

## MASONRY VENEER SUPPORT DETAILS: THERMAL BRIDGING

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### ABSTRACT

The use of increased levels of insulation within masonry veneer walls places increased demands on the gravity support systems including exposed slab edge, edge-connected steel angles, and discretely connected steel angles. In addition to structural and durability criteria, designers also need to assess masonry gravity support systems for thermal continuity and thermal bridging.

This paper examines and summarizes the essential thermal design criteria related to masonry veneer gravity support systems. The results from three-dimensional thermal modelling of typical masonry veneer gravity support systems is presented to illustrate the impact of thermal bridging and the inherent benefits of de-coupling masonry supports from the building structure.

This paper will prove useful to both masonry contractors and designers responsible for the construction or design and detailing of masonry veneer gravity support systems.

**KEYWORDS:** masonry veneer, thermal bridging

### INTRODUCTION

To achieve compliance with current building codes and standards, design criteria for masonry veneer support systems need to include structural capacity, deflection control, building movements, thermal conductance, and durability. While most design criteria are well understood and appreciated, current building codes prescribe multiple paths for compliance with overall building energy performance; and the impact and responsibility for addressing thermal bridging of the masonry gravity support system may not be collectively appreciated by the design and construction community. The demands and expectations of component and assembly thermal performance vary with each compliance path. The significance and importance of each design criteria also varies with the energy code compliance path chosen for the building.

Awareness and understanding of the energy compliance path for the building is required in order to establish the design criteria requirements for masonry veneer support systems in either combustible or non-combustible construction.

### BACKGROUND

Over the years the application of masonry veneer as a cladding material, supported laterally by steel or wood framing, or poured concrete, has become a traditional form of exterior wall construction. The insulation, or thermal performance, of these traditional masonry veneer wall assemblies was not critical; and nominal R-values (IP) ranged from R-12 to R-20, with effective

R-values of R-5 to R-7 accounting for thermal bridging of steel framing and slab edges. With building codes increasing thermal performance requirements and moving towards effective R-values and the use of continuous insulation, traditional masonry veneer wall assemblies will only satisfy basic prescriptive criteria in certain climatic zones. Design and construction standards have made significant moves towards the use of continuous exterior insulation to address the need for improved thermal performance; and this design evolution places new demands on the design of masonry veneer support systems.

In addition to demands for better and more thermally efficient wall assemblies, most building code energy compliance paths require overall building thermal performance to account for thermal bridging (energy loss) at penetrations through the insulation material. Penetrations such as brick ties and steel shelf angle supports penetrate the insulation in a masonry veneer wall assembly, and generally need to be accounted for as part of the overall building thermal performance requirements for energy compliance.

This paper summarizes current design criteria for the support of masonry veneer with a focus on the impact of thermal bridging on design options and overall building thermal performance. A companion paper at this conference by Finch, Wilson, and Higgins (2013) has been prepared which specifically deals with thermal bridging issues at brick masonry veneer connectors.

## **SUMMARY OF THERMAL INSULATION REQUIREMENTS IN CANADIAN BUILDING CODES**

In Canada there are two national model codes that specify energy efficiency provisions for buildings: the National Building Code of Canada (NBC) and the National Energy Code for Buildings (NECB), which was previously called the Model National Energy Code for Buildings (MNECB). These National Codes are adopted either with or without modifications by each of the Provinces and Territories. The Municipalities of Vancouver, BC and Toronto, ON each have a modified version of the Provincial Building Code written into their respective municipal building bylaws.

The thermal performance requirements for the building enclosure within the NBC are intended for single family housing and low-rise buildings (Part 9 buildings). The thermal performance requirements within the NECB (previously MNECB) are generally intended for larger buildings (Part 3). The adoption of either the 1997 MNECB or 2011 NECB requirements depends on the reference within each Provincial Building Code.

The Province of BC has adopted ASHRAE 90.1-2004 and Ontario has adopted a combination of ASHRAE 90.1-1989 and 2004 for large building energy code compliance. The City of Vancouver through its Building Bylaw has adopted ASHRAE 90.1-2007 and the City of Toronto through its Municipal Code has adopted ASHRAE 90.1-2004. Both the Province of BC and City of Vancouver are in the process of public review to adopt ASHRAE 90.1-2010 (plus NECB 2011). The 1997 MNECB building enclosure performance requirements are often used in LEED energy simulations and the new 2011 NECB is currently undergoing review for adoption into many of the provinces.

Compliance of the building enclosure with ASHRAE Standard 90.1 requires meeting prescriptive mandatory requirements as well as one of the three building enclosure compliance

paths. The three compliance paths include, in order of lowest to highest complexity and level of work required to demonstrate building project compliance: Prescriptive Building Envelope (Enclosure) Option, Building Envelope (Enclosure) Trade-off Option, or Energy Cost Budget Method.

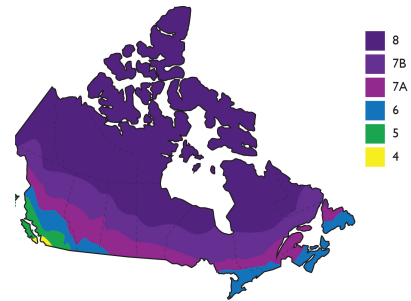
With respect to design criteria for masonry veneer supports, the above compliance paths will influence the significance of the various criteria in the following manner:

- NBC (Part 9 or low rise buildings): Code requirements are related to nominal insulation R-values. Nominal insulation R-values do not account for losses due to thermal bridging. Until such time that the nominal insulation R-values include requirements for continuous insulation (ci) the basic design criteria for masonry veneer supports will not vary from traditional considerations. It is important to note that proposed changes to Part 9 insulation requirements within the 2010 NBC, similar to that within the new 2011 NECB (replacing the older 1997 MNECB) will require effective R-values to be considered, and therefore will affect masonry veneer support design in the future.
- NECB and ASHRAE 90.1 Prescriptive Compliance path (Part 3 or high rise buildings). In addition to minimum nominal R-value requirements for insulation, the standard also provides the option for maximum assembly U-values (minimum R-values). The determination of an assembly U-value requires the calculation of an effective assembly R-value accounting for type of framing and degree of thermal bridging. The use of effective R-values is a more rational measure of the true thermal performance of an assembly. The use of effective R-values rather than nominal R-values in building and energy codes is becoming more common because two and three-dimensional finite element heat flow calculation software is readily available and used by practitioners to calculate effective R-values. Depending on the wall type and climatic zone in consideration, traditional masonry veneer wall assemblies will not satisfy the prescriptive requirements of ASHRAE 90.1 and the design criteria for masonry veneer supports will be affected.
- NECB and ASHRAE 90.1 Building Envelope Trade Off and Energy Cost Budget. In most situations, the distribution of opaque wall and fenestration area does not satisfy the basic limitations governing the use of the prescriptive compliance path. The prescriptive compliance path is generally only available for buildings with a fenestration area less than 40 to 50% of the overall wall area. Overall building compliance requires demonstration that the “proposed design” achieves the same energy performance as a “base-line” building that would otherwise be compliant with the standard. With respect to the design criteria for masonry veneer supports, this means that the design needs to address thermal conductance, and the impact of thermal bridging becomes an important factor. The addition of “continuous insulation” also increases the importance of structural consideration as the masonry support is typically located further outboard of the building structure increasing eccentric loads and bending forces on supporting plates and angles.

## THERMAL DESIGN CRITERIA

As indicated in the previous section, the thermal design criteria are going to vary with the overall building energy compliance path. With larger buildings in Canada as the example explored in this paper, Figure 1 summarizes the minimum effective R-values currently required by NECB and ASHRAE 90.1-2010 (Part 3), within the six different Canadian Climate Zones.

Climate Zone – By Zone and HDD(°C)	NECB 2011 - Above Grade Walls (All Construction Types)	ASHRAE 90.1-2010 – Above Grade Walls Residential Building (Mass Concrete, Wood-Frame, Steel-Frame)
	Minimum Effective Assembly R-value (IP)	Minimum Effective Assembly R-values (IP)
Zone 4 - <3000 HDD	18.0	(9.6, 11.2, 15.6)
Zone 5 - 3000 – 3999 HDD	20.4	(11.1, 15.6, 15.6)
Zone 6 - 4000 – 4999 HDD	23.0	(12.5, 19.6, 15.6)
Zone 7a - 5000 – 5999 HDD	27.0	(14.1, 19.6, 15.6)
Zone 7b - 6000 – 6999 HDD	27.0	(14.1, 19.6, 15.6)
Zone 8 - >7000 HDD	31.0	(14.1, 27.8, 15.6)



**Figure 1 Minimum Effective R-Value Requirements for Building Enclosure Assemblies within 2011 NECB and ASHRAE 90.1-2010 in Canadian NECB and ASHRAE 90.1 Climate Zones (Note that within ASHRAE 90.1, The small area of Climate Zone 4 in Canada (Lower Mainland and Victoria, BC) is bumped into Climate Zone 5.**

A significant portion of the higher populated regions of British Columbia fall into zone 4 and 5, and the above effective R-value requirements will impose limitations on the use of traditional masonry veneer wall assemblies. In fact, the use of traditional (no insulation placed in the air space) masonry veneer wall assemblies will be limited to buildings that achieve compliance through the building enclosure trade off or energy cost budget at the expense of other more thermally effective assemblies. Masonry veneer assemblies do have the opportunity to exceed the above effective R-value requirements when 3 to 4 inches of continuous insulation is added to the wall assembly and support details are designed to minimize thermal bridging at shelf angles thus maximizing overall wall thermal performance.

Without considering thermal losses at shelf-angles or connectors, masonry veneer wall assembly can be designed to satisfy all the above requirements with effective R-value ranging from R-10 to R-20 depending on the amount of insulation and type of construction.

## IMPACT OF THERMAL BRIDGING

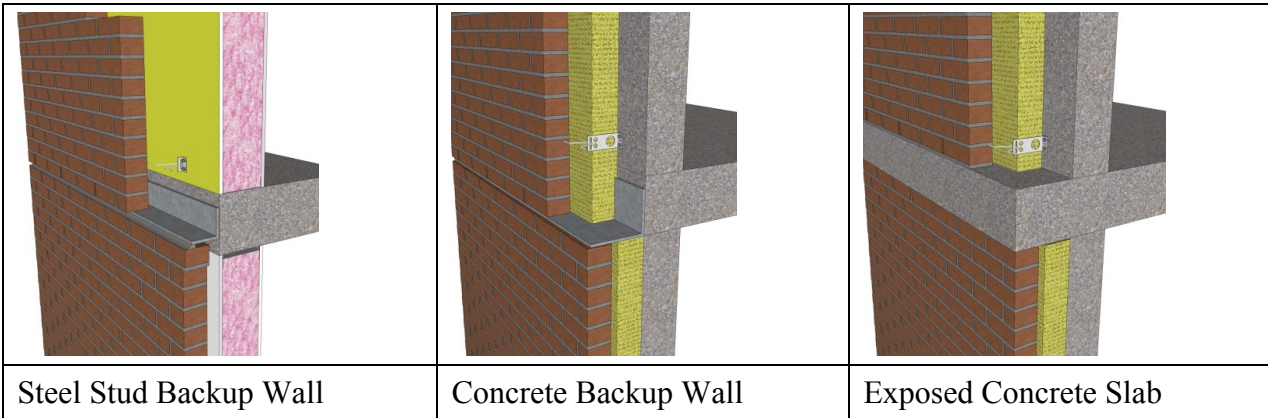
While an ideal design would minimize the use of shelf angles and maximize thermal performance, most applications require discrete and intermittent support of the masonry veneer, such as those shown in Figure 2, over the building height. The impact of thermal bridging at such shelf angles can however be reduced with alternate masonry shelf angle support strategies; such as stand-off plates and other proprietary components.

As part of building enclosure strategies developed in order to meet energy code requirements and green building criteria (i.e. LEED), there is often a need to improve the thermal performance of shelf angle supports through exterior insulated masonry walls. While the leg of a steel shelf angle attached to the concrete slab edge cutting through the exterior insulation at every floor may not appear to be a significant issue, it generally results in an effective R-value reduction in the order of 40% for the full height wall assembly. It is such a substantial reduction, that even adding thicker amounts of exterior insulation cannot overcome the thermal bridging effect, necessitating a design change to the shelf angle support.

Several different acceptable methods to reduce thermal bridging at the shelf angle support have been developed by structural engineers and product manufacturers. All of these strategies involve decoupling the direct connection of the shelf angle from the slab edge, allowing for continuous insulation behind the shelf angle, and some optimized connection from the shelf angle back to the supporting structure.

Figure 2 presents a series of sketches of the “traditional” representing common shelf angle support details that can be considered “baseline” conditions within the context of the comparative analysis presented in this paper. The common features and characteristics of the baseline masonry support details include:

- 3 ½” clay brick,
- 1” minimum airspace (ventilated),
- 4” semi-rigid mineral fibre insulation (R-4.2/inch, R-16.8 nominal)
- Connectors: 16 gauge x 2” tall x 4.5” deep stainless steel slotted L-bracket with 0.19” wire ties, spaced at 16” horizontally and 24” vertically
- 8” reinforced concrete or 5 1/2” steel stud backup wall, steel studs with 5 1/2” fibreglass insulation (R-3.6/inch, R-20 nominal),
- Interior finish



**Figure 2: Typical “Baseline” Masonry Veneer Support Details**

Replacing the concrete backup wall component in the above assemblies with either infill concrete block or un-insulated steel stud framing with gypsum sheathing would not impact the resulting R-values. Options with addition insulation (4” or more), which would generally be sufficient to meet current energy code requirements, are not presented as additional structural design consideration are required for both gravity and lateral supports.

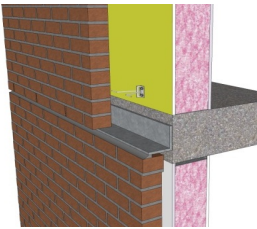
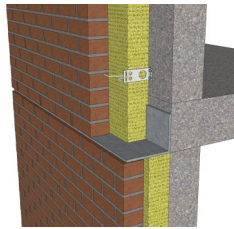
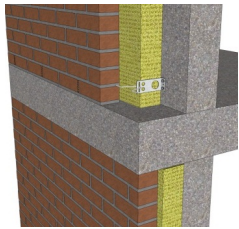
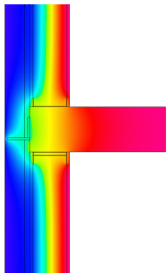
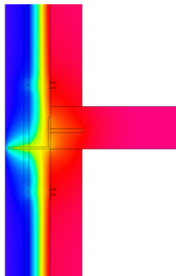
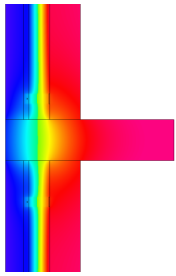
## ANALYSIS OF BASELINE MASONRY VENEER SUPPORT DETAILS

Three-dimensional thermal modelling for each wall assembly and slab edge detail was performed using the finite element program HEAT3 ([www.blocon.se](http://www.blocon.se)). The HEAT3 software package has been well tested and validated by the building industry and is commonly used to calculate effective R-values for enclosure assemblies.

For each baseline detail, the effective R-value for an 8'-8" high masonry wall (8" slab, 8'-0" floor-ceiling) including the thermal bridging through the standard brick ties and shelf angle detail is calculated. It should be noted that a shorter height wall (i.e. area below a window) would have a lower effective R-value due to the larger area weighting of the shelf angle area. As the U-value and linear transmittance psi-values are also provided, effective R-values for different height walls can also be determined.

The nominal R-value for the poured concrete backup wall, accounting for all materials and surface conditions (ignoring thermal bridging) is R-19.6 (RSI 3.45). Accounting for the effect of thermal bridging through optimized stainless steel brick ties, the effective R-value is R-17.7 (RSI 3.11), an R-value reduction of approximately 10%. A companion paper at this conference by Finch, Wilson, and Higgins (2013) provides additional information related to the impact of variations in the masonry veneer design. Use of galvanized or solid masonry connectors can increase the thermal loss in the above wall assembly by another 5% to 7%. Table 1 contains a summary of the analysis of all baseline masonry veneer support details.

**Table 1: Summary of Nominal and Effective R-Values and U-Values for Baseline Masonry Shelf Angle Support Options Showing Impact of Thermal Bridging**

	Steel Stud Backup	Poured Concrete Backup	Exposed Slab Edge
			
			
Nominal Insulation R-Value/U-Value	R-20 (RSI 3.52) U-0.05 (USI 0.284)	R-16.8 (RSI 2.95) U-0.060 (USI 0.339)	R-16.8 (RSI 2.95) U-0.060 (USI 0.339)
Effective Assembly R-Value/U-Value	R-7.3 (RSI 1.29) U-0.137 (USI 0.777)	R-10.5 (RSI 1.84) U-0.096 (USI 0.543)	R-9 (RSI 1.58) U-0.112 (USI 0.634)
Effective Reduction	63.5%	37.5%	46.4%
Linear Transmission		$\psi = 0.339$ IP (0.586 SI)	$\psi = 0.478$ IP (0.827 SI)

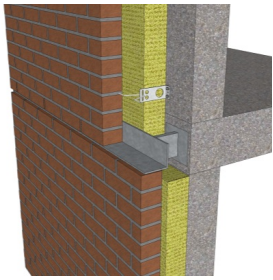
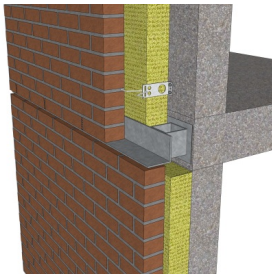
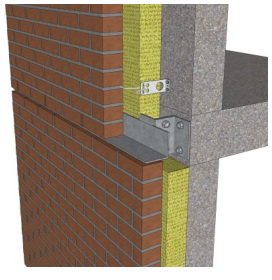
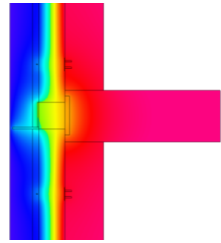
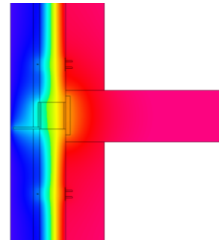
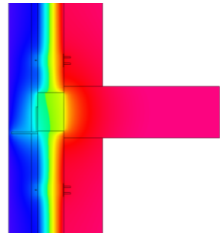


Without addressing the shelf angle connection to reduce the impact of thermal bridging, a range of 40% to 60% R-value reduction (for the level of insulation provided) can be expected for the above baseline assemblies. Such large reductions in thermal performance make it nearly impossible to support their use in any application in modern building construction seeking to comply with current energy codes. The only “baseline” option that provides an opportunity to improve overall thermal effectiveness is the poured concrete backup model with continuous insulation (recall an un-insulated steel stud backup wall or a CMU backup wall could be substituted for the poured concrete backup wall with no significant implications to the analysis).

### ANALYSIS OF ALTERNATE MASONRY VENEER SUPPORT DETAILS

The standard approach to improve the thermal effectiveness of the traditional steel shelf angle is to “stand-off” the angle with a knife plates, structural section, or overlapping angles. Reductions in overall wall assembly thermal values are reduced to approximately 15% (for the provided insulation thickness) when the design accommodated moving the shelf angle away from the slab edge using one of several common approaches. Table 2 provides a summary of the comparative analysis carried out for three alternative support details.

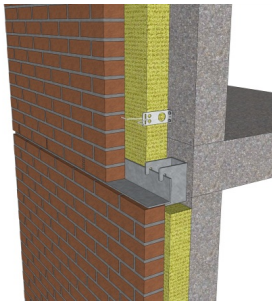
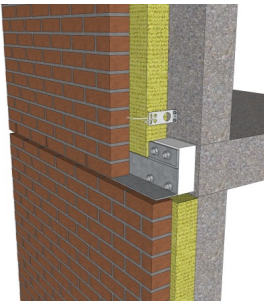
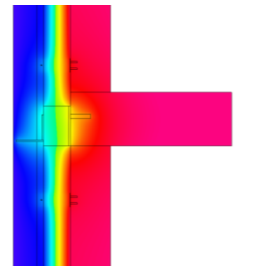
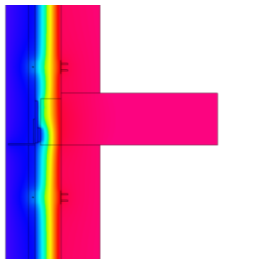
**Table 2: Summary of Nominal and Effective R-Values and U-Values for Typical Stand-Off Modifications to the Baseline Masonry Shelf Angle Support Options Showing Impact of Thermal Bridging**

	Knife Plate	HSS Structural Section	Overlapping Angles
			
			
	shelf angle: 4”x4”x1/4” outside of insulation. 4”x4”x3/4” stand-off knife plates welded to embed plates at 48” o.c.	shelf angle 4”x4”x1/4” outside insulation. 4”x4”x1/4” HSS tube welded to embed plates at 48” o.c.	shelf angle 4”x4”x1/4” outside insulation. 2-6”x4”x5/16” angles bolted to slab edge at 48” o.c.
Nominal Insulation R-Value/U-Value	R-16.8 (RSI 2.95) U-0.060 (USI 0.339)	R-16.8 (RSI 2.95) U-0.060 (USI 0.339)	R-16.8 (RSI 2.95) U-0.060 (USI 0.339)
Effective Assembly R-Value/U-Value	R-14.8 (RSI 2.6) U-0.068 (USI 0.384)	R-14.8 (RSI 2.6) U-0.068 (USI 0.385)	R-15.0 (RSI 2.64) U-0.067 (USI 0.379)
Effective Reduction	16.4%	16.5%	15.3%

Linear Transmission	$\psi = 0.096$ IP (0.166 SI)	$\psi = 0.097$ IP (0.168 SI)	$\psi = 0.089$ IP (0.153 SI)
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Proprietary connections, such as the cast-in 4-bolt stainless steel bolt thermal break, result in reductions in the 7% range. Table 3 provides a summary of the analysis undertaken on two proprietary shelf angle connections. Like most thermal bridging scenarios, this percentage R-value reduction is not linear, and increases with thicker insulation levels. Another way of looking at these shelf angle details is in terms of an effective R-value for the 8" slab area as compared to the centre of wall (R-17.7 in this wall case). This can be calculated using the linear thermal transmittance values, and works out to approximately R-1.8 for the direct attached angle (and R-0.9 for exposed slab edge), up to R-5 range for stand-off supports and R-9 for proprietary thermal break connections.

**Table 3: Summary of Nominal and Effective R-Values and U-values for Proprietary Masonry Shelf Angle Support Options Showing Impact of Thermal Bridging**

	Standoff Bracket	4-Bolt Cast-In
		
		
	shelf angle 4"x4"x1/4" outside insulation. Proprietary clip is 1/4" thick steel, 4"x4"x1/4" 6 "lg C-section. Non-welded connection. .	Shelf angle 4"x4"x1/4" outside insulation. Pre-manufactured cast-in place thermal break connection with 4 stainless steel bolts attached to 7"x7"x 3/8" plate.
Nominal Insulation R-Value/U-Value	R-16.8 (RSI 2.95) U-0.060 (USI 0.339)	R-16.8 (RSI 2.95) U-0.060 (USI 0.339)
Effective Assembly R-Value/U-Value	R-14.9 (RSI 2.62) U-0.067 (USI 0.381)	R-16.4 (RSI 2.9) U-0.061 (USI 0.345)
Effective Reduction	16.4%	7%
Linear Transmission	$\psi = 0.091$ IP (0.158 SI)	$\psi = 0.037$ IP (0.064 SI)

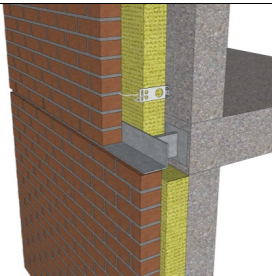
The 16% to 7% reduction in thermal R-value that is possible for shelf angle stand-off designs is a significant improvement over traditional masonry support systems. The stainless steel masonry veneer connections account for approximately 5% of the above thermal reductions. Regardless



of the representative surface area of the masonry support shelf angle (less than 1% of the weighted wall area), the impact of the thermal bridging on the effective R-value is significant.

In addition to the decoupled design for shelf angle attachment, an analysis was conducted to examine the effect of the spacing of the intermittent stand-off connections. Table 4 shows a comparison of different spacing for knife plate connection from 12" o.c. to 72" o.c. with 4" of exterior continuous insulation.

**Table 4: Summary of Nominal and Effective R-Values and U-values for Knife Plate Supported Masonry Shelf Angle Support Demonstrating Impact of Knife Plate Spacing on Thermal Bridging**

	Knife Plate					
						
	shelf angle: 4"x4"x1/4". 4"x4"x1/4" knife plates at 12" o.c.	shelf angle: 4"x4"x1/4". 4"x4"x3/8" knife plates at 24" o.c.	shelf angle: 4"x4"x1/4". 4"x4"x1/2" knife plates at 36" o.c.	shelf angle: 4"x4"x1/4". 4"x4"x3/4" knife plates at 48" o.c.	shelf angle: 4"x4"x5/16". 4"x4"x3/4" knife plates at 60" o.c.	shelf angle: 4"x4.5"x3/8". 4"x4.5"x3/4"knife plates at 72" o.c.
Nominal Insulation R-Value/U- Value	R-16.8 (RSI 2.95) U-0.060 (USI 0.339)					
Effective Assembly R-Value/U- Value	R-12.5 (RSI 2.2) U-0.080 (USI 0.454)	R-13.7 (RSI 2.42) U-0.073 (USI 0.414)	R-14.4 (RSI 2.55) U-0.069 (USI 0.393)	R-14.8 (RSI 2.6) U-0.068 (USI 0.384)	R-15.1 (RSI 2.66) U-0.066 (USI 0.376)	R-15.4 (RSI 2.7) U-0.065 (USI 0.370)
Effective Reduction	29.1%	22.3%	18.2%	16.4%	14.5%	13.1%
Linear Transmission	$\psi = 0.202$ IP (0.349 SI)	$\psi = 0.141$ IP (0.244 SI)	$\psi = 0.109$ IP (0.188 SI)	$\psi = 0.096$ IP (0.166 SI)	$\psi = 0.083$ IP (0.144 SI)	$\psi = 0.074$ IP (0.128 SI)

The different spacing of the knife plate stand-off support produces reductions from 30% at 12" down to 13% at 72". Even the worst performing support spacing (12") has a lower reduction on the overall thermal performance than a directly attached shelf angle. Increased spacing beyond 36" to 48" does not gain significant thermal effectiveness. Any reduced impact of thermal bridging gained by spacing beyond 48" may however be lost if additional anchors or increases in plate/section thickness is required. Under rigorous analysis an optimum balance between structural requirements and thermal efficiency could be defined for each different stand-off support systems.

## CONCLUSION

Building energy efficiency requirements within Canadian Energy and Building Codes have increased to the point where the use of exterior insulation within masonry walls is becoming common. The use of exterior insulation reduces thermal bridges through major structural elements such as infill framing, shear walls, columns and floor slab edges however thermal bridges still exist at all penetrations through the exterior insulation. This paper assessed the significance of the thermal bridge that occurs at the penetration through the exterior insulation at the masonry veneer shelf angle support.

While the relative area of the masonry support angle is relatively small compared to the exterior insulation (less than 1% of the surface area), the impact on the effective R-value of wall is very significant. Traditional construction approaches where the shelf angle is bolted directly to the slab edge, or the masonry is supported directly on an exposed concrete slab edge result in effective R-value reductions in the 40% range and mean that prescriptive compliance with energy code requirements will be limited to very mild climates and use in buildings with non-prescriptive compliance will require a “trade-off” with other more thermally effective assemblies.

In order to comply with prescriptive building code requirements, and/or positive contribute to the overall non-prescriptive energy code compliance for buildings; the use of alternate shelf angle support strategies where the shelf angle is supported intermittently outside of the exterior insulation are necessary. The use of intermittent supporting knife plates, HSS tubes, angle brackets and proprietary brackets are much more thermally efficient, and effective insulation reductions for whole wall assemblies are improved to approximately 11%. Drawing on the companion paper by Finch, Wilson, and Higgins (2013) the combined thermal bridge impact of de-coupled shelf angle support and stainless steel masonry veneer connectors’ results in a total R-value reduction of 16%.

The rigorous analysis presented in the paper supports the use of masonry veneer assemblies in both the prescriptive and, in a positive way, the non-prescriptive energy code compliance paths employed in current Canadian Building and Energy Codes.

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