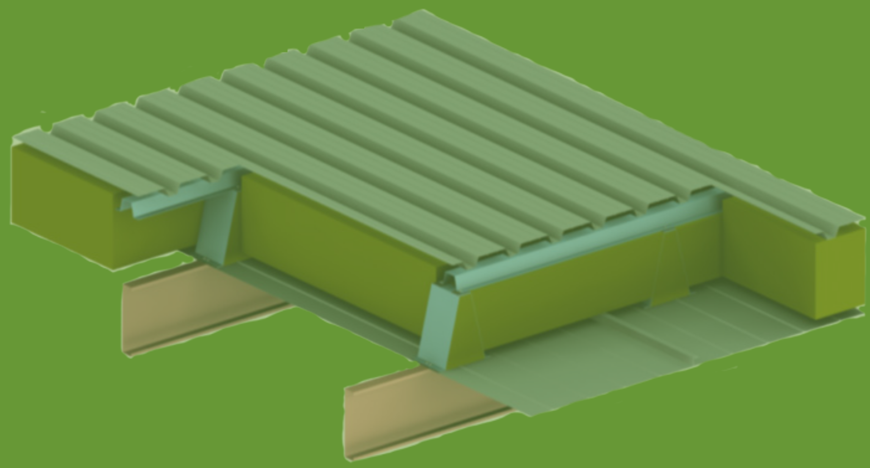
CANADIAN SHEET STEEL BUILDING INSTITUTE

Thermal Transmittance of Insulated Sheet Steel Wall and Roof Assemblies



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Canadian Sheet Steel Building Institute

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PREFACE

This Bulletin gives guidance on the thermal transmittance of generic insulated sheet steel wall and roof assemblies. Tables are provided with U-factors and effective R-factors for common assemblies. Parametric studies were also carried out to show the influence of varying the spacing or characteristics of the components. The objective is to provide the building designer with the information needed to comply with the new energy codes.

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1. ENERGY CODE REQUIREMENTS IN CANADA

Most provinces in Canada are in the process of enacting energy conservation requirements for new buildings. The *National Energy Code of Canada for Buildings, 2010* (NECB) is the model code that the province may adopt or alter as they deem necessary. For example, Ontario has enacted *Supplementary Standard SB-10 Energy Efficiency Supplement* that has different requirements than the NECB. Another standard also referenced in Canada is ASHRAE 90.1-2010, *Energy Standard for Buildings Except Low-Rise Residential Buildings.*

Listed in Tables 1 and 2 are the maximum thermal transmittance limits of above-ground opaque assemblies based on these three standards. The requirements vary by geographic location as defined by the heating degree days. The map of Canada in Figure 1 shows the demarcation of the zones. The specific degree-days for cities in Canada can be found in Appendix C of the *National Building Code of Canada, 2010*.

Table 1
Prescriptive Requirements for Maximum Overall Thermal Transmittance for Roofs (W/m²K)

Code or Standard	Heating Degree-Days of Building Location (Celsius Degree-Days)				
	Zone 4 < 3000	Zone 5 3000 to 3999	Zone 6 4000 to 4999	Zone 7 5000 to 6999	Zone 8 >6999
NECB 2011	0.227	0.183	0.183	0.162	0.142
ASHRAE 90.1-2010 (metal building)	0.312	0.312	0.278	0.278	0.199
ASHRAE 90.1-2010 (Insul. above deck)	0.273	0.273	0.273	0.273	0.273
OBC SB-10 (metal building)	n/a	0.20	0.18	0.16	n/a
OBC SB-10 (Insul. above deck)	n/a	0.22	0.18	0.16	n/a

Table 2
Prescriptive Requirements for Maximum Overall Thermal Transmittance for Walls (W/m²K)

Code or Standard	Heating Degree-Days of Building Location (Celsius Degree-Days)				
	Zone 4 < 3000	Zone 5 3000 to 3999	Zone 6 4000 to 4999	Zone 7 5000 to 6999	Zone 8 >6999
NECB 2011	0.315	0.278	0.247	0.210	0.183
ASHRAE 90.1-2010 (metal building)	0.477	0.392	0.392	0.324	0.324
OBC SB-10 (metal building)	n/a	0.30	0.30	0.30	n/a

Figure 1: Average Annual Heating Degree-Days (C-degrees)
Source: NECB 2010, National Research Council of Canada

2. TRADE-OFFS FOR MEETING ENERGY CODE REQUIREMENTS

The values for thermal transmittance of the assemblies listed in this bulletin can be used by the building designer to meet the requirements of the energy code. However, meeting these requirements is not only a function of the enclosure (i.e. wall and roof assemblies). There are other components in the building that affect the energy demands (e.g. windows, doors, lighting, mechanical, heating). One solution to achieving the energy conservation target is to trade-off the higher performance in once system to compensate for something else. For example, it may be more economical to install high efficiency lighting and heating systems and reduce the insulation in the walls or roof. The entire obligation for meeting the energy code requirements does not rest on the sheet steel building assemblies.

3. THERMAL MODELING

The CSSBI engaged Morrison-Hershfield (M-H) to evaluate the thermal transmittance of several insulated sheet steel roof and wall assemblies. The objective was to identify those sheet steel assemblies that will comply with current Canadian codes related to energy efficiency and to provide guidance to viable approaches that could improve thermal performance for these assemblies.

Using 3D heat transfer modeling, the effective R- and U-values for several sheet steel insulated wall and roof assemblies were calculated using common components. These values were compared to the energy requirements in NECB 2011. Material changes to these structural attachments, including steel thickness and placement of thermal breaks, were also analyzed to determine their impact on the heat transmittance through the assembly.

4. MODELING OUTLINE

The thermal performance of the sheet steel assemblies was evaluated by modeling using the Nx software package from Siemens, which is a general purpose computer aided design and finite element package. The thermal solver and modeling procedures utilized for this study were extensively calibrated and validated in a previous study and against guarded hot box measurements.

The thermal analysis utilized steady-state conditions, published thermal properties of materials, and information provided by the CSSBI. Boundary conditions were modeled using heat transfer coefficients to simulate convection, conduction and radiation (i.e. film coefficients). Assumptions for the boundary conditions are summarized in Appendix A of MH report number 5140037.00, *Thermal Performance of Sheet Steel Wall and Roof Assemblies* available from the CSSSBI.

5. SHEET STEEL WALL ASSEMBLY WITH NOTCHED Z-BAR

The baseline sheet steel wall assembly with notch z-bars is shown in Figure 2. This assembly has 6” (152 mm) of mineral wool insulation (R4.2/inch) between a 24 gauge (0.024 in., 0.061 mm), interior steel liner and exterior steel sheet cladding, supported by an 18 gauge (0.048 in., 1.21 mm) notched z-bar with 1/8” (3 mm) thermal tape between the intermittent connections to the backup framing. Outboard of the notched z-bar is an 18 gauge steel u-channel with 2” (50 mm) of XPS insulation (R5/in) attached to the sheet steel cladding.

The wall assembly was analyzed for the following variations in configurations.

- Varying vertical spacing of the notched z-bar (Table 3).
- Varying steel liner and notched z-bar thickness (see MH report).
- Continuous versus intermittent notched z-bar (see MH report).
- Addition of a PVC coating onto the notched z-bar (see MH report).
- Varying the thermal tape thickness (see MH report).

The thermal transmittance of the assembly is not significantly impacted by the steel thickness, using intermittent notched z-bars, a PVC coating or the thermal tape thickness. The specific results are available in the M-H report available from the CSSBI.

One design option for the wall assembly is the vertical spacing of the wall girts, which affects the vertical spacing of the notched z-bar. Listed in Table 3 are the thermal properties of the wall assembly with three different z-bar spacing.

Table 3
Wall: Variable Spacing of Girts and Notched Z-Bar

Vertical Spacing of Z-bar (in)	Insulation Thickness (in)	Insulation 1D R-Value (RSI)	"Effective" R-Value R_o ft²·hr·°F/Btu (m²·K/W)	Overall Thermal Transmittance U_o Btu/ft²·hr·°F (W/m²·K)	Highest NECB 2011 Zone Requirement Met
48	6	R-25 (4.4)	R-21.8 (3.84)	0.046 (0.260)	5
60	6	R-25 (4.4)	R-22.5 (3.96)	0.044 (0.253)	5
72	6	R-25 (4.4)	R-23.0 (4.05)	0.044 (0.247)	6

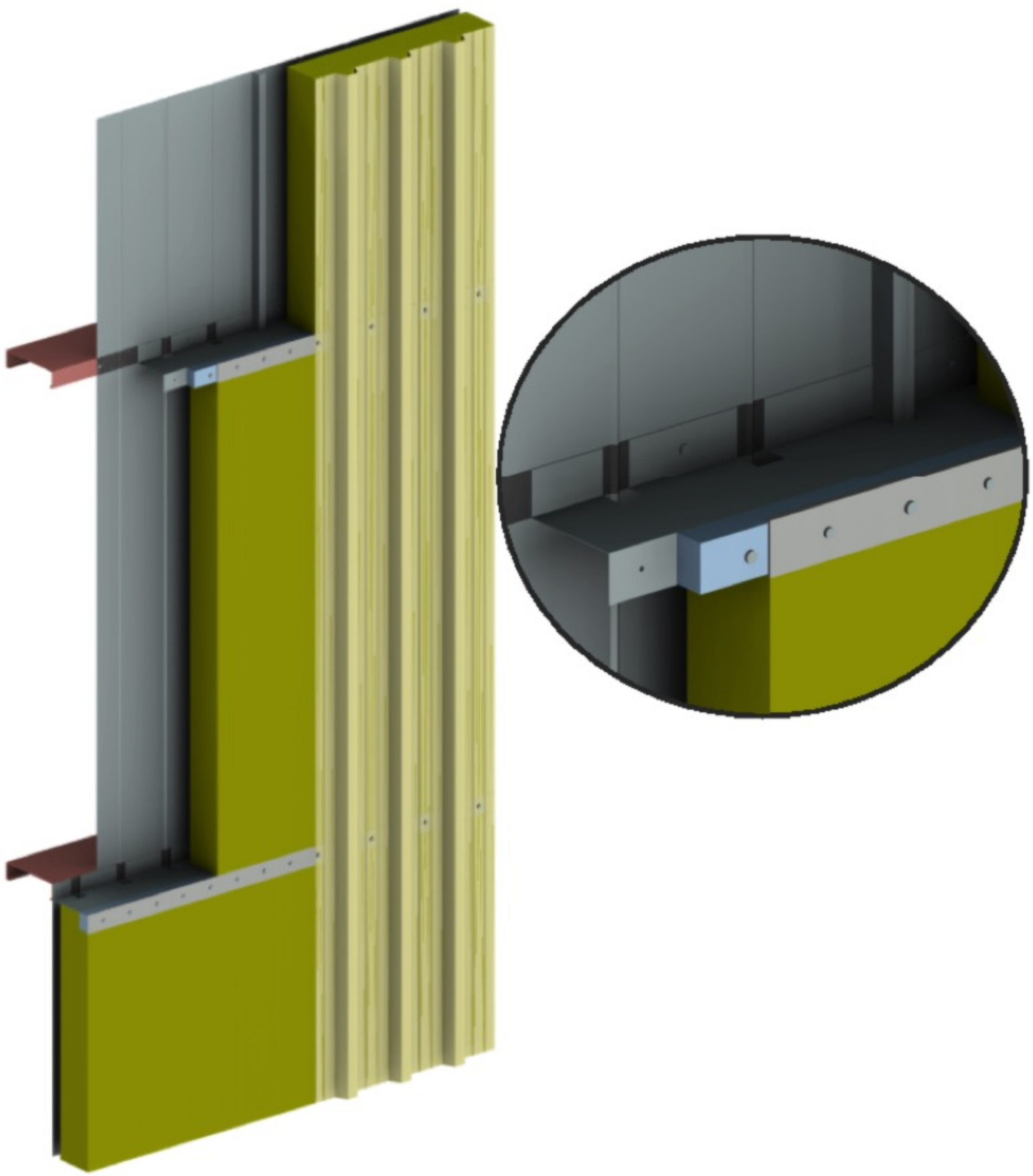

Figure 2: Sheet Steel Wall Assembly with Notched Z-Bars

As there are several insulation types that can be used in these wall assemblies, a sensitivity analysis was done to determine the impact of the insulation type (insulation R per inch). Results are shown in Table 4 for varying the insulation thickness for R-4.2/inch (mineral wool), R-5/inch (XPS) and R-6/inch (Polyisocyanurate). This study was done using the base assembly described above (i.e. notched z-bar spaced at 60").

Table 4
Wall: Insulation Type and Thickness

Insulation Type	Insulation Thickness (in)	Insulation 1D R-Value (RSI)	"Effective" R-Value R_o ft²·hr·°F/Btu (m²·K/W)	Overall Thermal Transmittance U_o Btu/ft²·hr·°F (W/m²·K)	Highest NECB 2011 Zone Requirement Met
Mineral Wool R-4.2/inch	6	R-25 (4.44)	R-22.5 (3.96)	0.044 (0.253)	5
	7	R-29 (5.18)	R-25.7 (4.52)	0.039 (0.221)	6
	8	R-34 (5.92)	R-28.4 (5.01)	0.035 (0.200)	7
XPS R-5/inch	6	R-30 (5.24)	R-26.0 (4.57)	0.039 (0.219)	6
	7	R-35 (6.16)	R-29.6 (5.21)	0.034 (0.192)	7
	8	R-40 (7.04)	R-32.7 (5.76)	0.031 (0.173)	8
Polyisocyanurate R-6/inch	6	R-36 (6.34)	R-30.1 (5.31)	0.033 (0.188)	7
	7	R-42 (7.40)	R-34.2 (6.03)	0.029 (0.166)	8
	8	R-48 (8.45)	R-37.8 (6.65)	0.026 (0.150)	8

6. SHEET STEEL WALL ASSEMBLY WITH THERMAL CHAIRS

The same sheet steel wall from the previous section was also modeled with intermittent thermal chairs replacing the notched z-bar summarized in Table 3. The thermal chairs were 18 gauge (0.048 in., 1.21 mm) spaced at various horizontal intervals and spaced at 60" (1 520 mm) vertically. The assembly is illustrated in Figure 3 and the results are given in Table 5.

Table 5
Wall: Variable Spacing of Thermal Chairs

Horizontal Spacing of Thermal Chair (in)	Insulation Thickness (in)	Insulation 1D R-Value (RSI)	"Effective" R-Value R_o ft²·hr·°F/Btu (m²·K/W)	Overall Thermal Transmittance U_o Btu/ft²·hr·°F (W/m²·K)	Highest NECB 2011 Zone Requirement Met
24	6	R-25 (4.44)	R-24.3 (4.28)	0.041 (0.233)	6
36	6	R-25 (4.44)	R-24.4 (4.30)	0.041 (0.233)	6
48	6	R-25 (4.44)	R-24.8 (4.36)	0.040 (0.229)	6

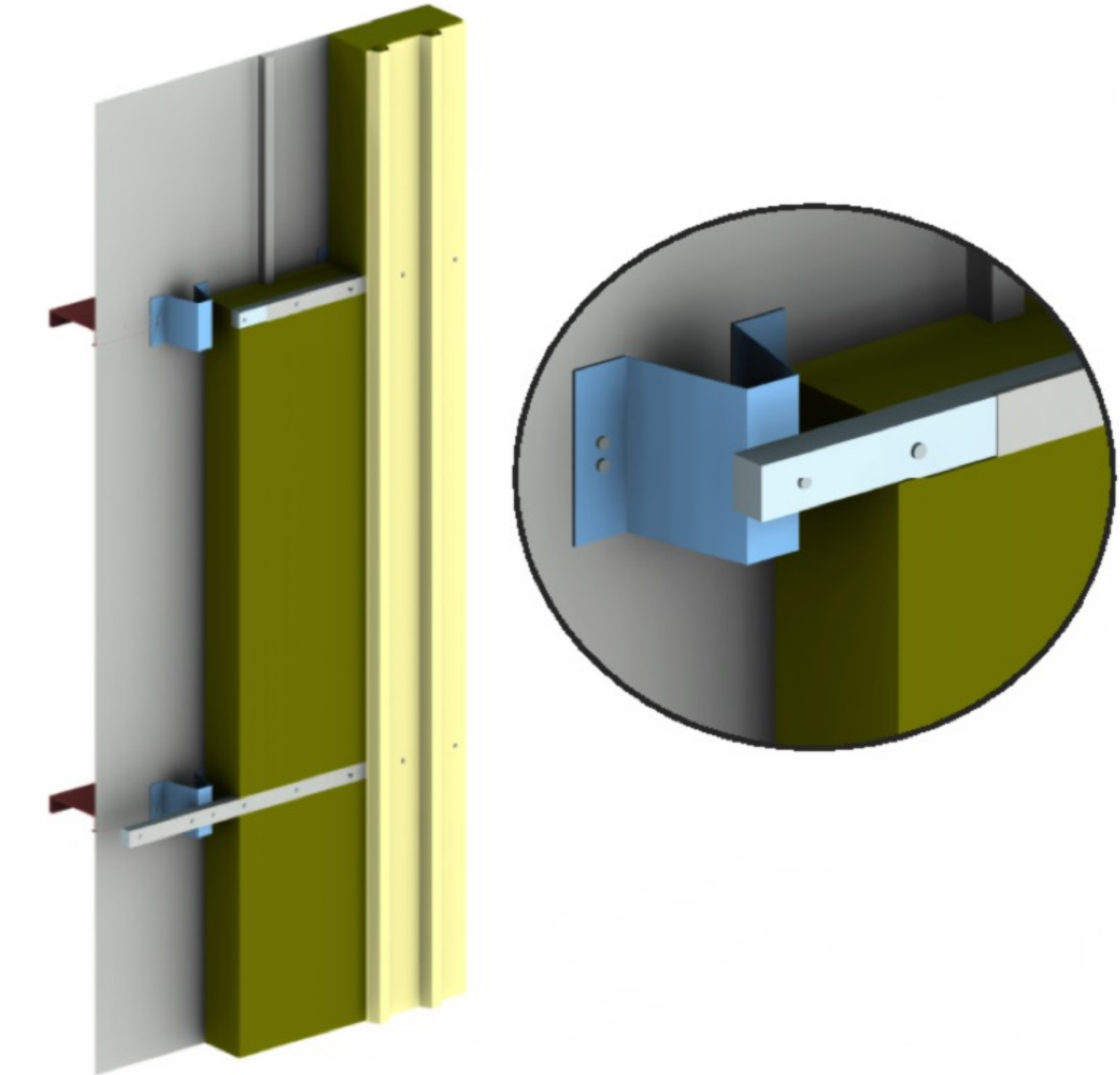

Figure 3: Sheet Steel Wall Assembly with Thermal Chairs

7. INSULATED SHEET STEEL ROOF SUPPORTED BY THERMAL CHAIRS

The baseline sheet steel roof assembly has 22 gauge (0.030 in., 0.76 mm) profiled cladding fastened to 2” high (50 mm), 18 gauge (0.048 in., 1.21 mm) hat sections that are supported by 10” high (254 mm), 18 gauge thermal chairs. The thermal chairs have a 1/8” (3 mm) thermal tape at all steel-to-steel connections. The steel liner is 24 gauge (0.024 in., 0.61 mm) on 14 gauge (0.075 in., 1.90 mm) purlins. There is 10 ¾” (273 mm) of mineral wool insulation (R-4.2/inch) between the cladding and the liner filling all voids. The assembly is shown in Figure 4 and a detail of the thermal chair is shown in Figure 5.

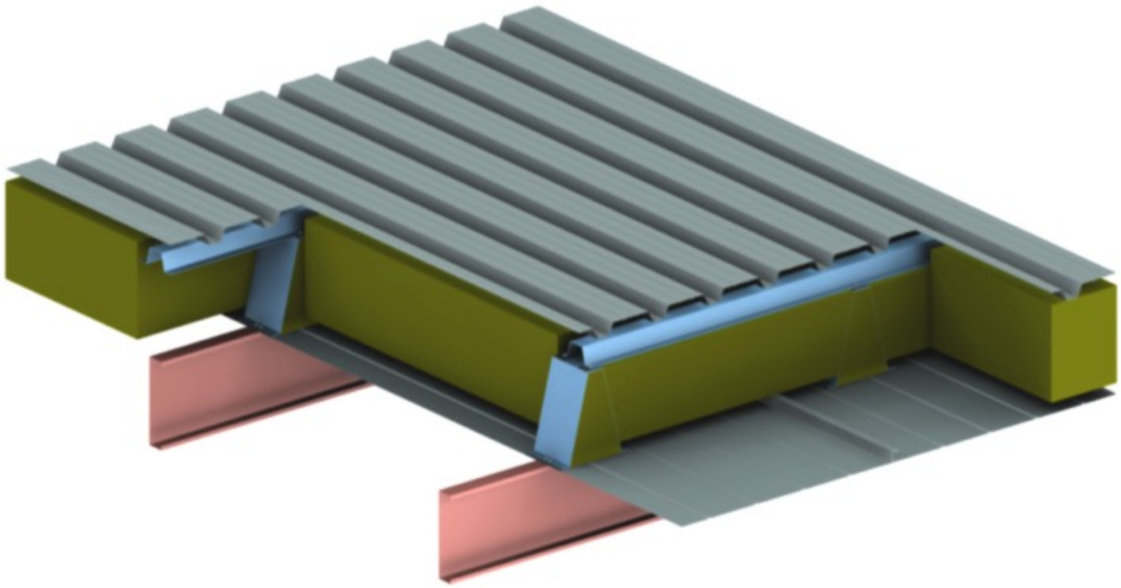

Figure 4: Insulated Sheet Steel Roof Supported by Thermal Chairs

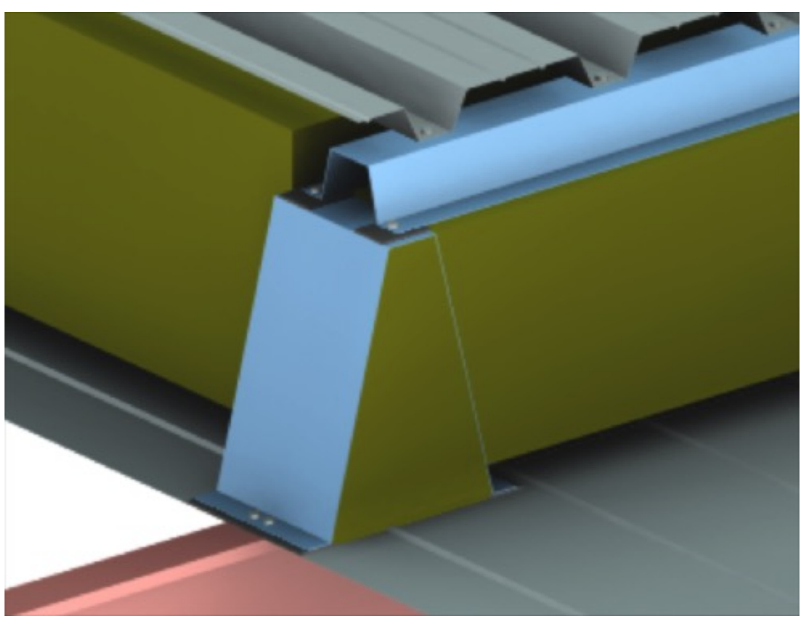

Figure 5: Detail of Thermal Chair

The roof assembly was analyzed for the following configurations:

- Varying thermal chair and purlin spacing.
- Varying thermal tape thickness
- Reductions in steel area of thermal chairs using perforations
- Addition of PVC coating onto thermal chairs and hat section surfaces
- Change thermal chair material from steel to plastic
- Varying steel thickness for liner, cladding, chair and purlin.

The parametric study showed that the significant variables that affect the thermal performance are the spacing of the thermal chairs, purlin spacing, insulation type, insulation thickness, and thickness of the thermal tape between steel components. The results of these studies are given in Tables 5, 6 and 7. The results for the other parameters listed above are in the M-H report available from the CSSBI.

Table 5
Roof: Variable Spacing of Thermal Chairs

Chair Spacing (in)	Purlin Spacing (in)	Insulation 1D R-Value (RSI)	"Effective" R-Value R_o ft²·hr·°F/Btu (m²·K/W)	Overall Thermal Transmittance U_o Btu/ft²·hr·°F (W/m²·K)	Highest NECB 2011 Zone Requirement Met
24	48	R-45 (7.95)	R-30.5 (5.38)	0.033 (0.186)	4
24	60	R-45 (7.95)	R-32.7 (5.76)	0.031 (0.174)	6
24	72	R-45 (7.95)	R-34.3 (6.04)	0.029 (0.166)	6
36	48	R-45 (7.95)	R-33.8 (5.96)	0.030 (0.168)	6
36	60	R-45 (7.95)	R-35.9 (6.32)	0.028 (0.158)	7
36	72	R-45 (7.95)	R-37.4 (6.58)	0.027 (0.152)	7
48	48	R-45 (7.95)	R-39.6 (6.97)	0.025 (0.143)	7
48	60	R-45 (7.95)	R-40.4 (7.11)	0.025 (0.141)	8
48	72	R-45 (7.95)	R-41.4 (7.29)	0.024 (0.137)	8

Table 6
Roof: Various insulation levels

Insulation Type	Insulation Thickness (in)	Insulation 1D R-Value (RSI)	"Effective" R-Value R_o ft²·hr·°F/Btu (m²·K/W)	Overall Thermal Transmittance U_o Btu/ft²·hr·°F (W/m²·K)	Highest NECB 2011 Zone Requirement Met
Mineral Wool R-4.2/inch	5	R-21 (3.70)	R-19.4 (3.41)	0.052 (0.293)	None
	6 ¾	R-28 (4.99)	R-25.0 (4.40)	0.040 (0.227)	4
	9	R-38 (6.66)	R-30.7 (5.42)	0.033 (0.185)	4
	10 ¾	R-45 (7.95)	R-33.8 (5.96)	0.030 (0.168)	6
XPS R-5/inch	5	R-25 (4.40)	R-22.2 (3.91)	0.045 (0.256)	None
	6 ¾	R-34 (5.95)	R-28.6 (5.04)	0.035 (0.198)	4
	9	R-45 (7.93)	R-35.0 (6.17)	0.029 (0.162)	7
	10 ¾	R-54 (9.46)	R-38.3 (6.74)	0.029 (0.148)	7
Polyisocyanurate R-6/inch	5	R-30 (5.29)	R-25.6 (4.51)	0.039 (0.222)	4
	6 ¾	R-41 (7.13)	R-32.9 (5.80)	0.030 (0.172)	6
	9	R-54 (9.51)	R-40.0 (7.04)	0.025 (0.142)	8
	10 ¾	R-64 (11.36)	R-43.4 (7.64)	0.023 (0.131)	8

Notes:
- Chair height is ¾" less than insulation thickness
- 36" o.c. chair spacing and 48" o.c. purlin spacing

Table 7
Roof: Variable Thermal Tape Thickness

Tape Thickness (in)	Tape R-Value (RSI)	Insulation 1D R-Value (RSI)	"Effective" R-Value R_o ft²·hr·°F/Btu (m²·K/W)	Overall Thermal Transmittance U_o Btu/ft²·hr·°F (W/m²·K)	Highest NECB 2011 Zone Requirement Met
0	R-0 (0.00)	R-45 (7.95)	R-30.4 (5.36)	0.033 (0.187)	4
1/8	R-1 (0.23)	R-45 (7.95)	R-33.8 (5.96)	0.030 (0.168)	6
1./4	R-3 (0.45)	R-45 (7.95)	R-34.3 (6.04)	0.029 (0.166)	6

8. INSULATED STANDING SEAM ROOF

The standing seam roof is similar to the baseline roof described previously; however, the cladding is a different shape and connected to the structure differently. The standing seam roof is supported by 3" high clips instead of being attached directly to the hat section. The insulation between the hat section and the roofing panel was draped R-19 batt which was compressed between the roof panel and the hat section. The assembly has 24" o.c. thermal chair spacing and 48" o.c. purlin spacing. The insulated sheet steel standing roof assembly is shown in Figure 6 and a detail of the components is shown in Figure 7.

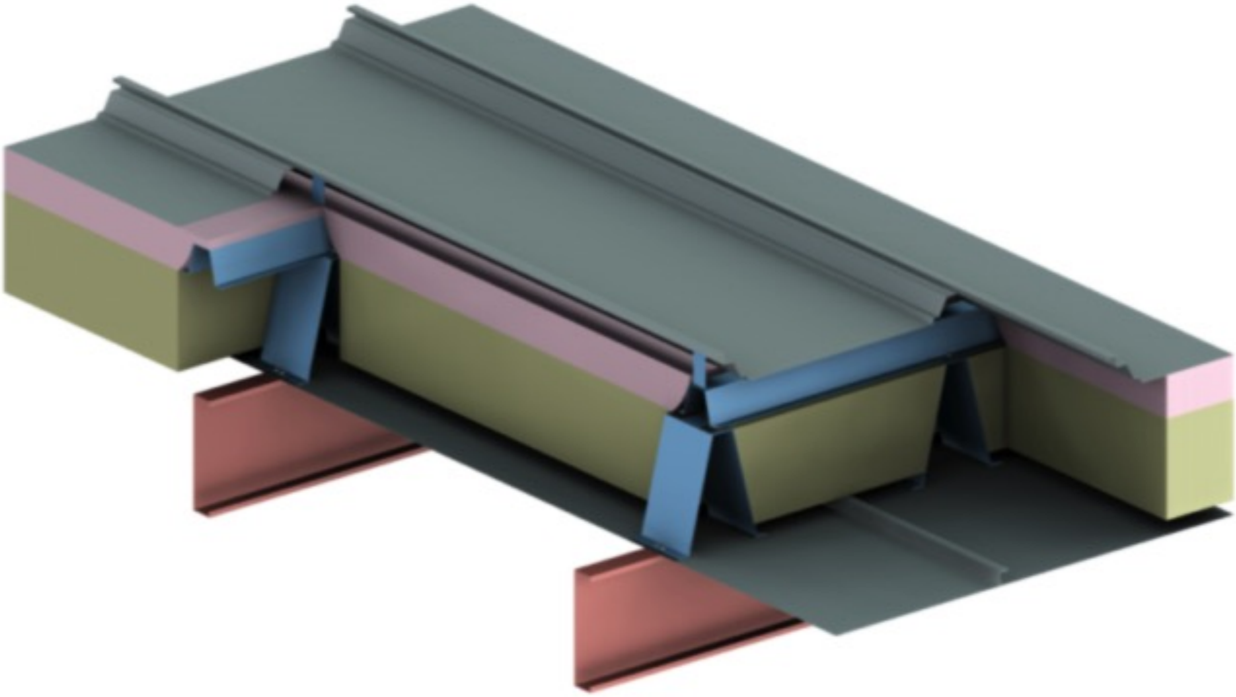

Figure 6: Insulated Standing Seam Roof Supported by Thermal Chairs

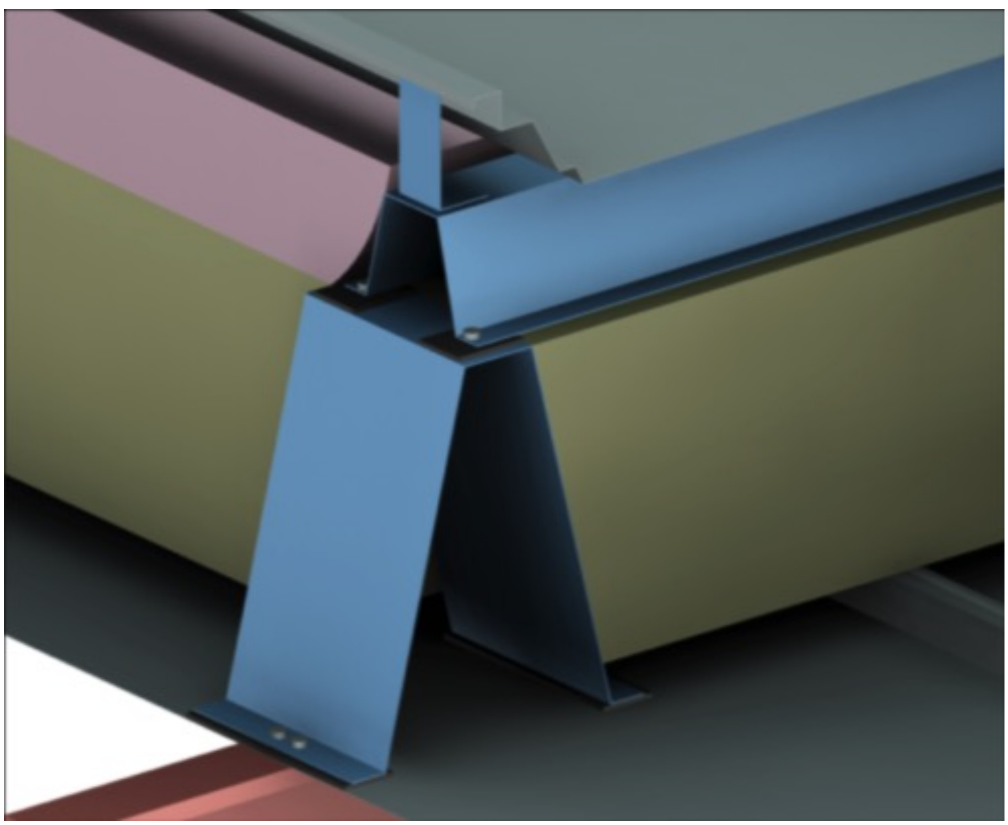

Figure 7: Detail of Standing Seam Roof Thermal Chair

The parametric study investigated the influence of different insulation combinations. The results are given in Table 8 for 24” o.c. thermal chair spacing and 48” o.c. purlin spacing.

Table 8
Standing Seam Roof

Insulation Placement	Insulation 1D R-Value (RSI)	“Effective” R-Value R_o ft²·hr·°F/Btu (m²·K/W)	Overall Thermal Transmittance U_o Btu/ft²·hr·°F (W/m²·K)	Highest NECB 2011 Zone Requirement Met
Compressed R-19 batt between and over hat tracks	R-57.6 (10.1)	R-33.4 (5.87)	0.030 (0.170)	6
Compressed R-19 batt between and over hat tracks with 1” XPS thermal block	R-57.6 (10.1)	R-36.4 (6.40)	0.028 (0.156)	7
Compressed R-19 batt between hat tracks, insulation over hat tracks	R-57.6 (10.1)	R-31.7 (5.59)	0.032 (0.179)	6
Mineral Wool between hat tracks, no compressed insulation over hat tracks	R-51.2 (9.0)	R-32.4 (5.71)	0.031 (0.175)	6

9. FOR ADDITIONAL INFORMATION

For information on sheet steel building products, or to obtain other CSSBI publications, contact the CSSBI at the address shown below or visit the web site at www.cssbi.ca

Canadian Sheet Steel Building Institute
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Canadian Sheet Steel Builidng Institute
652 Bishop Street North, Unit 2A
Cambridge, Ontario Canada N3H 4V6
T: 519-650-1285 F: 519-650-8081
www.cssbi.ca