FERO RAP TIE AND FAST SYSTEM THERMAL ANALYSIS

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Abstract

Current industry standards for overall building energy efficiency have resulted in a significant trend towards the placement of exterior semi-rigid or rigid insulation within the exterior air space behind exterior masonry veneers. Compliance with new energy standards brings attention to the impact of thermal bridging caused by masonry connectors that penetrate this exterior insulation.

Thermal bridging at masonry connectors and shelf angle supports has an impact on thermal performance and compliance with either the National Energy Code for Buildings (NECB) or ASHRAE Standard 90.1. This paper presents the results of three dimensional thermal modelling which quantifies the actual impact of thermal bridging in typical exterior masonry veneer wall assemblies. Modelling was completed for the Fero Rap tie with various backup walls, and various brick shelf angle and shelf angle support configurations. The results demonstrate that masonry tie selection on thermal performance is important and can be significant. In addition, results are also presented to illustrate the impact of thermal bridging on non-masonry cladding supported by continuous/intermittent metal Z-girts, clips or screws.

This paper provides valuable design information for professionals assessing overall building energy efficiency and code compliance.

Introduction

National, Provincial and Municipal building codes in Canada have for some time referenced either ASHRAE Standard 90.1 or the National Energy Code for Buildings (NECB, previously MNECB) for the energy efficiency requirements for buildings. Both of these energy standards have been recently updated (2011 NECB and 2010 ASHRAE 90.1) and more stringent thermal requirements for walls (i.e. minimum R-values) have been adopted.

Minimum R-values in 2011 NECB and ASHRAE 90.1 require that thermal bridging through the exterior insulation be accounted for. This means that structural framing including the studs, girts, slab edges etc. need to be considered in thermal calculations.

In some jurisdictions, Energy Codes may be interpreted to allow for some analysis simplifications to reduce the burden on designers to account for thermal bridging in enclosure assemblies. One such simplification in the allowance is for the designer to ignore the area of a thermal bridge if its area occupies less than 1% (or in some cases up to 5%) of the wall surface area for energy code compliance calculations. This means that small clips including masonry ties and shelf angles may be ignored in some energy code compliance checks. This may not seem that significant, however as will be demonstrated in this paper, metal ties and support components for brick veneer, occupying less than 0.5% of the wall surface area, can have a profound impact on effective R-values, ranging anywhere from 5% to over 50% reduction.

This paper presents typical exterior insulation reduction factors and effective R-values for masonry walls with various Fero Rap ties and the FAST System. The analysis focuses on the comparison between various Fero Rap ties and some generic brick tie products or equal or similar mass. The influence of the masonry support shelf angle is also presented, with a comparison between Fero's FAST System and other generic methods of shelf angle supports.

Background & Energy Code Requirements for Walls in Canada

Awareness and understanding of the building code, related standards, and the various energy compliance paths is required in order to establish the context for thermal considerations related to brick ties and masonry veneer support systems.

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 City of Vancouver, BC has a modified version of the BC Building Code written into their municipal building bylaws.

The NBC thermal performance requirements for the building enclosure are provided for single family housing and low-rise buildings (Part 9 buildings). The thermal performance requirements for larger (Part 3) buildings are provided by the NECB.

As part of the new energy code requirements, there has been a shift away from nominal insulation R-values towards required effective insulation R-values. Nominal insulation R-values are the rated R-value of the insulation product being installed and do not account for losses due to thermal bridging. Thermal bridging is the energy loss that occurs through framing, gaps, fasteners, structural elements, and any other penetrations through the installed insulation. Historically, most building codes have specified nominal insulation R-values in order to simplify the requirements for builders and designers of small buildings (i.e. Part 9). The effective assembly R-values that could be constructed using the nominal insulation value would of course vary depending on the type of framing and degree of thermal bridging, thereby resulting in a significant range of actual thermal performance. Therefore, the use of effective R-values is a more rational measure of the true thermal performance. The use of effective R-values rather than nominal R-values in building and energy codes is also 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.

Guidance is provided within the codes and standards regarding how to calculate the effective R-values of common enclosure assemblies. The use of nominal insulation R-values for building enclosure code compliance is still permitted in most current versions of Provincial and National Building Codes in Canada for Part 9 buildings (though this is set to change soon). While nominal insulation R-values may be referenced within codes, there is some understanding of the most common assemblies that will be built (i.e. batt insulation of certain R-value between wood or steel studs) and hence the need for continuous insulation requirements for some assemblies to ensure a minimum effective insulation level (effective R-value).

Continuous Insulation (ci) is a definition used with ASHRAE 90.1 and other Energy Codes and standards with the intended purpose of providing at least a minimum continuous layer of insulation that has an effective R-value equal to or very close to equal to its nominal R-value (i.e. no or minimal thermal bridging). Continuous insulation is often specified in energy codes alone or in conjunction with thermally bridged nominal insulation (i.e. between wood studs) to achieve higher effective R-values. This ci requirement is commonly addressed with exterior rigid or semi-rigid insulation installed on the exterior of a framed assembly. Continuous insulation could also be installed on the interior or within the middle of some assemblies, although it would not meet the requirement for continuity at floor levels in multi-storey buildings. Figure 1 summarizes the thermal insulation requirements within the 2011 NECB, ASHRAE 90.1-2010, and 2010 NBC for walls of all types in climate zones across Canada.

Climate Zone – By Zone and HDD(˚C)	NBC 2010 Part 9.36. – Above Grade Walls (Wood Frame)	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 [RSI]	Minimum Effective Assembly R-values [RSI]	Minimum Effective Assembly R-values [RSI]
Zone 4 - <3000 HDD	15.8 [2.78]	18.0 [3.17]	(9.6, 11.2, 15.6) [1.69, 1.97, 2.75]
Zone 5 - 3000 – 3999 HDD	17.5 [3.08]	20.4 [3.59]	(11.1, 15.6, 15.6) [1.95, 2.75, 2.75]
Zone 6 - 4000 – 4999 HDD	17.5 [3.08]	23.0 [4.05]	(12.5, 19.6, 15.6) [2.20, 3.45, 2.75]
Zone 7a - 5000 – 5999 HDD	17.5 [3.08]	27.0 [4.76]	(14.1, 19.6, 15.6) [2.48, 3.45, 2.75]
Zone 7b - 6000 – 6999 HDD	21.8 [3.85]	27.0 [4.76]	(14.1, 19.6, 15.6) [2.48, 3.45, 2.75]
Zone 8 - >7000 HDD	21.8 [3.85]	31.0 [5.46]	(14.1, 27.8, 15.6) [2.48, 3.45, 2.75]

Figure 1: Minimum Effective R-Value Requirements for Building Enclosure Assemblies within NBC 2010, 2011 NECB and ASHRAE 90.1-2010 in Canadian Climate Zones (Note that ASHRAE 90.1 includes Climate Zone 4, Lower Mainland and Victoria, BC with Climate Zone 5 in Canada)

Masonry Supports & Thermal Bridging

With higher effective R-Values prescribed by new energy codes, the design of masonry ties and support shelf angles is an important factor in overall energy efficiency. As will be presented in the next section, reduction of the insulation value due to thermal bridging through the masonry ties and support shelf angles can be significant. Where masonry is used with exterior continuous insulation, stainless steel or galvanized masonry ties will penetrate the exterior insulation, creating a thermal bridge through the insulation and reducing the overall insulation level (referred to as thermal degradation). This is even more pronounced at each floor level and over openings and windows, where the large steel shelf angle will reach from the front face of the masonry back to through the insulation to the support structure.

The main focus of the thermal analysis is on a the Fero Rap ties and FAST System, as compared to other generic masonry ties and shelf angle supports. The “holes” in the Fero Rap ties reduce the effect of thermal bridging by reducing the amount of material that penetrates the insulation. The Fero FAST System is discrete and installed intermittently thereby reducing the amount of steel in continuous contact with the concrete slab edge.

Thermal Analysis & Discussion

Three-dimensional thermal analysis of various masonry tie and support techniques was performed using HEAT3 (www.blocon.se). The HEAT3 software package has been well tested and validated by the building industry and is commonly used by practitioners to calculate effective R-values for enclosure assemblies (more so in Europe than North America due to more stringent European Energy code requirements and other energy efficiency programs). Three-dimensional thermal modeling, versus two dimensional modelling, allows for more accurate representation of discrete cladding attachment elements such as brick ties

The purpose of the analysis is to assess the thermal impact and provide data on the effective R-values of the Fero Rap ties and FAST System. In our experience the R-values calculated from HEAT3 tend to be conservative due to the way that surface film resistances are included in the model. Results from guarded hot-box testing and other three-dimensional finite element thermal modeling software packages may be more optimistic (by up to 5% to 10%) depending on the back-up wall and assumed material contact resistances. When accounting for real-life construction practices (e.g. air/insulation gaps around ties, extra ties and fasteners etc.) the conservative results from HEAT3 tend to be more realistic in our view.

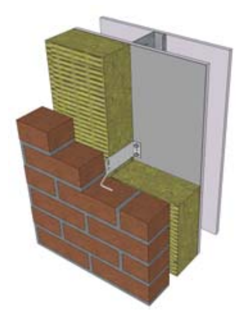
Fero Rap Ties

A series of thermal models were developed to assess the thermal bridging impact of different Fero Rap ties through exterior insulation and different backup wall types. The intent is to show the difference between the various tie products with holes and other generic brick ties. Three different back-up wall types including:

- 6” concrete,
- 3-5/8” steel studs (uninsulated), and
- 2x6 wood studs (insulated with R-22 batts)

The above wall assemblies were modelled with varying levels of exterior insulation and the following different masonry tie products.

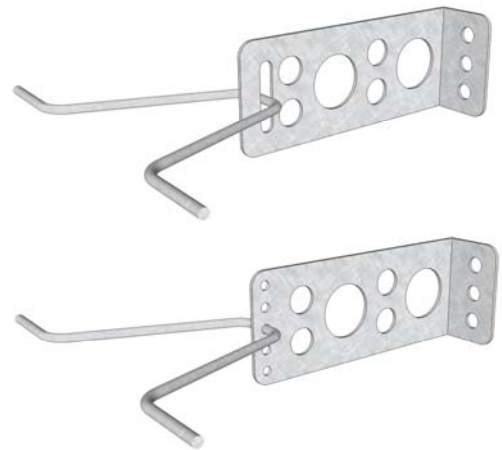
- Galvanized and stainless steel masonry tie products (2 inch x 16 gauge masonry ties)
    - Slotted face mount tie with and without punched holes
    - Holed face mount tie with and without punched holes
    - Slotted side mount tie with and without holes (steel studs only)



Standard face mount 2 inch 16 gauge masonry tie (no punched holes)

The specific products are modelled based on product data and samples. It should be noted the limitations of the modelling program prevented round holes from being used and instead equivalent sized square cut-outs were used.

Figure 2, 3, and 4 respectively present the effective R-values and percentage thermal degradation for the exterior insulation for the different ties (slotted face mount only) on three backup wall assemblies: 6" concrete, empty 3-5/8" steel studs, and R-12 insulated 2x4 wood studs. The effective R-values for the centre of wall away from slab edge or masonry shelf angle demonstrate only the impact of the masonry tie (16 inch horizontal by 24 inch vertical spacing). This works out to the surface area of wall being occupied by the masonry ties at an almost negligible 0.04%.



Fero slotted and holed Rap ties (with punched holes)

A range of exterior insulation R-values have been considered from 0 to 6 inches in nominal R-4.3/inch increments (i.e. from R-0 to R-25.8 (RSI 0 to RSI 4.54)) based on product data for exterior rigid mineral wool insulation. The results for each masonry tie type are consistent, with slight variations in the absolute R-values and percentage reductions due to the different back-up wall configurations. The back-up wall affects the thermal transfer through the brick ties due to the contact resistance of the connections, with concrete being the worst, followed by steel stud/gypsum, and wood. To convert from IP R-values to metric RSI values, divide values in the chart by a factor of 5.678.

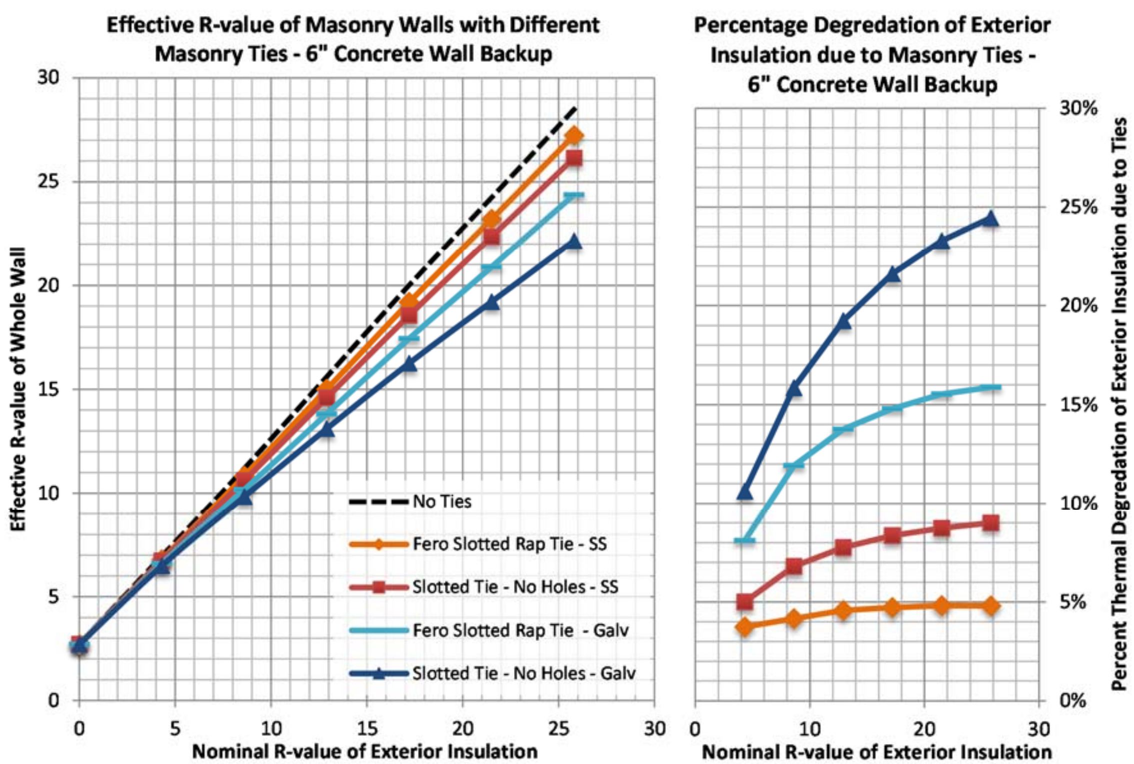


Figure 2: Effective R-value and Corresponding Percent Thermal Degradation of Masonry Walls with Different Masonry Ties – 6" Concrete Wall Backup

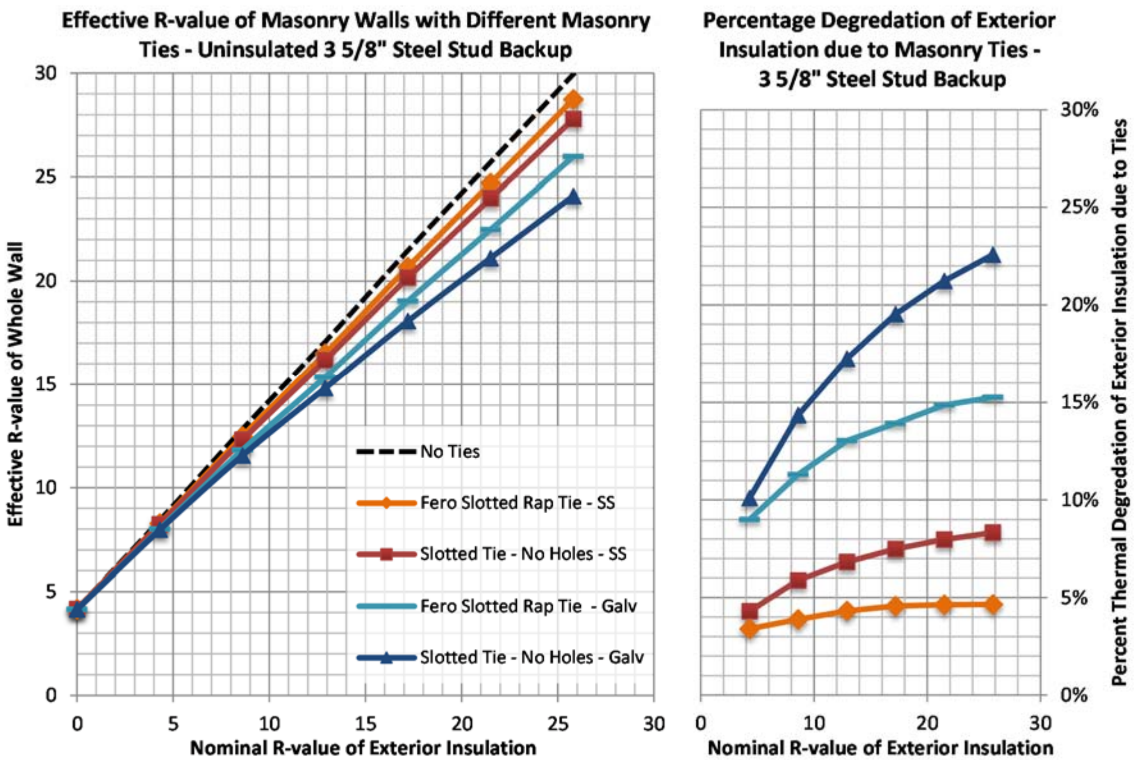


Figure 3: Effective R-value of Masonry Walls with Different Masonry Ties – Uninsulated 3 5/8" Steel Stud Wall Backup

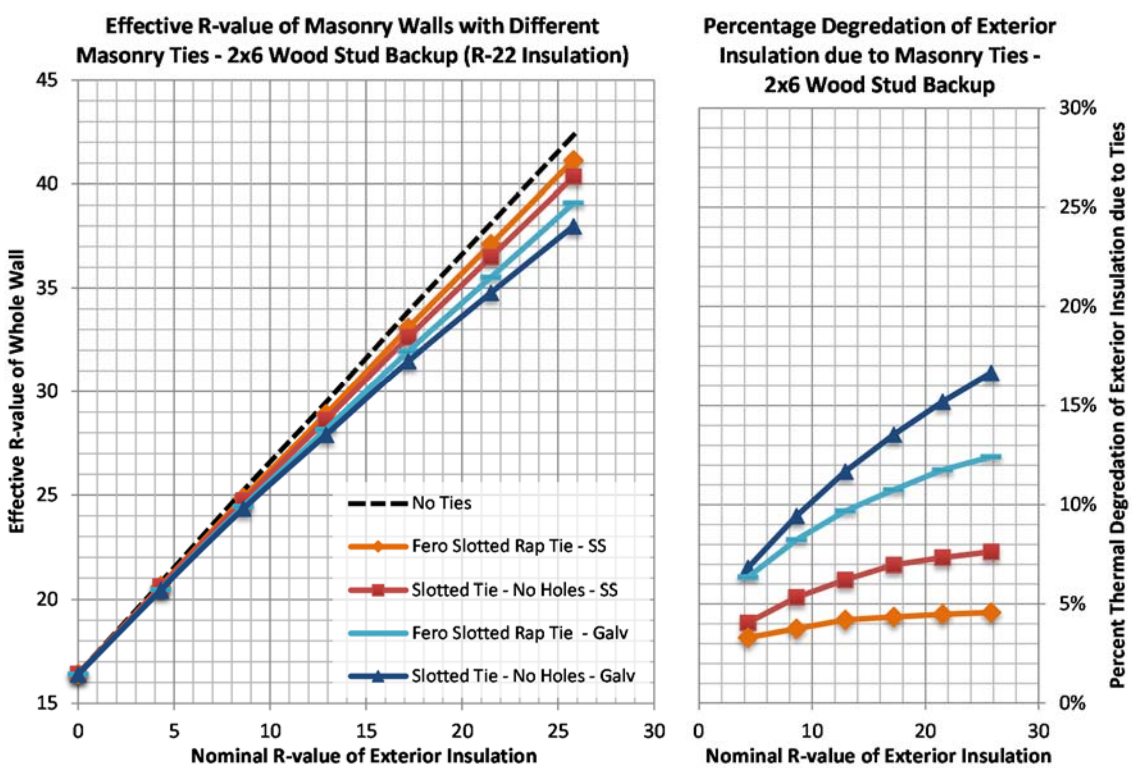


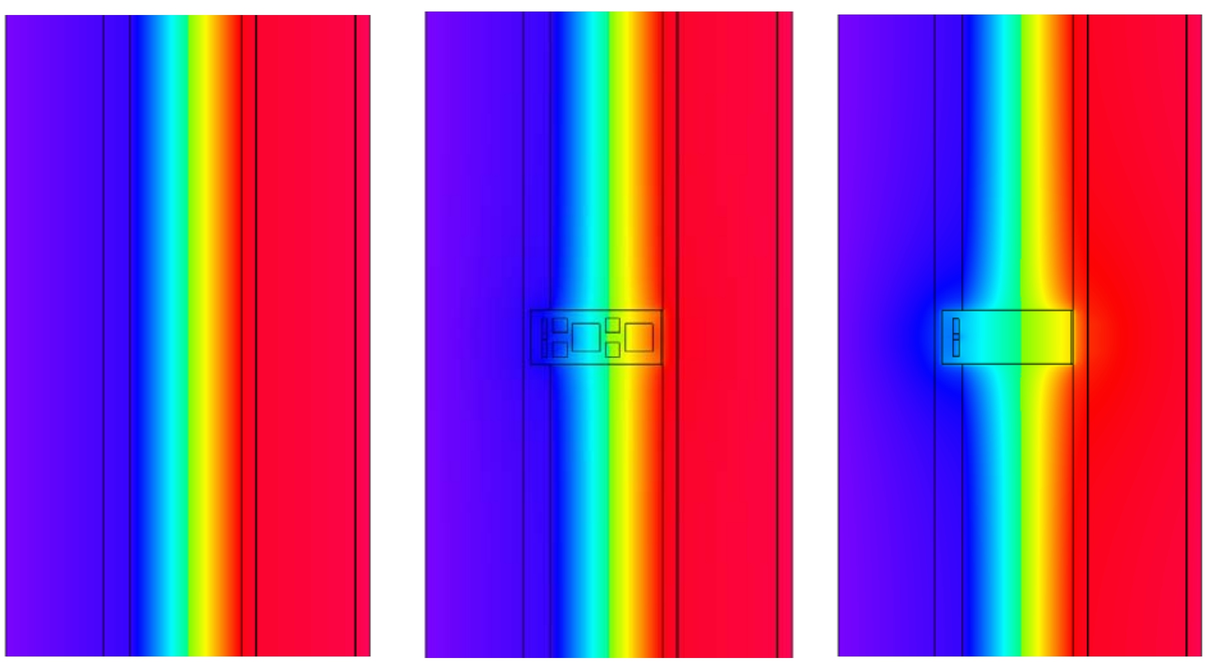
Figure 4: Effective R-value and Corresponding Percent Thermal Degradation of Masonry Walls with Different Masonry Ties – 2 x 6 Wood Stud Wall Backup (R-22 Batt Insulation)

The selection of masonry tie material and tie design can have a significant impact on the effective R-value of masonry veneer walls; the effective reduction can be anywhere from 3% to almost 25% depending on the thickness of exterior insulation and back-up wall structure, which can be an important consideration for energy code compliance.

In terms of masonry tie selection, stainless steel performs better than galvanized steel, with exterior insulation reductions in the order of 3% to 9% for stainless steel over concrete/steel wall backup versus 8% to 25% for galvanized steel. These insulation reductions are less in wood-framing, in the 3% to 8% range for stainless ties and 6% to 17% for galvanized ties. In addition, the Fero Rap ties with punched holes perform better for both materials than the generic ties without punched holes. The stainless steel Fero Rap tie with holes causes reductions of less than 5% for all the types of wall backup, while the stainless steel generic tie causes reductions of 4% to 9%. The difference is even more significant for galvanized steel, where the Fero Rap ties with holes create between 8% to 16% reduction for a concrete wall backup, while the generic tie creates a 10% to 24% reduction.

Costs related to stainless steel Fero Rap ties with holes over generic ties without punched holes can be offset by savings resulting from reduced insulation thickness to meet R-value targets.

Figure 5 presents a graphical comparison of the best and worst case scenario using a stainless steel Fero Rap tie with holes versus a generic galvanized tie without holes. The relative temperature gradient across the ties shows the more pronounced heat loss through the galvanized tie, where the stainless steel tie shows very little thermal variation from the section without a masonry tie.



No Ties *Stainless steel tie with holes* *Galvanized tie without holes*

Figure 5: Relative temperature gradient across a masonry veneer wall at a section without ties, a stainless steel tie, and a galvanized tie without holes.

Figure 6 presents the results of the thermal impact of the Fero Rap ties and generic counterparts. All models were completed using an uninsulated 3 5/8” steel stud backup wall and 4” of exterior mineral wool insulation.

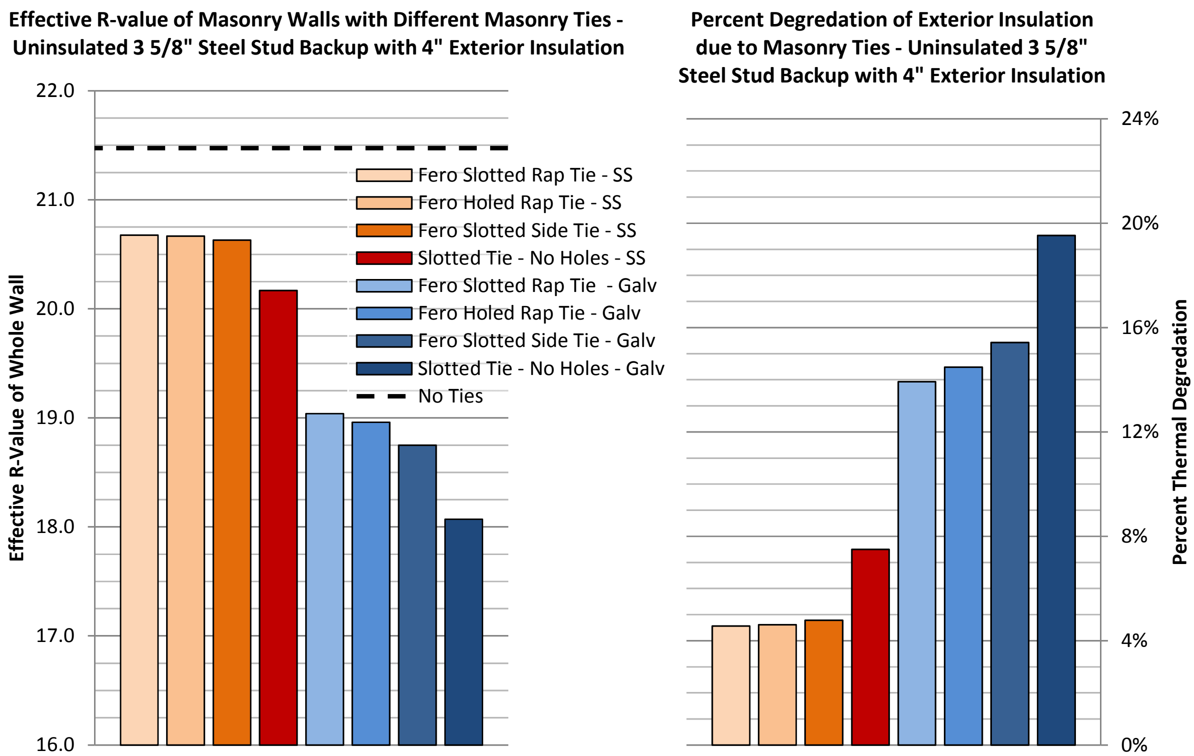


Figure 6: Effective R-value and Corresponding Percent Thermal Degradation of Masonry Walls with Different Fero Rap Ties and Installation Modifications – 3 5/8" Steel Stud Wall Backup

The different brick ties variations using punched holes have very similar results to the slotted face mount tie (used alone in the previous section) for both stainless steel and galvanized steel ties. The design variations are intended to accommodate different backup wall and installation types, while providing similar thermal performance. The masonry ties that do not use punched holes create lower R-values and larger thermal degradation than their respective stainless steel and galvanized counterparts.

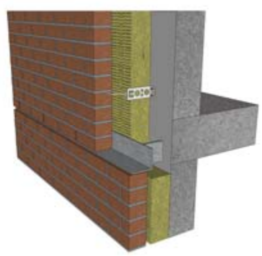
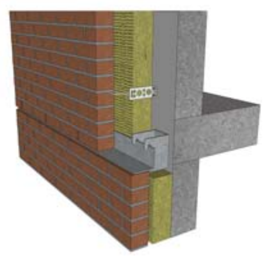
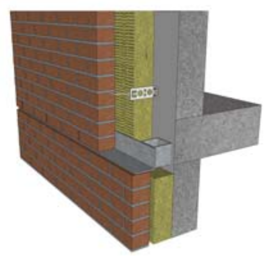
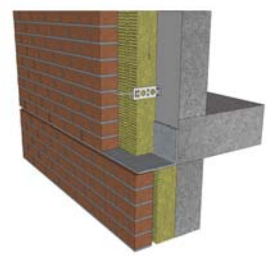
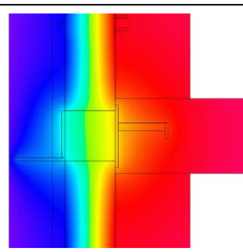
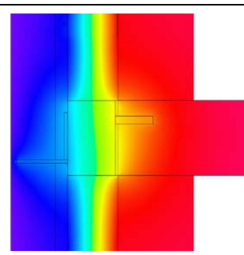
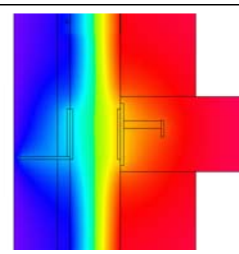
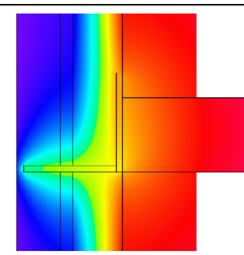
Masonry Shelf Angle Supports

Steel shelf angles structurally support masonry veneers and they are typically placed at openings (i.e. over windows and doors) and at each floor slab edge. Although steel shelf angles are not necessarily required at every floor, this typical design practice does accommodate ease of construction, alignment, and tolerance requirements. In addition to structural implications, the placement and design of masonry shelf angles also impacts overall thermal performance of the cladding.

Traditionally in multi-storey concrete structure buildings, steel shelf angles have been directly attached to the concrete slab edge, either welded to embed plates cast in the slab edge, or bolted with adhesive/expansion anchors. This practice does not have a significant impact on the thermal performance of wall assemblies with stud cavity insulation, or insulation placed to the interior of the backup wall (i.e. discontinuous insulation), however with ci insulation these wall assemblies will likely fail to meet most current energy code requirements. Where exterior insulation is included and where the bottom leg of the shelf angle cuts through the exterior insulation, the shelf angle has a significant impact on the overall thermal performance of the whole wall area. In terms of an area of wall, a steel plate of up to ½" thick steel might represent less than 0.5% of the surface area of the insulation, but can result in an effective thermal degradation of the insulation in the order of 30% to 50%+. Current energy codes may even be interpreted to permit the thermal bridging impact of a shelf angle to be ignored on the basis of limited wall area. The analysis presented here demonstrates the importance of rigour in energy analysis and calculations and confirms that the intermittent shelf angle support system can reduce the large thermal bridge to one that is more manageable.

A thermal analysis was performed to assess the impact of the Fero FAST System and continuous fastened steel shelf angles. The modelling was completed using a concrete wall backup with 4" of exterior mineral wool insulation, representing a typical exterior insulated masonry veneer wall. In addition to the Fero FAST System, the analysis considered the use of intermittent knife plates and HSS tubes to support shelf angles outside of the exterior insulation. The amount of insulation displaced by the knife plates, HSS tubes and the FAST System are similar, and as such the reduction factor of the exterior insulation R-value by 14% to 16%. Figure 8 presents the results of the analysis of the influence of the shelf angle (both direct attached and thermally de-bridged) on the effective R-value of a masonry wall with stainless steel masonry ties with holes.

Table 1: Summary of Effective R-Values and thermal degradation for Large Shelf Angle and Typical Stand-Off Configurations for the Steel Shelf Angle Support Options Showing Impact of Thermal Bridging

	Knife Plate	Fero FAST System	HSS Section	Large Angle
				
				
Effective Assembly R-Value	R-16.4 (RSI 2.89)	R-16.3 (RSI 2.87)	R-16.1 (RSI 2.84)	R-10.6 (RSI 1.87)
Effective Reduction	14.0%	14.6%	15.7%	43.0%

The thermal impact of steel shelf angles at every floor can have a profound effect on the thermal efficiency of the wall assembly in addition to the previously shown impact of the masonry ties (16 gauge stainless ties with holes are shown here for demonstration). Direct attached masonry shelf angles perform quite poorly from a thermal standpoint with exterior insulation R-value reductions of 43% for 4" exterior insulation. Depreciating returns for additional exterior insulation mean that it is extremely difficult to attain R-values of greater than R-15 (RSI 2.64) in this scenario.

Shelf angles supported outside of the exterior insulation with intermittent knife plate, Fero FAST System, or HSS section supports with stainless (or galvanized) ties have more manageable insulation reductions in the order of 14% to 16%. Effective R-values for wall assemblies with these details are all around or above R-16. This means that in order to comply with current prescriptive energy code requirements in Canada, generally in the R-15 to R-20 (RSI 2.64 to 3.52) or higher range, the use of intermittently supported and thermally improved shelf angle supports are necessary.

Comparison of Masonry to Other Cladding Systems

A final analysis is performed to compare masonry veneer to other cladding systems supported through exterior insulation. Claddings such as metal panel, fiber cement panels, stucco, thin cultured stone, and thin brick etc. with exterior insulation are typically supported by systems including continuous girts, intermittent clips, screws and other systems. These structural elements penetrate the exterior insulation and are typically larger in size than masonry ties and designed to carry gravity and live loads from the claddings. Historically the use of continuous metal Z-girts was most common in construction in Canada, however in recent years the use of more thermally efficient systems has evolved.

Figure 9 presents two masonry veneer support conditions including stainless steel Fero Rap ties (with holes) and Fero FAST System with stainless steel Fero Rap ties (with holes. These are compared to exterior insulated walls with continuous Z-girts (horizontal and vertical 18 gauge) and intermittent 6 inch long 18 gauge clips. The backup wall assembly for this analysis is an uninsulated 3-5/8" steel stud wall with gypsum sheathing and gypsum interior finish. The results for concrete and concrete block wall backup would be similar and for wood-frame are slightly improved as previously shown.

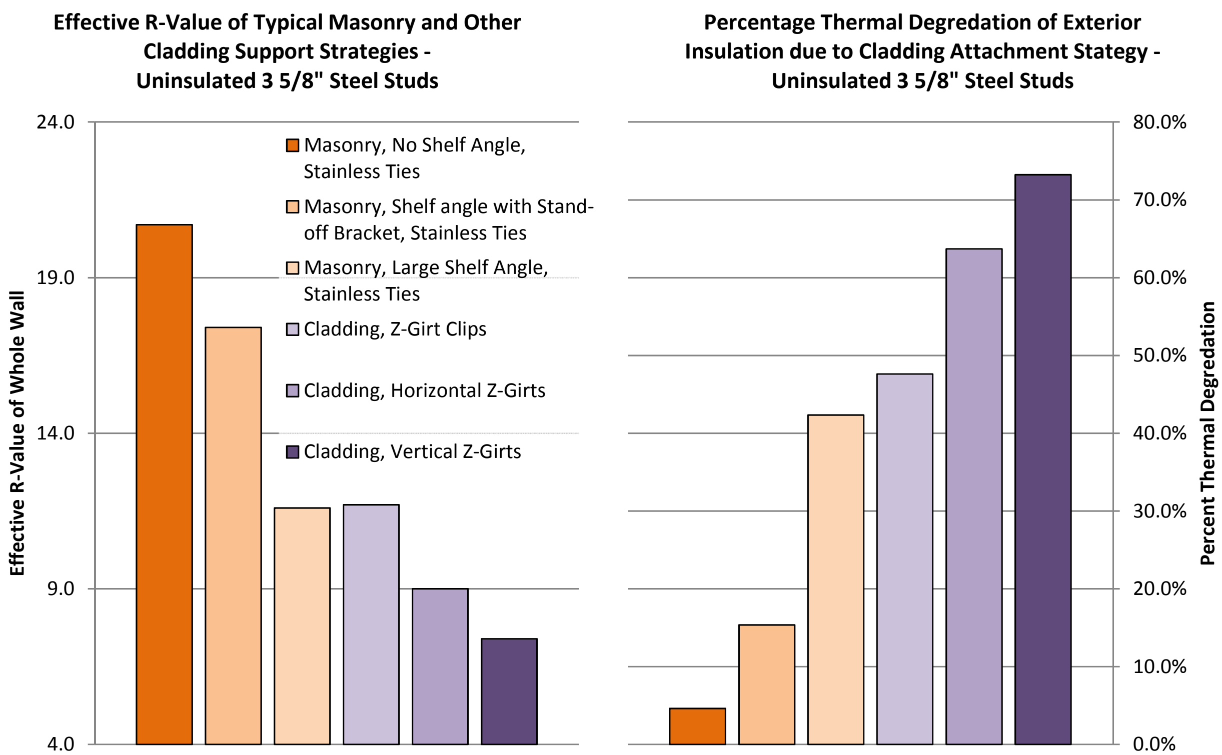


Figure 9: Effective R-value and Corresponding Percent Thermal Degradation of Typical Masonry and Other Cladding Support Strategies – 4" exterior insulation over uninsulated 3 5/8" steel studs

As demonstrated by this comparative analysis of other cladding support systems, masonry veneers with Fero Rap ties and the FAST System have the potential to be one of the most thermally efficient cladding systems, provided they are detailed properly. The results demonstrate that where effective R-value targets are in the R-15 to R-20 (RSI 2.64 to 3.52) range, 4 inches (or less depending on backup wall) of exterior insulation will be enough for masonry walls using stainless steel Fero Rap ties and a Fero FAST System for shelf angle support, whereas many other systems would require considerable more insulation to do so, or cannot practically meet the requirements due to the amount of thermal bridging.

Thermal bridging through the Fero Rap ties is only 5% through the efficient use of stainless steel (punched holes). With the Fero FAST System for shelf angle support, the exterior insulation reduction factor is only 16% with 4" of exterior insulation over an uninsulated 3-5/8" steel stud backup wall. This is significantly better than the reductions of about 50% to over 70% which can be seen with other cladding materials supported on continuous Z-girts and Z-girt clips. Brick veneer can be one of the most thermally efficient wall claddings over exterior insulation.

Conclusion

The effective R-values of Fero Rap ties and generic ties of similar size fastened to different back-up wall construction (concrete, steel stud/gypsum, and wood-frame) were modeled using a three-dimensional finite element computer software program. The results show that the Fero Rap ties can significant reduce the impact of thermal bridging and maximize the effective R-value of masonry walls with exterior ci insulation. The use of stainless steel Fero Rap ties or galvanized Fero Rap ties with punched holes result in the lowest insulation reductions (4% - 16%) compared to generic ties of similar size without holes (5% to 24%) over concrete/steel stud backup and lower for wood frame.

The thermal impact of the design of masonry veneer shelf angles was also shown to be very important. Direct attached masonry shelf angles perform quite poorly thermally with exterior insulation R-value reductions of over 40% for 4" of exterior insulation with stainless ties over a 6" concrete backup wall. Shelf angles supported outside of the exterior insulation with intermittent knife plates, the Fero FAST System, or HSS tubes supports for the shelf angle have more tolerable insulation reductions in the order of 14% - 16% for the same wall.

Masonry veneer walls with effective R-values in the range of R-15 to R-20 (RSI 2.64 to 3.52) range can be achieved with 3 to 6 inches of exterior insulation depending on masonry tie selection and backup wall, provided that shelf angles are intermittently supported. This generally means that in order to comply with the current and future prescriptive energy code requirements in Canada, the use of intermittently supported and thermally improved shelf angles are necessary. There are potential cost implications to these recommendations towards the use of stainless steel brick ties and intermittently supported shelf angles. These costs can be offset by savings created by reduced insulation thickness to meet R-value targets for energy code compliance or energy consumption target.

It is shown that masonry veneer claddings with Fero Rap tis and Fero FAST System have the potential to achieve exceptional thermal performance, and will outperform many other exterior insulated cladding assemblies. Typical exterior insulation R-value reductions for well-designed masonry walls will be in the order of 16% for 4" of exterior insulation, whereas continuous girt systems will have reductions in the 50% to 75% range. This means that less exterior insulation can be used and thinner masonry walls can be constructed to achieve the same performance as other less thermally efficiently supported claddings.

This paper demonstrates that thermal efficiency must be addressed as part of the material selection and design process of exterior insulated masonry veneer wall assemblies. With the use stainless steel Fero Rap ties and Fero FAST System, the thermal degradation of the wall can be minimized, and the masonry veneer wall can be one of the most thermally efficient wall assemblies available.

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