

# ROK-ON SIS

## Thermal And Dew Point Analysis

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### **Abstract**

The R-value of building products was developed over 50 years ago as a way to compare a repeatable measure of resistance to heat transfer and insulation performance. However, wall assemblies use a number of components with varying geometries and 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. The effective R-value of a wall assembly is therefore not just the sum of the R-value of various components.

A ROK-ON panel with both a phenolic or an EPS core including studs and screws are analyzed by the finite element method, a steady state thermal analysis is conducted to find its temperature field and the thermal flux from where the effective R-Values of the assemblies is derived. Additionally, the Dew Point location is derived from the temperature field at sea level conditions and 25% Relative humidity.

## **1 Introduction**

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:

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

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 area. The latter is the approach taken in this paper and was calculated by the Finite Element Analysis method.

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

## 2 3D Model of the Wall System

In order to simulate steel studs every 406.4mm (16") and screws every 304.8mm (12") a model with exactly those dimensions on the following components was created and meshed with 1,650,437 linear elements. The axis are chosen when Z is vertical and Y goes across the panel with its positive direction being from the outside going to the inside.

The 3D model has the following layers starting from the inside of the wall to the outside:

### 2.1 Components From Inside Out (See Figure: [1](#))

- Drywall: A regular gypsum board 406.4mm x 15.9 mm x 304.8 mm (16"x0.625"x12") sheet.
- Steel Stud: One 600S162-43 (6"x1.5" x 1.1mm) steel stud. 18 Ga.
- Fiberglass batt insulation inside the stud cavity.
- First ROK-ON Panel: A regular ROK-ON panel with 2.75" either Phenolic or EPS foam core

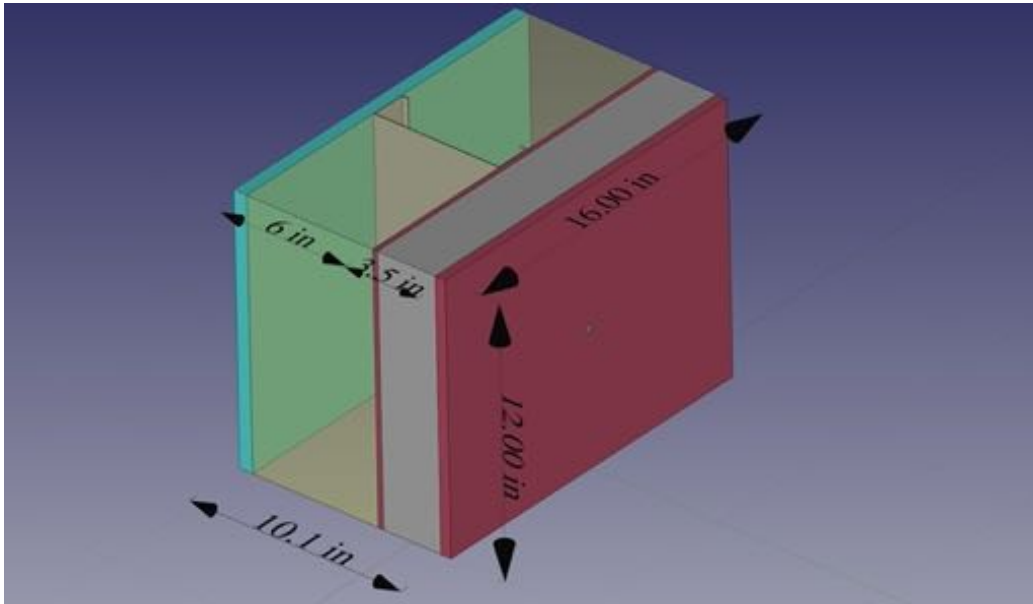


Figure 1: Model for the Study

- Screw: One 4.8mm diameter Rok-On Screw.

## 3 Modelization

### 3.1 Finite Element Model

The model considered is a steady state 3D thermal linear conduction calculation, no convection or radiation are considered, the temperature field and the thermal flux is calculated and integrated over the outside area.

### 3.2 Units

This study is conducted using the SI unit system unless otherwise stated.

### 3.3 Material Properties

The physical properties of the materials considered in this analysis can be found in the following table: where:

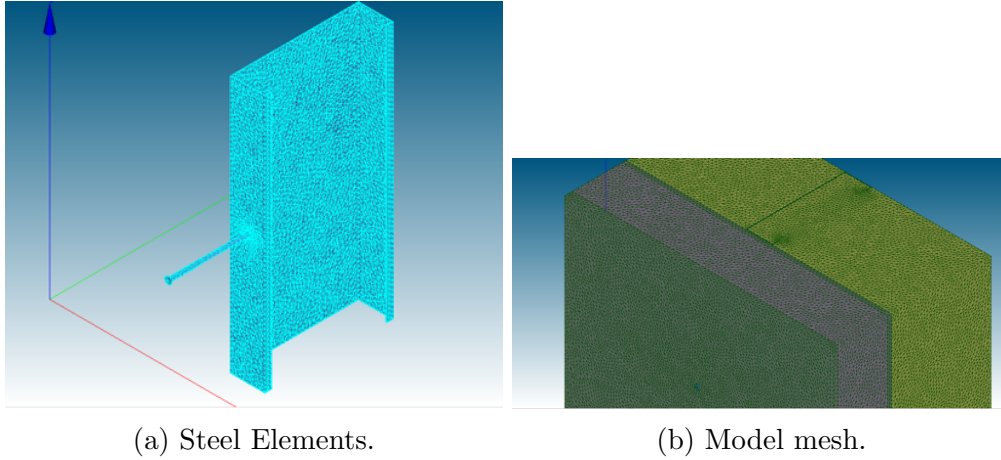


Figure 2: Model mesh

Table 1: Physical Material Properties [6]

<b>Material</b>	$\rho \frac{Kg}{m^3}$	$\lambda \frac{W}{m \cdot ^\circ K}$	$C_P \frac{J}{Kg \cdot ^\circ K}$
Drywall	850	0.16	1090
Batt Insul	45	0.035	457
Steel	7850	62	490
RO FRCC	1150	0.18	874
Phenolic	48	0.0188	452
EPS Foam	16	0.0346	1400

$\rho$  = Density.

$\lambda$  = Thermal Conductivity.

$C_p$  = Heat Capacity at Constant Pressure.

## 4 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) applied to the interior and exterior faces, additionally an exterior and interior surface films of  $0.17 \left[ \frac{ft^2 F hr}{Btu} \right]$  and  $0.68 \left[ \frac{ft^2 F hr}{Btu} \right]$  respectively (ASHRAE [1]). No other input or output of energy is modelled.

## 5 Results

The 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.

### 5.1 Temperature Field

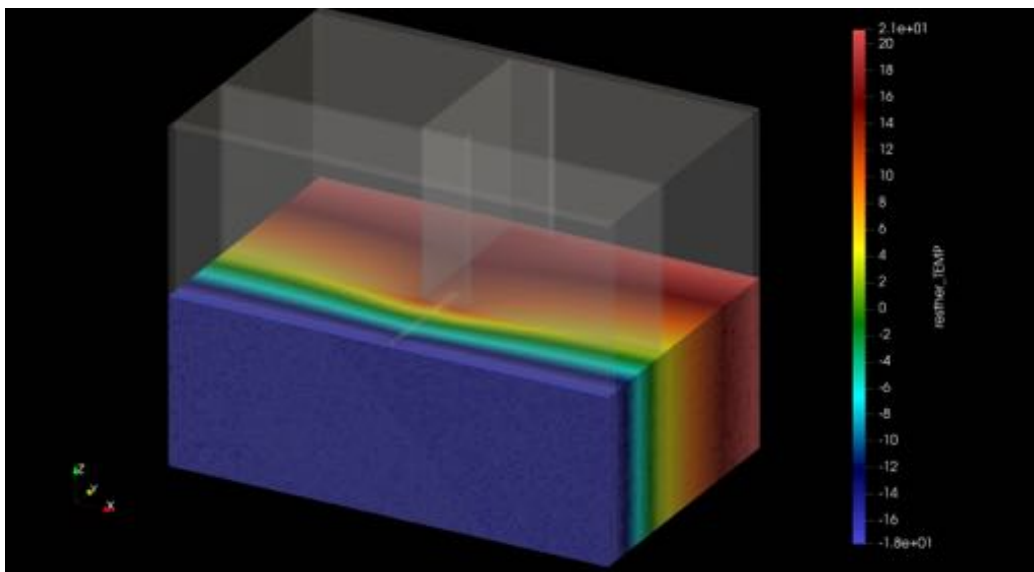


Figure 3: Temperature Field on a Section °C

### 5.2 Heat Flux

Using Code-Aster, [3] the heat flux was integrated over exterior wall surface with the results in tables [2] and [3]:

In Code-Aster verbage FLUY means Energy Flux in the Y axis.

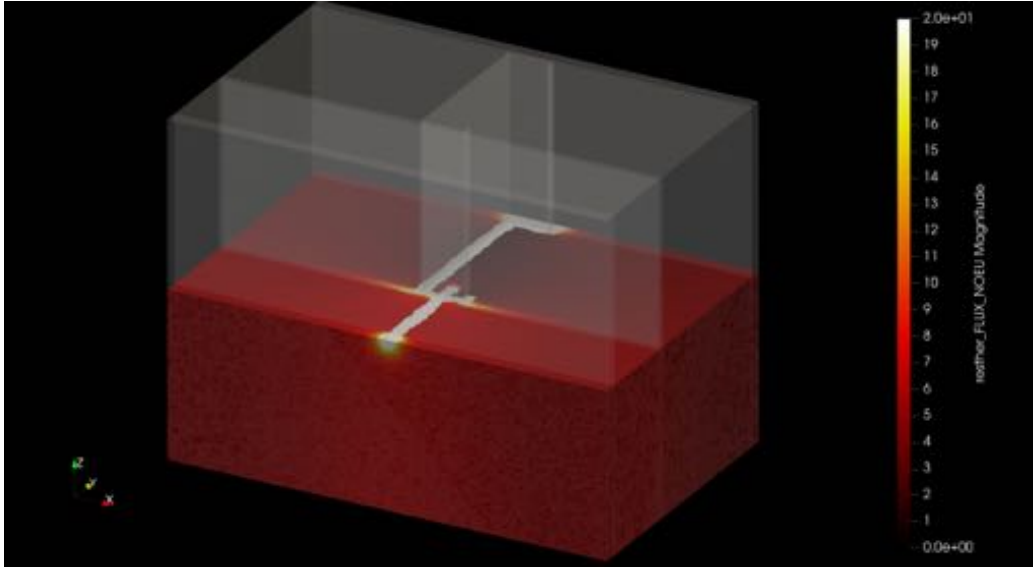
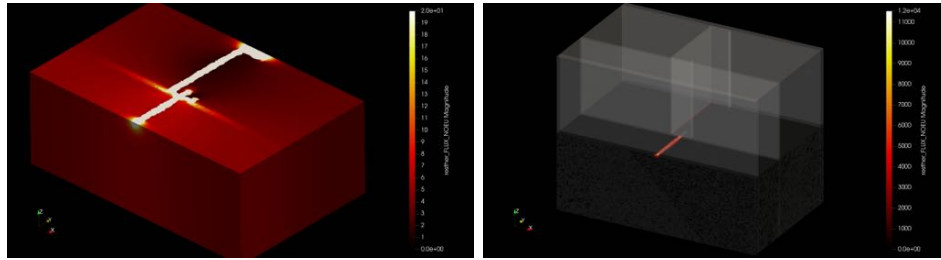


Figure 4: Thermal Flux (Magnitude) W

Table 2: Phenolic Core FLUY

Mesh Group	Area [ $m^2$ ]	Energy [W]
Outside	1.23813E-01	-8.09520E-01
Screw Tip	5.79024E-05	-1.54131E-01
Total	1.238709E-01	-9.63651E-01



(a) Flux Magnitude W

(b) Flux in Y direction W

Figure 5: Heat Flux

Table 3: EPS Core FLUY

Mesh Group	Area [m <sup>2</sup> ]	Energy [W]
Outside	1.23813E-01	-1.15732E+00
Screw Tip	5.79024E-05	-1.41144E-01
Total	1.238709E-01	-1.298464E+00

### 5.3 Effective R-Value

#### 5.3.1 Phenolic Core

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

where  $\dot{Q}_a = \int_a q = -7.7794 \left[ \frac{W}{m^2} \right]$

The previous value converted to the Imperial system becomes:

$$-7.7794 \left[ \frac{W}{m^2} \right] = -2.466079 \left[ \frac{Btu}{Hr Ft^2} \right]$$

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

$$R = \frac{(0 - 70)}{-2.466079} = 28.38 \left[ \frac{F Hr Ft^2}{Btu} \right]$$

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

$$R = 29.23 \left[ \frac{F \text{ Hr Ft}^2}{\text{Btu}} \right]$$

### 5.3.2 EPS Core

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

where  $\dot{Q}_a = \int_a q = -10.482365 \left[ \frac{W}{m^2} \right]$

The previous value converted to the Imperial system becomes:

$$-10.482365 \left[ \frac{W}{m^2} \right] = -3.32289221 \left[ \frac{\text{Btu}}{\text{Hr Ft}^2} \right]$$

According to the ASHRAE winter exterior and interior conditions respectively of  $0 \text{ °F}$  and  $70 \text{ °F}$ .

$$R = \frac{(0 - 70)}{-3.32289221} = 21.06 \left[ \frac{F \text{ Hr Ft}^2}{\text{Btu}} \right]$$

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

$$R = 21.91 \left[ \frac{F \text{ Hr Ft}^2}{\text{Btu}} \right]$$

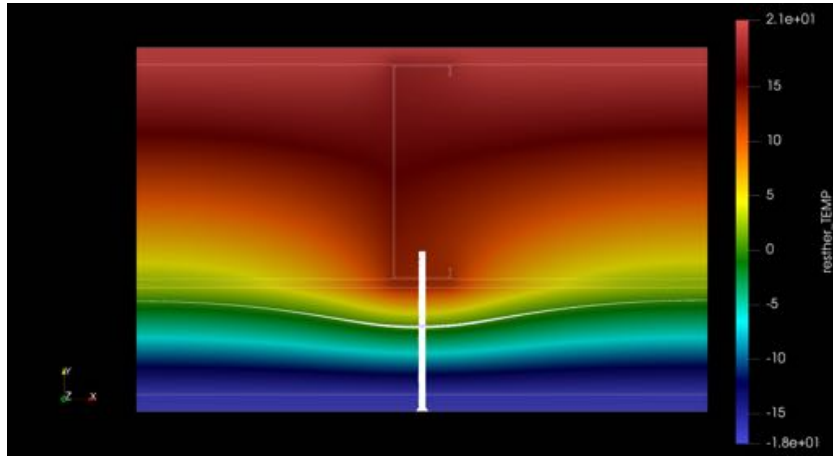


Figure 6: Dew Point Surface Location (White)

## 5.4 Dew Point Location

Using the assembly with the phenolic core, a finite element analysis using Code Aster was conducted to determine the dew point location under winter conditions.

In this analysis, the temperature values were 0 degrees F (-18C) on the outside with an internal temperature of 70 degrees F (21C) with an internal relative humidity of 25% . This is consistent with the ASHRAE standards. (0F/70F) and represents a lower temperature than is common in most parts of North America. The elevation considered was 40 ft. which is consistent with many cities near the coasts. A similar analysis can be run for any climate and location. See ROK-ON representative for details.

As noted, the assembly was consistent with the values used in the Thermal Analysis for the ROK-ON XT (phenolic core) and included the fastener.

In figure [6](#), the coldest section of the wall is represented in blue, with the warmest in red. In the analysis, the dew point is represented by the white line. In this analysis, the dew point resides outside the wall cavity.

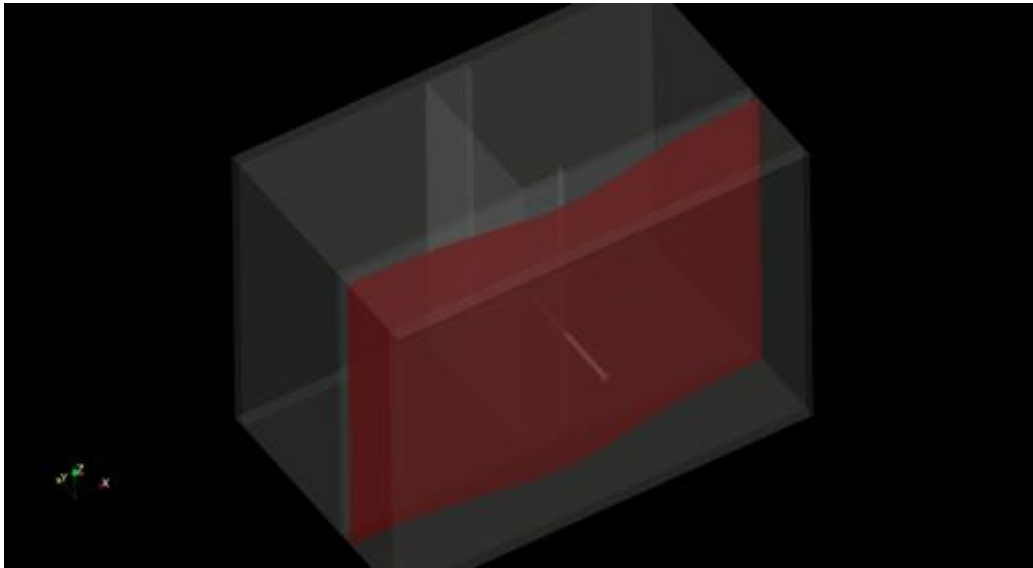


Figure 7: Dew Point Surface 3D view

## 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](http://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](http://www.engineeringtoolbox.com), April 2017.