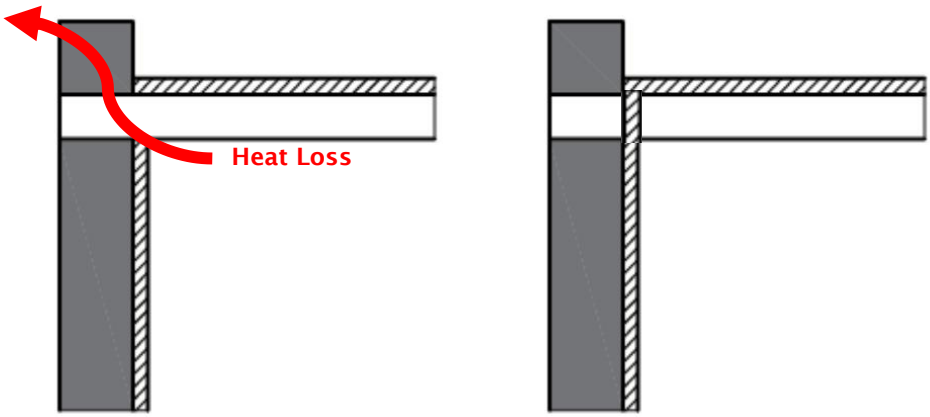

Figure 2-12: Illustration of roof-to-wall interface with internal insulation showing the major resulting thermal bridge through the roof slab and the thermal break possible with total precast concrete assemblies (base illustrations from ISO 14683)

Roof Parapet

ISO 14863 has a Ψ value of **0.65** W/K m for the assembly in Figure 2-12 on the left. BETBG includes detail 6.5.6 which is a similar assembly but with a metal stud wall on the inward-facing side of the parapet with a lower Ψ value of 0.579 W/K m.

Roof Parapet with Thermal Break

BETBG detail 6.5.7 includes a parapet with 25.4 mm (1") mineral wool insulation between the hollow core and precast wall as well as a pair of thermal break options for the metal stud wall set on the hollow core. Detail 6.5.7 B includes a thermal break under the bottom of the metal channel for the stud wall and has a Ψ value of **0.216** W/K m.

2.8 Wall-to-floor Interface Over Unheated Space

Wall-to-floor interface losses over unheated spaces are losses through the floor slab to the outdoors and the unheated space. They are losses additional to those captured by clear wall and floor R-values.

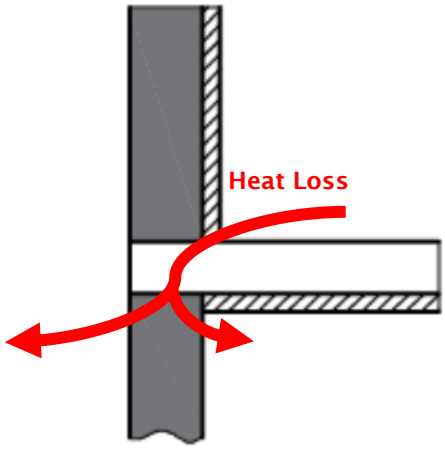

Figure 2-13: Illustration of wall-to-floor interface over a parking garage internal insulation showing the major resulting thermal bridge through the floor slab (base illustrations from ISO 14683)

Interface with Floor Slab over Unheated Space

ISO 14863 has a Ψ value of **0.55** W/K m for the assembly in Figure 2-13. No suitable detail was found in BETBG for this assembly. As the floor slab and wall are cast-in-place no suitable thermal break approach was determined for this assembly.

3 Case Study

In this section, a case study is presented to illustrate the method and level of detail appropriate for thermal bridging calculation and to investigate the challenges to meeting NECB prescriptive wall performance requirements when thermal bridging effects are captured. The case study is an 18-storey total precast tower which sits over a cast-in-place above grade unheated parking podium shown in Figure 3-1.

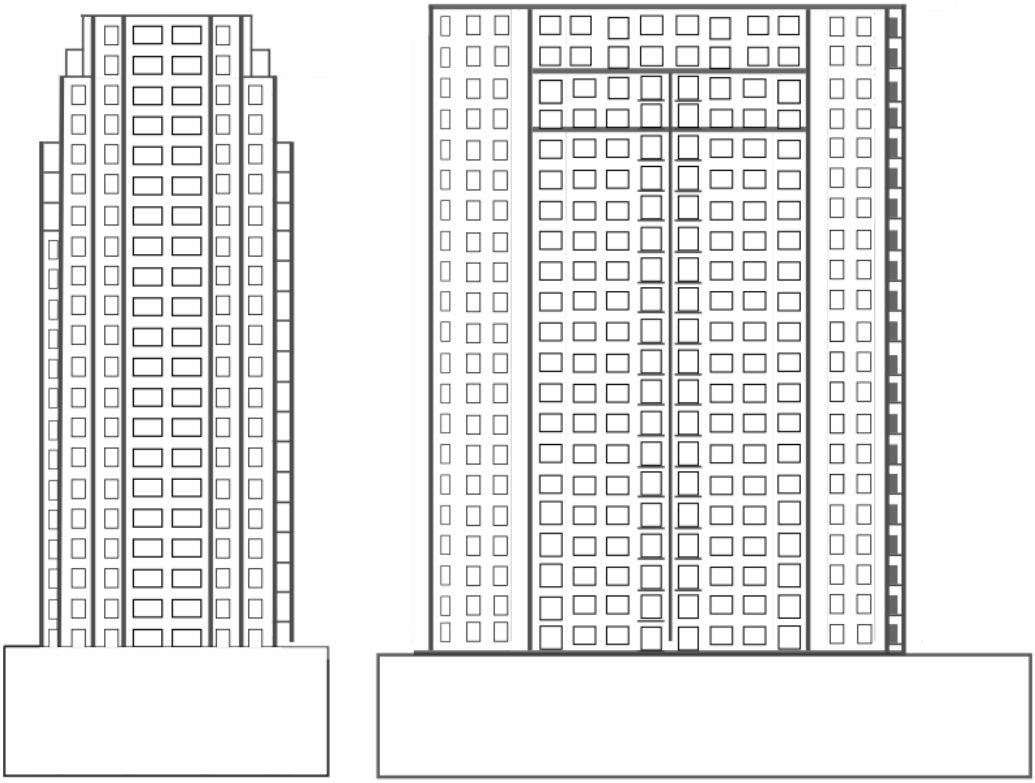

Figure 3-1: Sketch of case study total precast tower front and side elevations

A list of windows and doors in structural and non-structural precast exterior wall panels is given in Table 3-1 showing a total window and door area of 2922 m^2. The window-to-wall ratio can be calculated from the total above-grade vertical enclosure area of 9382 m^2 to be 31%. The windows (and doors) with sill aligned with the floor slab are also indicated in the table. Floor-to-wall interfaces, balconies, and outriggers lengths are included in the Appendix.

Table 3-1 Case Study Building Window and Doors

Type	Non-Structural Walls (#)	Structural Walls (#)	Width (m)	Height (m)	Total Area (m^2)	Sill set at Slab?
Window 1	168	336	2	1.6	1613	No
Window 2	126		1.8	1.6	363	No
Window 3	144		1.3	1.6	300	Yes
Window 4	50		1	2.2	110	Yes
Door 1	92	102	1	2.2	427	Yes
Door 2	50		1	2.2	110	Yes
Total Window and Door Area (m^2)					2922	

Three design cases have been considered for the case study.

1. A *Baseline* case capturing the performance of typical total precast concrete MURB in Ontario except that a greater amount of wall insulation was considered to provide some allowance for thermal bridging. The wall insulation considered include 4" continuous insulation and 2.5" insulation between the metal studs, all ccSPF, for a clear wall R-value of 5.8 RSI (R-35). The thermal bridges considered are listed in the appendix and include no thermal break for structural precast panel interfaces, a 25 mm (1") of mineral wool insulation at the floor slab to non-structural precast panel interfaces, and poor window and door alignment with insulation.
2. An *Improved Design* case include low and no-cost design elements to reduce thermal bridging. The thermal bridges considered are listed in the appendix and include a 25 mm (1") of mineral wool insulation at the floor slab to non-structural and structural precast panel interfaces, good window and door alignment with insulation, the outriggers have also been eliminated by providing support columns.
3. An *NECB 2017 Compliant* case to illustrate measures that would be needed for total precast concrete MURB building to meet future codes. The thermal bridges considered are listed in the appendix and include 102 mm (4") of mineral wool insulation at the floor slab to non-structural precast panel interfaces. The floor-to-wall interface for the structural precast panels use 51 mm (4") of mineral wool, a thermal break separating the supporting angle from the wall, negligible flanking at windows and doors, the outriggers have also been eliminated by providing exterior support columns, and a thermal break has been applied at the parapet. An additional 2" of continuous ccSPF insulation was required to increased clear wall R-value to 7.3 RSI (R-43.7).

3.1 Results and Discussion

BC Hydro thermal bridging worksheets are included in the appendix for calculation of thermal performance and summarized in Table 3.2 below.

TABLE 3.2 SUMMARY OF THERMAL PERFORMANCE VALUES

	Thermal Transmittance		Effective Whole Wall R-Value	
Scenario	$W/m^2 K$	$Btu/hr\ ft^2 F$	$m^2 K/W$	$hr\ ft^2 F/Btu$
Baseline	0.809	0.142	1.2	7.0
Improved	0.460	0.081	2.2	12.3
NECB 2017	0.278	0.049	3.6	20.4

Heat loss contributions from clear wall loss and the considered thermal bridges is further plotted in Figure 3-2. The following key observations can be drawn from the plot.

1. The baseline clear wall accounts for only 21% of the opaque wall heat loss. The effective thermal performance does not meet NECB 2017 even with 2" more ccSPF than would be required for the clear wall R-value to meet the prescriptive requirement (ignoring thermal bridging). Window flanking accounts for more than half of the additional thermal bridging heat loss. Floor-to-wall interface and balconies account for about 40% of losses. The internal wall to exterior wall and outriggers contribute about 6% and the remainder are losses at the roof-to-wall and wall-to-parking garage interfaces.

2. The improved wall has 43% less heat loss with little additional costs but would still not meet NEC 2017. The major difference between the baseline and improved wall systems is the reduction of window and door flanking contributions to heat loss and reduction in structural floor-to-wall interface losses.

3. To meet NECB 2017 requirements the heat loss had to reduced 66% from the baseline design. The case study example demonstrates meeting this requirement through a greater clear wall R-value, greater thermal breaks at floor-to-wall and interior wall to exterior wall interfaces, and elimination of window flanking losses.

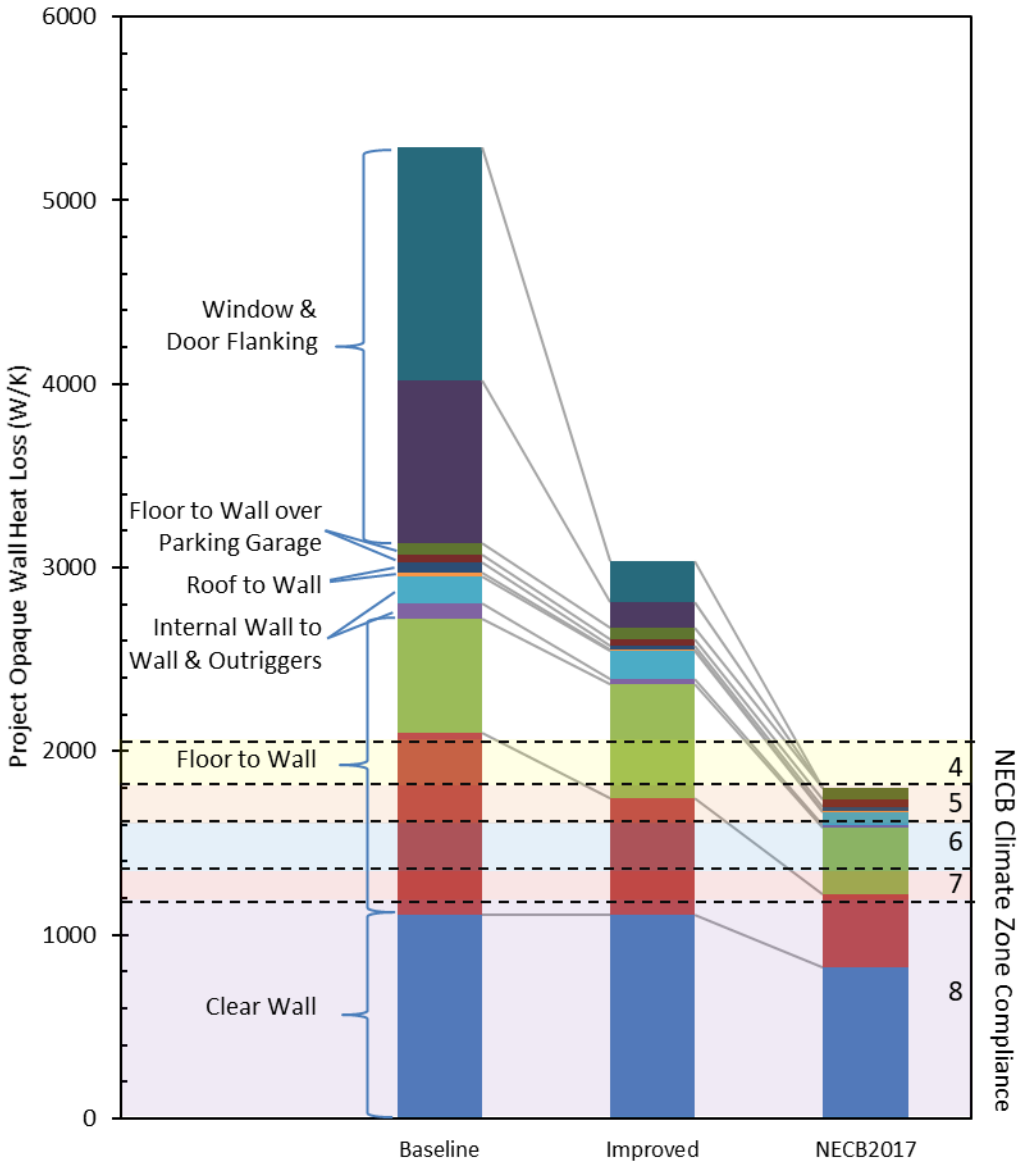

Figure 3-2: Breakdown of opaque wall heat loss and reduction of thermal bridging between Baseline, Improved design, and NECB climate zone 5 compliant wall Systems. Window & Door Flanking: Teal – Non-structural, Purple – Structural. Floor-to-wall: Green – Non-structural , Red – Structural.

4 Conclusions

This guide detailed a methodology for calculating the thermal performance of total precast wall systems for MURB applications. The methodology included clear wall R-values determined through 2D thermal modelling and thermal bridging transmittance values taken from the publications or determined through 3D thermal modelling. The follow observations can be drawn from the review of available thermal performance publications.

1. The available assemblies vary from those typically used in Ontario both in terms of insulation thicknesses and assembly details
2. It is difficult to determine the specific assembly details included in some thermal performance publications.
3. The methodology and thermal performance values presented in this guide are assumed to provide sufficient accuracy given a reasonable analysis effort for users although further investigation is recommended.

The case study results demonstrate the drastic thermal performance benefits available by addressing thermal bridging in design details. The case study illustrates two major measures for total precast concrete MURBs:

1. Window installation detailing to mitigate flanking heat loss by aligning window with insulation and avoiding metal flashing completely penetrating the insulation layer
2. Incorporate thermal breaks at the interface of floor slabs to walls including structural precast walls.

The case study results also illustrate the challenges for current total precast concrete MURB designs to meet NECB 2017 requirements. The following insights were drawn from the case study:

1. Total thicknesses of ccSPF of 216 mm (8.5") or more will be needed for total precast system to comply with NECB 2017 and may not be feasible;
2. Further combinations of wall assembly and thermal break options beyond those captured in the case study are possible to improve performance and meet NECB 2017 (e.g. development of affordable sandwich wall options);
3. Enclosure trade-offs with improved window U-value or other improvements demonstrated through whole building energy performance modelling could alternatively be employed to meet future codes with total precast wall system.

The results of the case study calculations illustrate the need for new approaches to limit thermal bridging in total precast concrete building design as code evolution demands higher effective thermal performance.

Appendix A

Case Study Thermal Performance Spreadsheets

BC Hydro powersmart FORTIS BC™

Scenario Description

Baseline
Create New Worksheet
Copy to New Worksheet
Reset Current WorkSheet

Enhanced Thermal Performance Spread Sheet SI Units

Change Units

Clear Field Area Method

Select Area Calculation (Choose One)	Area	Units
⊙ Sum of Active Clear Field Areas (Default)	6460.00	m^2
○ User Defined Area	Enter User Defined Opaque Area	m^2

Overall Opaque Wall Thermal Performance Values

Base Building		Proposed Building		% Below Baseline
Opaque USI-Value (W/m^2K)	Enter Base Building U-Value	Opaque USI-Value (W/m^2K)	0.819	-
Effective RSI-Value (m^2K/W)	-	Effective RSI-Value (m^2K/W)	1.2	

Proposed Building Entries

								Totals	5288.5	100%
Add/Remove Detail	Transmittance Type	Include	Transmittance Description	Area, Length or Amount Takeoff	Units	Transmittance Value	Units	Source Reference	Heat Flow (W/K)	%Total Heat Flow
Add Clear Field	Clear Field	☑	Precast w/ 4" c.i. & 2.5" stud ccSPF	6460	m^2	0.172	W/m^2K	Table 2-2	1111.1	21%
Add Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Floor to Wall	582	m	0.913	W/mK	CPCI Table 13	531.4	10%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Balcony to Wall	497	m	0.913	W/mK	CPCI Table 13	453.8	9%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Internal Wall	126	m	0.666	W/mK	BETBG 7.2.2	83.9	2%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Roof to Wall	37	m	0.579	W/mK	BETBG 7.5.6	21.4	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Wall to Parking	58	m	0.674	W/mK	BETBG 7.7.1 (R-15)	39.1	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Window 1 Header	672	m	0.224	W/mK	BETBG 7.3.3D	150.5	3%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Window 1 Jamb	1075	m	0.388	W/mK	BETBG 7.3.3D	417.1	8%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Window 1 Sill	672	m	0.333	W/mK	BETBG 7.3.3D	223.8	4%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Door 1 Header	50	m	0.224	W/mK	BETBG 7.3.3D	11.2	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Door 1 Jamb	220	m	0.388	W/mK	BETBG 7.3.3D	85.4	2%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Floor to Wall	1276	m	0.328	W/mK	CPCI Table B1	418.5	8%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Balcony to Wall	619	m	0.328	W/mK	CPCI Table B1	203.0	4%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Internal Wall	603	m	0.211	W/mK	BETBG 7.2.2	127.2	2%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Outrigger Support	27	m	0.805	W/mK	BETBG 7.2.2	21.7	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non - Structural - Roof to Wall	95	m	0.579	W/mK	BETBG 7.5.6	55.0	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Wall to Parking	95	m	0.674	W/mK	BETBG 7.7.1 (R-15)	64.0	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 1 Header	336	m	0.224	W/mK	BETBG 7.3.3D	75.3	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 1 Jamb	538	m	0.388	W/mK	BETBG 7.3.3D	208.7	4%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 1 Sill	336	m	0.333	W/mK	BETBG 7.3.3D	111.9	2%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 2 Header	227	m	0.224	W/mK	BETBG 7.3.3D	50.8	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 2 Jamb	403	m	0.388	W/mK	BETBG 7.3.3D	156.4	3%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 2 Sill	227	m	0.333	W/mK	BETBG 7.3.3D	75.6	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 3 Header	187	m	0.224	W/mK	BETBG 7.3.3D	41.9	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 3 Jamb	461	m	0.388	W/mK	BETBG 7.3.3D	178.9	3%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 4 Header	50	m	0.224	W/mK	BETBG 7.3.3D	11.2	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 4 Jamb	220	m	0.388	W/mK	BETBG 7.3.3D	85.4	2%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Door 1 Header	92	m	0.224	W/mK	BETBG 7.3.3D	20.6	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Door 1 Jamb	405	m	0.388	W/mK	BETBG 7.3.3D	157.1	3%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Door 2 Header	50	m	0.224	W/mK	BETBG 7.3.3D	11.2	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Door 2 Jamb	220	m	0.388	W/mK	BETBG 7.3.3D	85.4	2%
Add Point Interface Detail	Point Interface Detail	☑	Brick Ties	Enter Amount Here	#	Enter Chi-Value Here	W/K	Enter Source Here	-	-

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Scenario Description

Baseline

Create New Worksheet

Copy to New Worksheet

Reset Current WorkSheet

Enhanced Thermal Performance Spread Sheet IP Units

Change Units

Clear Field Area Method

Select Area Calculation (Choose One)	Area	Units
⊙ Sum of Active Clear Field Areas (Default)	69534.85	ft²
○ User Defined Area	Enter User Defined Opaque Area	ft²

Overall Opaque Wall Thermal Performance Values

Base Building		Proposed Building		% Below Baseline
Opaque U-Value (BTU/hr ft² °F)	Enter Base Building U-Value	Opaque U-Value (BTU/hr ft² °F)	0.144	-
Effective R-Value (hr ft² °F/BTU)	-	Effective R-Value (hr ft² °F/BTU)	6.9	

Proposed Building Entries

									Totals	10025.5	100%
Add/Remove Detail	Transmittance Type	Include	Transmittance Description	Area, Length or Amount Takeoff	Units	Transmittance Value	Units	Source Reference	Heat Flow (BTU/hr°F)	%Total Heat Flow
Add Clear Field	Clear Field	☑	Precast w/ 4" c.i. & 2.5" stud ccSPF	69535	ft²	0.030	BTU/ hr ft² °F	Table 2-2	2106.4	21%
Add Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Floor to Wall	1909	ft	0.528	BTU/ hr ft °F	CPCI Table 13	1007.3	10%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Balcony to Wall	1631	ft	0.528	BTU/ hr ft °F	CPCI Table 13	860.2	9%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Internal Wall	413	ft	0.385	BTU/ hr ft °F	BETBG 7.2.2	159.1	2%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Roof to Wall	121	ft	0.335	BTU/ hr ft °F	BETBG 7.5.6	40.6	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Wall to Parking	190	ft	0.389	BTU/ hr ft °F	BETBG 7.7.1 (R-15)	74.1	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Window 1 Header	2205	ft	0.129	BTU/ hr ft °F	BETBG 7.3.3D	285.4	3%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Window 1 Jamb	3527	ft	0.224	BTU/ hr ft °F	BETBG 7.3.3D	790.7	8%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Window 1 Sill	2205	ft	0.192	BTU/ hr ft °F	BETBG 7.3.3D	424.2	4%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Door 1 Header	164	ft	0.129	BTU/ hr ft °F	BETBG 7.3.3D	21.2	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Door 1 Jamb	722	ft	0.224	BTU/ hr ft °F	BETBG 7.3.3D	161.8	2%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Floor to Wall	4186	ft	0.190	BTU/ hr ft °F	CPCI Table B1	793.4	8%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Balcony to Wall	2031	ft	0.190	BTU/ hr ft °F	CPCI Table B1	384.9	4%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Internal Wall	1978	ft	0.122	BTU/ hr ft °F	BETBG 7.2.2	241.2	2%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Outrigger Support	89	ft	0.465	BTU/ hr ft °F	BETBG 7.2.2	41.2	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non - Structural - Roof to Wall	312	ft	0.335	BTU/ hr ft °F	BETBG 7.5.6	104.3	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Wall to Parking	312	ft	0.389	BTU/ hr ft °F	BETBG 7.7.1 (R-15)	121.4	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 1 Header	1102	ft	0.129	BTU/ hr ft °F	BETBG 7.3.3D	142.7	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 1 Jamb	1765	ft	0.224	BTU/ hr ft °F	BETBG 7.3.3D	395.7	4%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 1 Sill	1102	ft	0.192	BTU/ hr ft °F	BETBG 7.3.3D	212.1	2%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 2 Header	745	ft	0.129	BTU/ hr ft °F	BETBG 7.3.3D	96.4	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 2 Jamb	1322	ft	0.224	BTU/ hr ft °F	BETBG 7.3.3D	296.4	3%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 2 Sill	745	ft	0.192	BTU/ hr ft °F	BETBG 7.3.3D	143.3	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 3 Header	614	ft	0.129	BTU/ hr ft °F	BETBG 7.3.3D	79.4	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 3 Jamb	1512	ft	0.224	BTU/ hr ft °F	BETBG 7.3.3D	339.1	3%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 4 Header	164	ft	0.129	BTU/ hr ft °F	BETBG 7.3.3D	21.2	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 4 Jamb	722	ft	0.224	BTU/ hr ft °F	BETBG 7.3.3D	161.8	2%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Door 1 Header	302	ft	0.129	BTU/ hr ft °F	BETBG 7.3.3D	39.1	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Door 1 Jamb	1329	ft	0.224	BTU/ hr ft °F	BETBG 7.3.3D	297.9	3%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Door 2 Header	164	ft	0.129	BTU/ hr ft °F	BETBG 7.3.3D	21.2	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Door 2 Jamb	722	ft	0.224	BTU/ hr ft °F	BETBG 7.3.3D	161.8	2%
Add Point Interface Detail	Point Interface Detail	☑	Brick Ties	Enter Amount Here	#	Enter Chi-Value Here	BTU/ hr °F	Enter Source Here	-	-

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Scenario Description

Improved Details

Create New Worksheet

Copy to New Worksheet

Reset Current WorkSheet

Enhanced Thermal Performance Spread Sheet SI Units

Change Units

Clear Field Area Method

Select Area Calculation (Choose One)	Area	Units
⊙ Sum of Active Clear Field Areas (Default)	6460.00	m^2
○ User Defined Area	Enter User Defined Opaque Area	m^2

Overall Opaque Wall Thermal Performance Values

Base Building		Proposed Building		% Below Baseline
Opaque USI-Value (W/m^2K)	0.819	Opaque USI-Value (W/m^2K)	0.470	✔ -43%
Effective RSI-Value (m^2K/W)	1.2	Effective RSI-Value (m^2K/W)	2.1	

Proposed Building Entries

									Totals	3036.8	100%
Add/Remove Detail	Transmittance Type	Include	Transmittance Description	Area, Length or Amount Takeoff	Units	Transmittance Value	Units	Source Reference	Heat Flow (W/K)	%Total Heat Flow
Add Clear Field	Clear Field	☑	Precast w/ 4" c.i. & 2.5" stud ccSPF	6460	m^2	0.172	W/m^2K	Table 2-2	1111.1	37%
Add Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Floor to Wall	582	m	0.588	W/mK	RDH Simulation	342.2	11%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Balcony to Wall	497	m	0.588	W/mK	RDH Simulation	292.2	10%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Internal Wall	126	m	0.211	W/mK	BETBG 7.2.2	26.6	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Roof to Wall	37	m	0.216	W/mK	BETBG 7.5.7B	8.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Wall to Parking	58	m	0.674	W/mK	BETBG 7.7.1 (R-15)	39.1	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Window 1 Header	672	m	0.139	W/mK	BETBG 7.3.11D	93.4	3%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Window 1 Jamb	1075	m	0.051	W/mK	BETBG 7.3.11D	54.8	2%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Window 1 Sill	672	m	-0.040	W/mK	BETBG 7.3.11D	-26.9	-1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Door 1 Header	50	m	0.139	W/mK	BETBG 7.3.11D	6.9	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Door 1 Jamb	220	m	0.051	W/mK	BETBG 7.3.11D	11.2	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Floor to Wall	1276	m	0.328	W/mK	CPCI Table B1	418.5	14%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Balcony to Wall	619	m	0.328	W/mK	CPCI Table B1	203.0	7%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Internal Wall	603	m	0.211	W/mK	CPCI Table B1	127.2	4%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Outrigger Support	27	m	0.805	W/mK	BETBG 7.2.2	21.7	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non - Structural - Roof to Wall	95	m	0.216	W/mK	BETBG 7.5.7B	20.5	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Wall to Parking	95	m	0.674	W/mK	BETBG 7.7.1 (R-15)	64.0	2%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 1 Header	336	m	0.139	W/mK	BETBG 7.3.11D	46.7	2%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 1 Jamb	538	m	0.051	W/mK	BETBG 7.3.11D	27.4	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 1 Sill	336	m	-0.040	W/mK	BETBG 7.3.11D	-13.4	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 2 Header	227	m	0.139	W/mK	BETBG 7.3.11D	31.6	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 2 Jamb	403	m	0.051	W/mK	BETBG 7.3.11D	20.6	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 2 Sill	227	m	-0.040	W/mK	BETBG 7.3.11D	-9.1	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 3 Header	187	m	0.139	W/mK	BETBG 7.3.11D	26.0	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 3 Jamb	461	m	0.051	W/mK	BETBG 7.3.11D	23.5	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 4 Header	50	m	0.139	W/mK	BETBG 7.3.11D	6.9	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 4 Jamb	220	m	0.051	W/mK	BETBG 7.3.11D	11.2	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Door 1 Header	92	m	0.139	W/mK	BETBG 7.3.11D	12.8	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Door 1 Jamb	405	m	0.051	W/mK	BETBG 7.3.11D	20.7	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Door 2 Header	50	m	0.139	W/mK	BETBG 7.3.11D	6.9	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Door 2 Jamb	220	m	0.051	W/mK	BETBG 7.3.11D	11.2	0%
Add Point Interface Detail	Point Interface Detail	☑	Brick Ties	Enter Amount Here	#	Enter Chi-Value Here	W/K	Enter Source Here	-	-

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Scenario Description

Improved Details

Create New Worksheet

Copy to New Worksheet

Reset Current WorkSheet

Enhanced Thermal Performance Spread Sheet IP Units

Change Units

Clear Field Area Method

Select Area Calculation (Choose One)	Area	Units
⊙ Sum of Active Clear Field Areas (Default)	69534.84	ft²
○ User Defined Area	Enter User Defined Opaque Area	ft²

Overall Opaque Wall Thermal Performance Values

Base Building		Proposed Building		% Below Baseline
Opaque U-Value (BTU/hr ft² °F)	0.144	Opaque U-Value (BTU/hr ft² °F)	0.083	✔ -43%
Effective R-Value (hr ft² °F/BTU)	6.9	Effective R-Value (hr ft² °F/BTU)	12.1	

Proposed Building Entries

								Totals	5757.0	100%
Add/Remove Detail	Transmittance Type	Include	Transmittance Description	Area, Length or Amount Takeoff	Units	Transmittance Value	Units	Source Reference	Heat Flow (BTU/hr°F)	%Total Heat Flow
Add Clear Field	Clear Field	☑	Precast w/ 4" c.i. & 2.5" stud ccSPF	69535	ft²	0.030	BTU/ hr ft² °F	Table 2-2	2106.4	37%
Add Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Floor to Wall	1909	ft	0.340	BTU/ hr ft °F	RDH Simulation	648.7	11%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Balcony to Wall	1631	ft	0.340	BTU/ hr ft °F	RDH Simulation	554.0	10%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Internal Wall	413	ft	0.122	BTU/ hr ft °F	BETBG 7.2.2	50.4	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Roof to Wall	121	ft	0.125	BTU/ hr ft °F	BETBG 7.5.7B	15.2	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Wall to Parking	190	ft	0.389	BTU/ hr ft °F	BETBG 7.7.1 (R-15)	74.1	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Window 1 Header	2205	ft	0.080	BTU/ hr ft °F	BETBG 7.3.11D	177.1	3%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Window 1 Jamb	3527	ft	0.029	BTU/ hr ft °F	BETBG 7.3.11D	103.9	2%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Window 1 Sill	2205	ft	-0.023	BTU/ hr ft °F	BETBG 7.3.11D	-51.0	-1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Door 1 Header	164	ft	0.080	BTU/ hr ft °F	BETBG 7.3.11D	13.2	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Door 1 Jamb	722	ft	0.029	BTU/ hr ft °F	BETBG 7.3.11D	21.3	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Floor to Wall	4186	ft	0.190	BTU/ hr ft °F	CPCI Table B1	793.4	14%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Balcony to Wall	2031	ft	0.190	BTU/ hr ft °F	CPCI Table B1	384.9	7%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Internal Wall	1978	ft	0.122	BTU/ hr ft °F	CPCI Table B1	241.2	4%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Outrigger Support	89	ft	0.465	BTU/ hr ft °F	BETBG 7.2.2	41.2	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non - Structural - Roof to Wall	312	ft	0.125	BTU/ hr ft °F	BETBG 7.5.7B	38.9	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Wall to Parking	312	ft	0.389	BTU/ hr ft °F	BETBG 7.7.1 (R-15)	121.4	2%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 1 Header	1102	ft	0.080	BTU/ hr ft °F	BETBG 7.3.11D	88.5	2%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 1 Jamb	1765	ft	0.029	BTU/ hr ft °F	BETBG 7.3.11D	52.0	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 1 Sill	1102	ft	-0.023	BTU/ hr ft °F	BETBG 7.3.11D	-25.5	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 2 Header	745	ft	0.080	BTU/ hr ft °F	BETBG 7.3.11D	59.8	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 2 Jamb	1322	ft	0.029	BTU/ hr ft °F	BETBG 7.3.11D	39.0	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 2 Sill	745	ft	-0.023	BTU/ hr ft °F	BETBG 7.3.11D	-17.2	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 3 Header	614	ft	0.080	BTU/ hr ft °F	BETBG 7.3.11D	49.3	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 3 Jamb	1512	ft	0.029	BTU/ hr ft °F	BETBG 7.3.11D	44.6	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 4 Header	164	ft	0.080	BTU/ hr ft °F	BETBG 7.3.11D	13.2	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 4 Jamb	722	ft	0.029	BTU/ hr ft °F	BETBG 7.3.11D	21.3	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Door 1 Header	302	ft	0.080	BTU/ hr ft °F	BETBG 7.3.11D	24.2	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Door 1 Jamb	1329	ft	0.029	BTU/ hr ft °F	BETBG 7.3.11D	39.2	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Door 2 Header	164	ft	0.080	BTU/ hr ft °F	BETBG 7.3.11D	13.2	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Door 2 Jamb	722	ft	0.029	BTU/ hr ft °F	BETBG 7.3.11D	21.3	0%
Add Point Interface Detail	Point Interface Detail	☑	Brick Ties	Enter Amount Here	#	Enter Chi-Value Here	BTU/ hr °F	Enter Source Here	-	-

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FORTIS BC™

Scenario Description

NECB2017 Compliant

Create New Worksheet

Copy to New Worksheet

Reset Current WorkSheet

Enhanced Thermal Performance Spread Sheet SI Units

Change Units

Clear Field Area Method

Select Area Calculation (Choose One)	Area	Units
⊙ Sum of Active Clear Field Areas (Default)	6460.00	m^2
○ User Defined Area	Enter User Defined Opaque Area	m^2

Overall Opaque Wall Thermal Performance Values

Base Building		Proposed Building		% Below Baseline
Opaque USI-Value (W/m^2K)	0.819	Opaque USI-Value (W/m^2K)	0.278	✔ -66%
Effective RSI-Value (m^2K/W)	1.2	Effective RSI-Value (m^2K/W)	3.6	

Proposed Building Entries

									Totals	1797.8	100%
Add/Remove Detail	Transmittance Type	Include	Transmittance Description	Area, Length or Amount Takeoff	Units	Transmittance Value	Units	Source Reference	Heat Flow (W/K)	%Total Heat Flow
Add Clear Field	Clear Field	☑	Precast w/6" c.i. & 2.5" stud ccSPF	6460	m^2	0.128	W/m^2K	Table 2-2	825.0	46%
Add Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Floor to Wall	582	m	0.366	W/mK	RDH Simulation	213.0	12%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Balcony to Wall	497	m	0.366	W/mK	RDH Simulation	181.9	10%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Internal Wall	126	m	0.109	W/mK	BETBG 7.2.2	13.7	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Roof to Wall	37	m	0.216	W/mK	BETBG 7.5.7B	8.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Wall to Parking	58	m	0.674	W/mK	BETBG 7.7.1 (R-15)	39.1	2%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Window 1 Header	672	m	0.000	W/mK	Assume Negligible	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Window 1 Jamb	1075	m	0.000	W/mK	Assume Negligible	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Window 1 Sill	672	m	0.000	W/mK	Assume Negligible	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Door 1 Header	50	m	0.000	W/mK	Assume Negligible	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Door 1 Jamb	220	m	0.000	W/mK	Assume Negligible	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Floor to Wall	1276	m	0.192	W/mK	CPCI Table B1	245.0	14%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Balcony to Wall	619	m	0.192	W/mK	CPCI Table B1	118.8	7%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Internal Wall	630	m	0.109	W/mK	CPCI Table B2	68.7	4%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Outrigger Support	0	m	0.805	W/mK	BETBG 7.2.2	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non - Structural - Roof to Wall	95	m	0.216	W/mK	BETBG 7.2.7B	20.5	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Wall to Parking	95	m	0.674	W/mK	BETBG 7.7.1 (R-15)	64.0	4%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 1 Header	336	m	0.000	W/mK	Assume Negligible	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 1 Jamb	538	m	0.000	W/mK	Assume Negligible	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 1 Sill	336	m	0.000	W/mK	Assume Negligible	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 2 Header	227	m	0.000	W/mK	Assume Negligible	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 2 Jamb	403	m	0.000	W/mK	Assume Negligible	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 2 Sill	227	m	0.000	W/mK	Assume Negligible	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 3 Header	187	m	0.000	W/mK	Assume Negligible	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 3 Jamb	461	m	0.000	W/mK	Assume Negligible	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 4 Header	50	m	0.000	W/mK	Assume Negligible	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 4 Jamb	220	m	0.000	W/mK	Assume Negligible	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Door 1 Header	92	m	0.000	W/mK	Assume Negligible	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Door 1 Jamb	405	m	0.000	W/mK	Assume Negligible	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Door 2 Header	50	m	0.000	W/mK	Assume Negligible	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Door 2 Jamb	220	m	0.000	W/mK	Assume Negligible	0.0	0%
Add Point Interface Detail	Point Interface Detail	☑	Brick Ties	Enter Amount Here	#	Enter Chi-Value Here	W/K	Enter Source Here	-	-

BC hydro powersmart

FORTIS BC

Scenario Description

NECB2017 Compliant

Create New Worksheet

Copy to New Worksheet

Reset Current WorkSheet

Enhanced Thermal Performance Spread Sheet IP Units

Change Units

Clear Field Area Method

Select Area Calculation (Choose One)	Area	Units
⊙ Sum of Active Clear Field Areas (Default)	69534.84	ft²
○ User Defined Area	Enter User Defined Opaque Area	ft²

Overall Opaque Wall Thermal Performance Values

Base Building		Proposed Building		% Below Baseline
Opaque U-Value (BTU/hr ft² °F)	0.144	Opaque U-Value (BTU/hr ft² °F)	0.049	✔ -66%
Effective R-Value (hr ft² °F/BTU)	6.9	Effective R-Value (hr ft² °F/BTU)	20.4	

Proposed Building Entries

								Totals	3408.2	100%
Add/Remove Detail	Transmittance Type	Include	Transmittance Description	Area, Length or Amount Takeoff	Units	Transmittance Value	Units	Source Reference	Heat Flow (BTU/hr°F)	%Total Heat Flow
Add Clear Field	Clear Field	☑	Precast w/6" c.i. & 2.5" stud ccSPF	69535	ft²	0.022	BTU/ hr ft² °F	Table 2-2	1564.0	46%
Add Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Floor to Wall	1909	ft	0.211	BTU/ hr ft °F	RDH Simulation	403.8	12%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Balcony to Wall	1631	ft	0.211	BTU/ hr ft °F	RDH Simulation	344.8	10%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Internal Wall	413	ft	0.063	BTU/ hr ft °F	BETBG 7.2.2	26.0	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Roof to Wall	121	ft	0.125	BTU/ hr ft °F	BETBG 7.5.7B	15.2	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Wall to Parking	190	ft	0.389	BTU/ hr ft °F	BETBG 7.7.1 (R-15)	74.1	2%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Window 1 Header	2205	ft	0.000	BTU/ hr ft °F	Assume Negligible	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Window 1 Jamb	3527	ft	0.000	BTU/ hr ft °F	Assume Negligible	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Window 1 Sill	2205	ft	0.000	BTU/ hr ft °F	Assume Negligible	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Door 1 Header	164	ft	0.000	BTU/ hr ft °F	Assume Negligible	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Structural Wall - Door 1 Jamb	722	ft	0.000	BTU/ hr ft °F	Assume Negligible	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Floor to Wall	4186	ft	0.111	BTU/ hr ft °F	CPCI Table B1	464.4	14%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Balcony to Wall	2031	ft	0.111	BTU/ hr ft °F	CPCI Table B1	225.3	7%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Internal Wall	2067	ft	0.063	BTU/ hr ft °F	CPCI Table B2	130.2	4%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Outrigger Support	0	ft	0.465	BTU/ hr ft °F	BETBG 7.2.2	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non - Structural - Roof to Wall	312	ft	0.125	BTU/ hr ft °F	BETBG 7.2.7B	38.9	1%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Wall to Parking	312	ft	0.389	BTU/ hr ft °F	BETBG 7.7.1 (R-15)	121.4	4%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 1 Header	1102	ft	0.000	BTU/ hr ft °F	Assume Negligible	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 1 Jamb	1765	ft	0.000	BTU/ hr ft °F	Assume Negligible	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 1 Sill	1102	ft	0.000	BTU/ hr ft °F	Assume Negligible	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 2 Header	745	ft	0.000	BTU/ hr ft °F	Assume Negligible	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 2 Jamb	1322	ft	0.000	BTU/ hr ft °F	Assume Negligible	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 2 Sill	745	ft	0.000	BTU/ hr ft °F	Assume Negligible	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 3 Header	614	ft	0.000	BTU/ hr ft °F	Assume Negligible	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 3 Jamb	1512	ft	0.000	BTU/ hr ft °F	Assume Negligible	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 4 Header	164	ft	0.000	BTU/ hr ft °F	Assume Negligible	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Window 4 Jamb	722	ft	0.000	BTU/ hr ft °F	Assume Negligible	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Door 1 Header	302	ft	0.000	BTU/ hr ft °F	Assume Negligible	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Door 1 Jamb	1329	ft	0.000	BTU/ hr ft °F	Assume Negligible	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Door 2 Header	164	ft	0.000	BTU/ hr ft °F	Assume Negligible	0.0	0%
Remove Linear Interface Detail	Linear Interface Detail	☑	Non-Structural - Door 2 Jamb	722	ft	0.000	BTU/ hr ft °F	Assume Negligible	0.0	0%
Add Point Interface Detail	Point Interface Detail	☑	Brick Ties	Enter Amount Here	#	Enter Chi-Value Here	BTU/ hr °F	Enter Source Here	-	-