ROK-ON SteelStud
Thermal Analysis

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Abstract

All wall assemblies use a number of components with varying R-value properties. Heat transfer through these materials can significantly impact the overall thermal performance of the walls reducing the effective R-value of the assembly through thermal bridging the insulation layers. Effective R-value of a wall assembly is not just the sum of the R-value of various components due to the fact of thermal bridging.

Metal can be thousands of times better at conducting heat than the typical insulating materials found in a wall, therefore the thermal bridge incurred by using steel elements can be substantial if no continuous insulation break of the thermal bridge is provided

A finite element analysis of the thermal flux properties of a wall system using regular batt insulation with the ROK-ON Panel System coupled with different gauge 6" steel studs is studied, The effective R values are calculated and shown.

1 Thermal Theory

Thermal energy always flows from hot to cold and has three main ways of heat transfer: Conduction,Convection and Radiation. The R-Value deals only with **Conduction**.

The R-Value is a measure of the resistance of a material to heat flow, expressed as R-10, R-30, and so on; the higher the number, the greater the resistance to heat flow.

Its units in Imperial and International systems respectively are:

$$R = \frac{^\circ F\ Hr\ Ft^2}{Btu} = \frac{^\circ K\ m^2}{W}$$

The R-Value is also equal to the temperature gradient divided by the Thermal Flow over an area. This fact is used to measure its whole value from experiments, or compute it from the boundary conditions, a temperature field and the Energy Flux vector which needs to be integrated over the external wall. The latter is the approach taken in this paper and was calculated by the Finite Element Analysis method using Code-Aster [3].

$$R = \frac{\Delta T}{\dot{Q}_a}$$

2 3D Model of the Wall System

This analysis is conducted using the metric system of units. The 3D model has the following layers starting from the inside of the wall to the outside:

2.1 Components

Starting from the inside out:

2.1.1 Drywall

A regular gypsum board 1219mm x 12mm x 2440mm sheet:

2.1.2 Steel Studs

The studs analyzed are 600S162-30 (6"x1.5" x 30 mill), 600S162-33 (6"x1.5" x 33 mill), 600S162-43 (6"x1.5" x 43 mill), 600S162-54 (6"x1.5" x 54 mill) all spaced 16" O.C. (406.4mm).

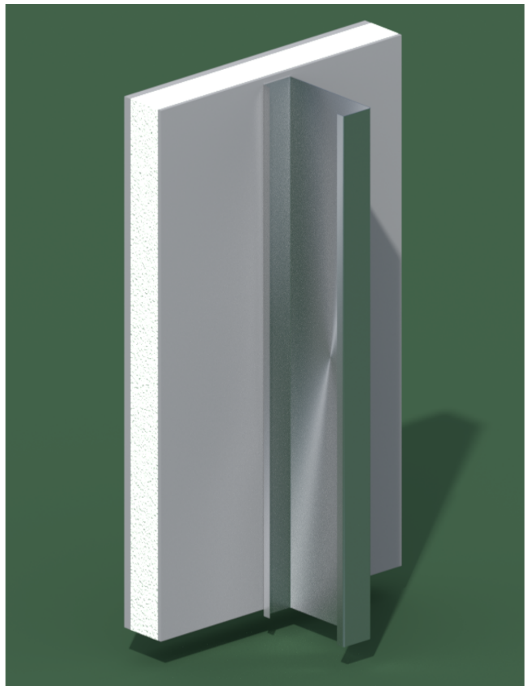

Figure 1: 3D Model, Batt insulation and Drywall not shown for clarity

2.1.3 Batt Insulation

R-19 fiberglass batt insulation between the studs.

2.1.4 ROK-ON Panel

A regular ROK-ON panel with 2" EPS foam core.

2.2 Material Properties

The physical properties of the materials considered in this analysis can be found in the following table: where:
ρ = Density.
λ = Thermal Conductivity.
C_p = Heat Capacity at Constant Pressure.

Material	$\rho \; \frac{Kg}{m^3}$	$\lambda \; \frac{W}{m\ ^\circ K}$	$C_P \; \frac{J}{Kg\ ^\circ K}$
Drywall	850	0.16	1090
Steel	7850	62	490
Batt	7	0.0437	843
RO FRCC	1150	0.15	874
Air	1.225	0.45	1005
Eps	16	0.026	1400

Table 1: Physical Material Properties [6]

3 Boundary Conditions

The boundary conditions used for this modeling are industry standard ASHRAE winter exterior and interior boundary conditions with temperatures of 0 °F (-17 °C) and 70°F (21 °C) and exterior and interior surface films of 0.17 $\left[\frac{ft^2\ ^\circ F\ hr}{Btu}\right]$ and 0.68 $\left[\frac{ft^2\ ^\circ F\ hr}{Btu}\right]$ respectively (ASHRAE [1]).

4 Results

A finite element analysis was performed using the Code-Aster [3] software incorporating the 3D model of the wall assembly, the boundary conditions and material properties outlined above.

4.1 Temperature Field

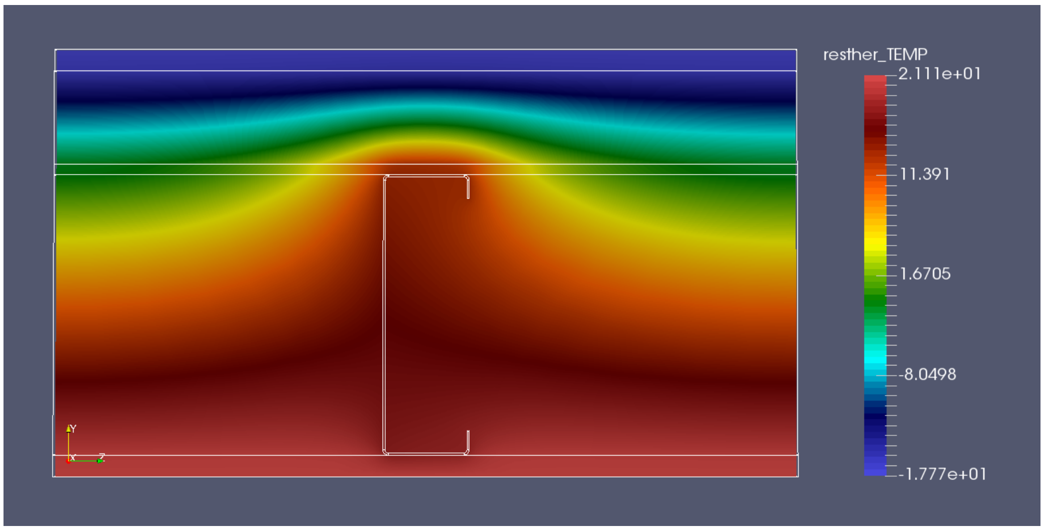

Figure 2: Gauge 18 Temperature Distribution

4.2 Heat Flux

In all cases the majority of the heat trasport happens at the studs, *it is very interesting to notice that the thermal bridging can happen next to a metal element even when the metal does not connect the cold and hot sides completely* as it can be seen in Figure 3

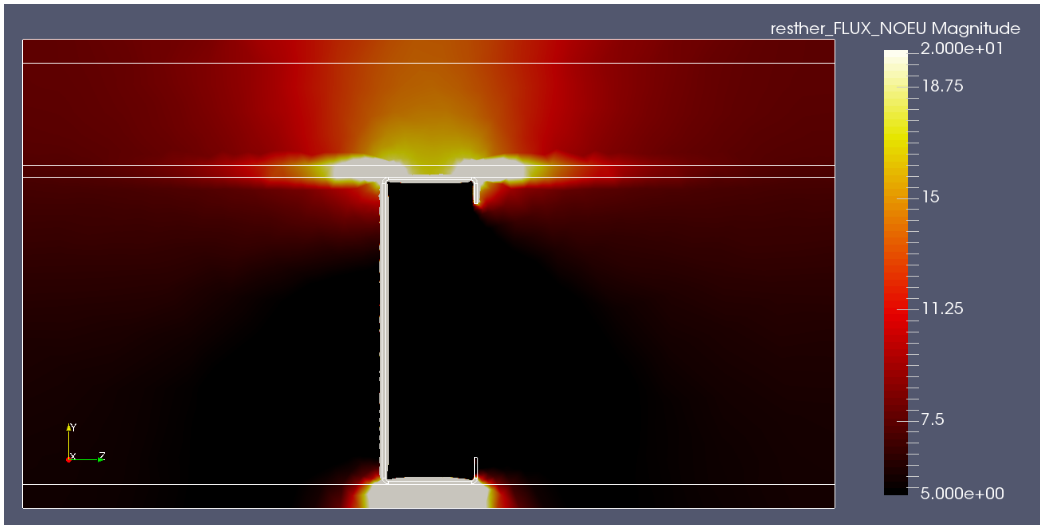

Figure 3: Energy Flux Magnitude Gauge 16. Notice how little energy flows trough the batt insulation (Black)

It is evident how The Rok-On Panel impedes the Heat Flux, when the bright white Energy comming into it is dispersed into darker yellow and red colors.

Using Code-Aster, [3] the heat flux was integrated over exterior wall surface with the following result and units where:

$\int_a q_{Ga20} = 9.779 \left[\frac{W}{m^2}\right]$ The same procedure was done for all the other gauges.

4.3 Effective R-Value

Recalling from the thermal theory $R = \dfrac{\Delta T}{\dot{Q}_a}$

where $\dot{Q}_a = \int_a q = 9.779 \left[\frac{W}{m^2}\right]$

The previous value converted to the Imperial system becomes:

$$9.88527 \left[\frac{W}{m^2}\right] = 3.0999267 \left[\frac{Btu}{Hr\ Ft^2}\right]$$

According to the ASHRAE winter exterior and interior conditions respectively of 0 °F and 70 °F.

$$R = \frac{(70-0)}{3.0999267} = 22.58 \left[\frac{^{\circ}F\ Hr\ Ft^2}{Btu}\right]$$

Adding the external and internal air films required by ASHRAE [1] with R=0.17 ft 2 ·°F·hr/BTU and 0.68 ft 2 ·°F·hr/BTU respectively the effective Wall R-Value is:

$$R = 23.43 \left[\frac{^{\circ}F\ Hr\ Ft^2}{Btu}\right]$$

Doing the same procedure to all the gauges in the study we get the following table:

Stud Gauge	**Thickness**	**Thermal Flux**	**R-Value**
20	30	9.779	23.43
20S	33	9.85796	23.25
18	43	10.0558	22.81
16	54	10.218	22.46

Table 2: Results

Where the units of Thickness are $[mill]$, Thermal Flux $\left[\frac{W}{m^2}\right]$ and R-Value $\left[\frac{^{\circ}F\ Hr\ Ft^2}{Btu}\right]$

5 Conclusion

The flow of thermal energy trough a wall is mostly done trough the steel studs, and changing gauges does not impact significantly the overall R-Value of the wall system analyzed.

References

[1] American Society of Heating Refrigerating and Air-Conditioning Engineers, *Ashrae handbook of fundamentals*, ASHRAE, 2013.

[2] International Code Council, *2015 international energy conservation code*, ISBN 9780000000000, 2015.

[3] Electricité de France, *Finite element code_aster, analysis of structures and thermomechanics for studies and research*, Open source on www.code-aster.org, 1989–2017.

[4] James Higgins, Colin Shane, and Graham Finch, *Thermal bridging from cladding attachment strategies through exterior insulation*, 9th Annual North American Passive House Conference, september 12–13, 2014.

[5] American Society of Heating Refrigerating and Air-Conditioning Engineers, *Energy standard for buildings except low-rise residential buildings*, ASHRAE, 2016.

[6] Engineering Toolbox, *The engineering toolbox*, www.engineeringtoolbox.com, April 2017.