Thermal Simulation Report | Project R-23875.003

Sapphire Balconies, 11 Arkwright Road, Reading, BERKS

To Andrew Parsons
Sapphire Balconies Ltd.
11 Arkwright Road
Reading BERKS RG2 0LU

Submitted May 11, 2022 by
RDH Building Science Inc.
4333 Still Creek Drive #400
Burnaby BC V5C 6S6

Contents

Appendices

1 Introduction

RDH Building Science Inc. (RDH) was retained by Sapphire Balconies Ltd. (Sapphire) to evaluate the thermal performance of the Sapphire G60 and G25 balcony connection anchor systems (Sapphire anchors). The intent of this analysis is to provide an overview of the thermal performance of the Sapphire Balcony system, including linear thermal transmittance (Psi-value) and point thermal transmittance (Chi-value), for a selection of common North American construction details. This report summarizes this analysis.

1.1 Project Background

The Sapphire G60 and G25 anchors are discrete anchor systems made to support prefabricated balconies on buildings. The point connection and thermal break within the anchor are intended to reduce heat loss compared to conventional cantilevered concrete balconies. The Sapphire anchor consists of an embedded steel anchor within the concrete slab edge, compressible mineral wool and high compressive strength phenolic resin thermal breaks outboard of the slab edge, and a bolt on exterior cantilevered steel beam to connect the balcony. The cantilevered beam compresses against the phenolic resin thermal break and is secured using stainless steel fasteners through the thermal break to the slab. Figure 1 shows a 3D model of the Sapphire G60 anchor.

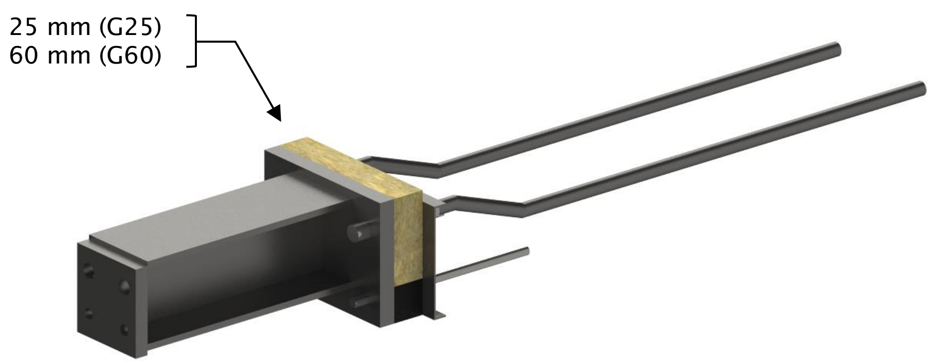


Figure 1: 3D model of the Sapphire anchor. G60 shown.

In this report, the Sapphire anchor was assessed for use with two common North American details:

- **Detail 1:** Sapphire anchor at a concrete slab edge with an exterior insulated steel framed infill wall.
- **Detail 2:** Sapphire anchor at a concrete slab edge with a sliding glass door above the floor slab and an exterior insulated steel framed wall below

Both details were analyzed with 51 mm, 102 mm, and 152 mm of exterior mineral wool insulation at the wall assembly. More information about the materials and their associated thermal performance is outlined in further detail within their respective sections of this report.

2 Methodology

2.1 Evaluation Assumptions

The Sapphire G60 and G25 anchors were evaluated using three-dimensional thermal modelling. This method allows for the analysis of complex and intermittent 3D geometries, such as bolts, clips, and balcony anchors, to provide a more comprehensive assessment of the impact of thermal bridging through building enclosure details.

Thermal modelling was performed in general conformance with CSA Z5010: *Calculation of Thermal Bridges in Building Enclosure Assemblies* and the ASHRAE Handbook Fundamentals. Per North American industry standard modelling practices, the analysis was conducted under steady-state heat flow using published material properties assuming isotropic and temperature independent thermal conductivities, and system information provided by Sapphire.

Further modelling assumptions and material properties used in this analysis are provided in Appendix A.

2.2 Software

The thermal modelling was performed using the NX software package from Siemens. NX is a three-dimensional multi-physics finite element analysis software tool. This software was validated as part of ASHRAE 1365-RP[1] and the Building Envelope Thermal Bridging Guide.

[1] https://www.techstreet.com/ashrae/standards/rp-1365-thermal-performance-of-building-envelope-details-for-mid-and-high-rise-buildings?gateway_code=ashrae&product_id=1806751

3 Results

3.1 Detail 1 – Exterior Insulated Steel Framed Wall at an Intermediate Concrete Floor

Detail 1 was analyzed with a characteristic section representing a single anchor penetration. The model was cut at symmetry planes aligned with steel framing spaced 406 mm (16”) O.C. and a floor-to-floor height of 2,660 mm. The Sapphire G60/G25 anchor was located at the slab edge and penetrated through the otherwise continuous exterior insulation. Figure 2 below shows the modelled assembly.

Figure 2: Detail 1, Sapphire G60/G25 through an exterior insulated steel famed wall

Table 1 presents Chi-values for the Sapphire anchor through Detail 1, along with the effective U-value of the modelled section with the spacing noted above. Examples thermal calculations using the Chi-values are provided in Appendix A. Example thermal profiles of Detail 1 are provided in Appendix B.

TABLE 1 DETAIL 1 SAPPHIRE THERMAL PERFORMANCE SUMMARY				
System	**Exterior Insulation Depth**	**Exterior Insulation 1D R-Value** m²·K/W (ft²·hr·°F/BTU)	**Modelled Section U-Value** W/m²·K (BTU/ft²·hr·°F)	**Anchor Chi-value** W/K (BTU/hr·°F)
G25	51mm (2”)	1.48 (8.4)	0.77 (0.14)	0.333 (0.632)
	102mm (4”)	2.96 (16.8)	0.58 (0.10)	0.386 (0.731)
	152mm (6”)	4.44 (25.2)	0.50 (0.09)	0.409 (0.775)
G60	51mm (2”)	1.48 (8.4)	0.72 (0.13)	0.226 (0.428)
	102mm (4”)	2.96 (16.8)	0.52 (0.09)	0.256 (0.485)
	152mm (6”)	4.44 (25.2)	0.43 (0.08)	0.274 (0.518)

As more exterior insulation is added to the wall assembly, more heat flows through the anchor and the Chi-value increases. This trend is consistent with other comparable thermal bridges.

3.2 **Detail 2** – Sliding Glass Door Above an Exterior Insulated Steel Framed

Detail 2 was analyzed with a double-glazed thermally broken aluminum sliding glass door with a U-value of 1.82 $W/m^2 \cdot K$ (0.32 $BTU/hr \cdot ft^2 \cdot {}^\circ F$). The modelled section which is 2,438 mm wide by 2,955 mm tall includes cut-off planes located mid-height across the door and the wall. The door was cut-off on either side where it would meet an adjacent window wall system above the slab, which aligned with the steel framed wall spaced 406 mm (16") O.C. below the slab. At the slab edge, two Sapphire anchors were modelled penetrating through the wall's exterior insulation. Figure 3 below shows the analyzed section.

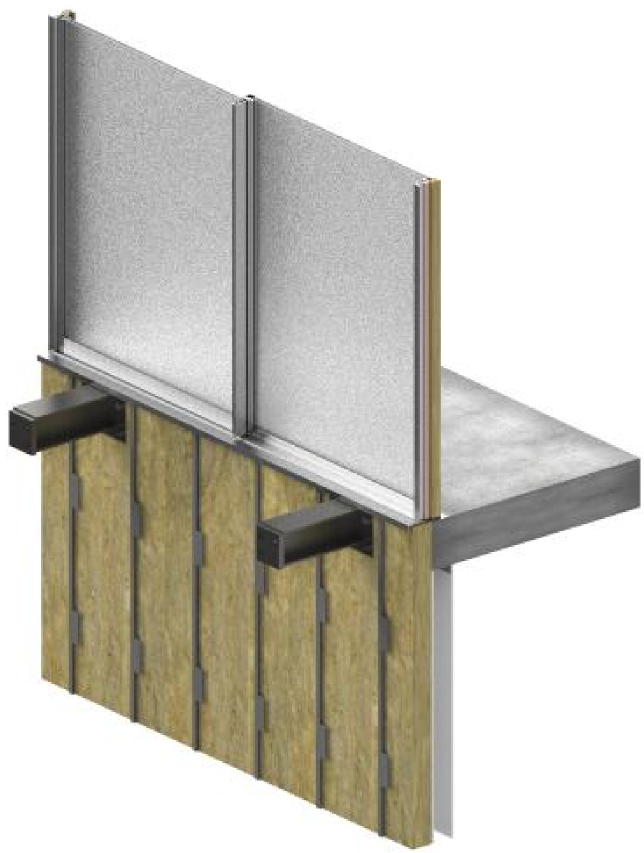


Figure 3: Representation of Detail 2, Sapphire anchor at sliding glass door

Table 2 presents Chi-values for the anchor and Psi-values for the sliding glass door interface to the concrete floor slab. Examples thermal calculations using the Chi-values and Psi-values are provided in Appendix A. Example thermal profiles of the Detail 2 are provided in Appendix B.

TABLE 3.2 SAPPHIRE BALCONY ANCHOR DETAIL 2 PERFORMANCE SUMMARY					
System	**Exterior Insulation Depth**	**Ext. Insulation 1D R-Value** $m^2 \cdot K/W$ ($ft^2 \cdot hr \cdot °F/BTU$)	**Sim. Section U-Value** $W/m^2 \cdot K$ ($BTU/ft^2 \cdot hr \cdot °F$)	**Door Sill Psi-value** $W/m \cdot K$ ($BTU/hr \cdot ft \cdot °F$)	**Anchor Chi-value** W/K ($BTU/hr \cdot °F$)
G25	51mm (2”)	1.48 (8.4)	1.40 (0.25)	0.289 (0.167)	0.276 (0.523)
	102mm (4”)	2.96 (16.8)	1.30 (0.23)	0.306 (0.177)	0.300 (0.568)
	152mm (6”)	4.44 (25.2)	1.27 (0.22)	0.325 (0.188)	0.303 (0.574)
G60	51mm (2”)	1.48 (8.4)	1.37 (0.24)	0.289 (0.167)	0.186 (0.353)
	102mm (4”)	2.96 (16.8)	1.28 (0.22)	0.306 (0.177)	0.202 (0.382)
	152mm (6”)	4.44 (25.2)	1.24 (0.22)	0.325 (0.188)	0.215 (0.407)

As more exterior insulation is added to the wall assembly, heat flow through the anchor and sliding glass door interface increases. This trend is similar to Detail 1; however the Chi-values for Detail 2 are lower than Detail 1 by approximately 20%. This can be attributed to the additional heat flow path through the sliding glass door.

4 Conclusion

RDH performed three-dimensional thermal simulations of Sapphire’s G60 and G25 balcony systems to determine their Psi-value and Chi-value when modelled for a selection of common North American construction details. The Chi-values for the G25 and G60 anchors range from approximately 0.2 W/K to 0.4 W/K depending on the anchor type, exterior insulation depth, and building enclosure detail.

We trust this report meets your needs at this time. Please do not hesitate to contact us with any questions you might have.

Yours truly,

2022 05 18
Permit Number: 1003380

Baihan Guo | EIT
Building Science Engineer (EIT)
bguo@rdh.com
T 778-370-6843
RDH Building Science Inc.

Reviewed by,
Daniel Haaland | MASc., P.Eng.,
Associate, Building Science Engineer
RDH Building Science Inc.

encl. Appendix A – Simulation Notes
Appendix B – Model Outputs

Appendix A

Simulation Notes

A.1 Additional Assumptions

Thermal modelling was performed in general conformance with CSA Z5010: *Calculation of Thermal Bridges in Building Enclosure Assemblies* and the ASHRAE Handbook Fundamentals. In addition to the standard modelling assumptions, the following additional assumptions and parameters were utilized for this study:

- → Specific surfaces utilized contract resistances, as per CSA Z5010 and ASHRAE 1365-RP and range between RSI-0.002 (R-0.01) and RSI-0.035 (R-0.2) depending on the materials.
- → The insulation was assumed to be installed tight to adjacent surfaces with no gaps.
- → No solar heating or heat storage of materials was included in this analysis.
- → Enclosed air spaces were provided with an equivalent conductivity as per calculation methods presented in ISO 10077.
- → Exterior cladding system was indirectly simulated using a protected air film and no cladding was explicitly modelled. This approach is considered conservative and permits the results to be used more broadly for a range of similar cladding options.

A.2 Temperature Index

The thermal simulations were performed using a Temperature Index (I). The Temperature Index is a non-dimensional ratio of the surface temperature over the change in temperature across the assembly (Equation 1).

$$I = \frac{T_s - T_e}{T_i - T_e} \tag{1}$$

Where,

T_s, is the surface thermal temperature of interest in ˚C

T_i, is the interior air temperature in ˚C

T_e, is the exterior air temperature in ˚C

I, is the Temperature Index

The simulations were run with an exterior temperature index of 0 and an interior index of 1. As the material properties were assumed independent of temperature, this allows the temperature profile to be reasonably applicable to any temperature difference. Equation 1 can be rearranged to solve for a specific surface temperature at different interior and exterior design temperatures.

$$T_s = I \cdot (T_i - T_e) + T_e \tag{2}$$

Temperature profiles shown in Appendix B provide surface temperatures and scale as per this index.

A.3 Example Thermal Calculations

The effective U- and R-values of an assessed section (U- and R-vales of a wall section including thermal bridges) can be calculated using equation 1 below:

$$U = \frac{\sum U_i \cdot A_i + \sum \Psi_i \cdot L_\mathrm{i} + \sum \mathrm{X_i} \cdot n_i}{A_{Total}} \tag{1}$$

Where,

U, is the overall effective thermal transmittance for the assessed section (W/m²·K)

U_i, is a clear field thermal transmittance an assembly (W/m²·K)

A_{total}, is the total section area being assessed (m²)

A_i, is the area of a clear field assembly (m²)

Ψ_i, is a linear thermal transmittance (W/m·K)

L_i, is the length of a linear thermal bridge (m)

X_i, is a point thermal transmittance (W/K)

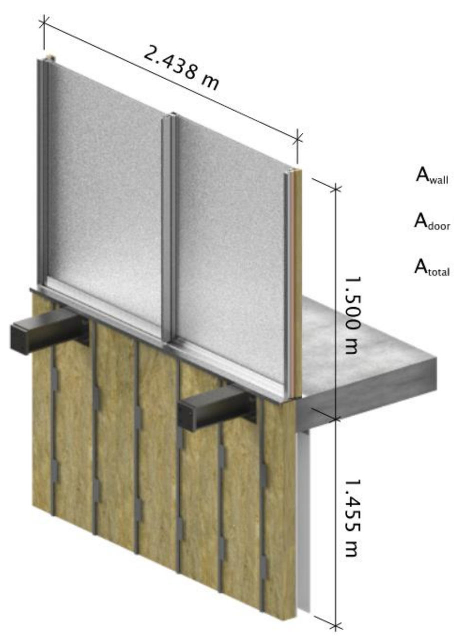
n_i, is the quantity of a point thermal bridge (#)

Sample Calculation:

To determine the effective U-value of Detail 2 with two G25 anchors and 2" of exterior insulation equation 1 can be rewritten as follows:

$$U = \frac{U_{wall} \cdot A_{wall} + U_{door} \cdot A_{door} + \Psi_{sill} \cdot L_\mathrm{sill} + \mathrm{X}_{anchor} \cdot n_{anchor}}{A_{Total}}$$

$$U = \frac{0.614 \cdot 3.547 + 1.809 \cdot 3.657 + 0.289 \cdot 2.438 + 0.276 \cdot 2}{7.204} = 1.40\ (\mathrm{W}/m^2 \cdot \mathrm{K})$$



A_{wall} = 1.455 x 2.438 = 3.547 m²

A_{door} = 1.500 x 2.438 = 3.657 m²

A_{total} = 3.547 + 3.657 = 7.204 m²

A.4 Boundary Conditions

Table A4 below presents the boundary condition properties used for this study. These values were taken from the ASHRAE Handbook of Fundamentals.

TABLE A4 BOUNDARY CONDITIONS	
Boundary Conditions	**Thermal Resistance ($m^2 \cdot K/W$)**
Exterior (Exposed)	0.03
Exterior (Protected)	0.12
Interior (opaque wall)	0.12
Interior (horizontal window frame)	0.20
Interior (vertical window frame)	0.13
Interior (IGU edge)	0.20
Interior (IGU center of glass)	0.13
Interior ceiling surface	0.11
Interior floor surface	0.16

A.5 Material Properties

Table A5 lists all materials included in the thermal simulation and their associated thermal properties. Materials were assigned to the models based on the documents provided by Sapphire or taken from published sources, including from Lawrence Berkley National Laboratories and the ASHRAE Handbook of Fundamentals.

TABLE A5 LIST OF MATERIAL PROPERTIES USED IN THE THERMAL MODELLING			
No.	**Component**	**Material**	**Conductivity (W/m·K)**
1	Gypsum	Gypsum	0.160
2	Steel Stud	Galv. Steel	62.00
3	Air Cavity	Air[1]	-
4	Exterior Sheathing	Gypsum	0.160
5	Exterior Insulation	Mineral Wool	0.034
6	Cladding Clips	Galv. Steel	62.00
7	Cladding Attachment Girts	Galv. Steel	62.00
8	Concrete Slab	Concrete	1.800
9	Sapphire G60/G25 Anchor		
	Pre-Welded Stub Assembly	Mild Steel	160.0
	Rock Wool Infill	Mineral Wool	0.034
	Thermal Break[2]	Thermal Break	0.200
	Shutter Plate	Mild Steel	50.00
	M16 Anchor	Stainless Steel	17.00
	M30 Stud	Stainless Steel	17.00
	Dia. 25 Re-bar	Mild Steel	50.00
10	Thermally Broken Aluminum Sliding Glass Door		
	Aluminum Frame	Aluminum	160.0
	Thermal Break	Polyamide	0.300
	Urethan Thermal Break	Urethan	0.121
	Frame Insulation	Mineral Wool	0.034
	Gaskets & Sealants	Silicone	0.350
	Mohair	Mohair	0.140
	Sill Track Cover	PVC	0.170
	Sill Angel	Aluminum	160.0
	Air Cavity	Air[1]	-
	IGU – Glass	Glass	1.000
	IGU Cavity	Gas Fill	0.023
	TGI Spacer – Silicone[3]	Silicone	0.400
	TGI Spacer – Spacer[3]	TGI Spacer	0.310

Notes to Table C1:

[1] The thermal conductivities of the air spaces were determined according to ISO 10077

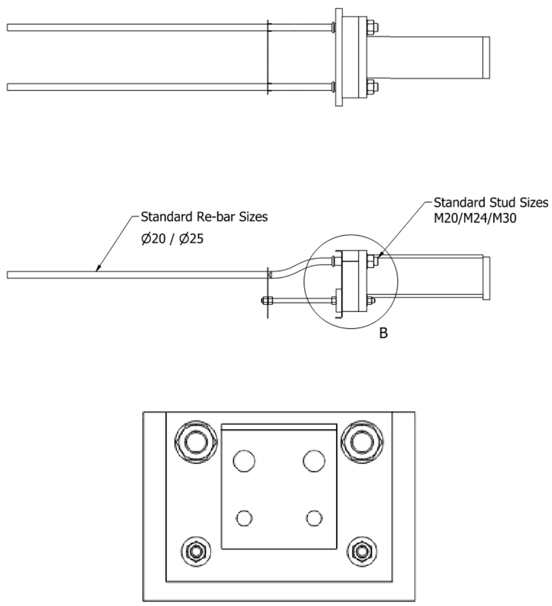
[2] Thermal break conductivity was assigned according to Sapphire M30 Anchor with Thermal Break Data Sheet V1.1 provided by Sapphire

[3] TGI-M two box model Equivalent Conductivity

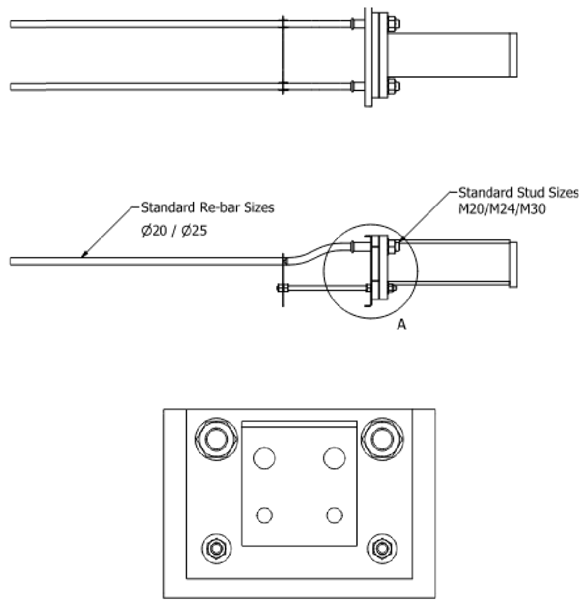
Appendix B

Model Outputs

MANUFACTURER'S DETAIL:

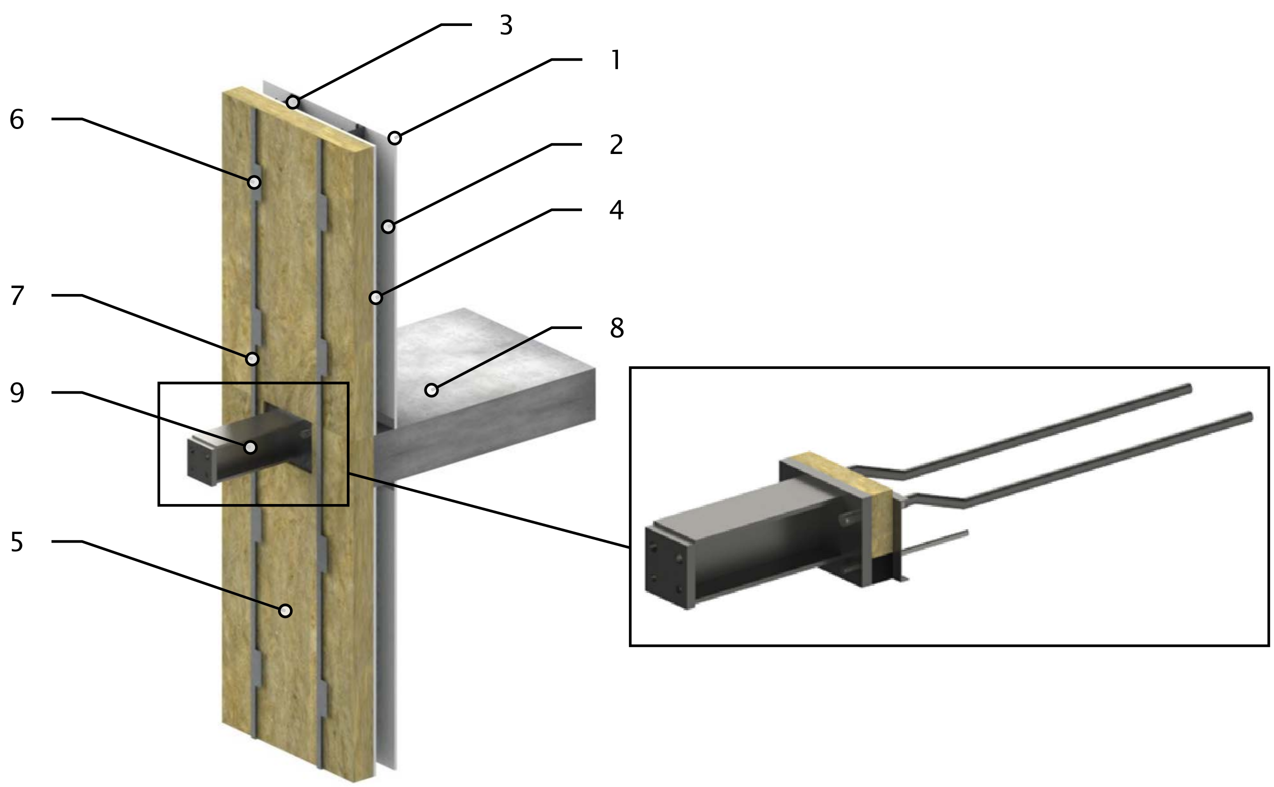


G60



G25

3D MODEL:



Sapphire Anchor Penetrating Exterior Insulated Steel Framed Wall

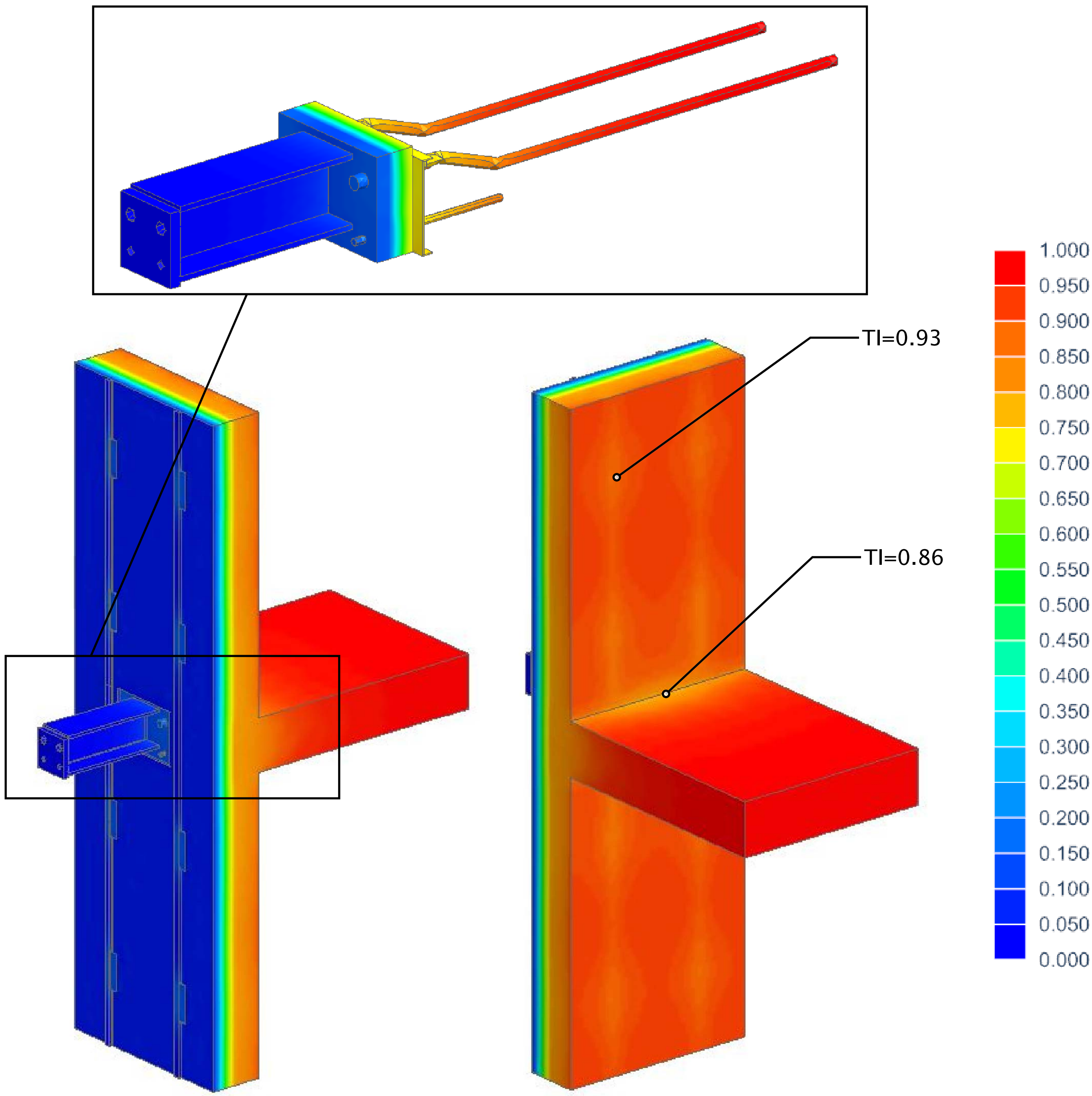
RDH

4333 STILL CREEK DRIVE #400 WWW.RDH.COM
BURNABY BC V5C 6S6 TEL 604 873 1181

THE DETAILS WERE MODELED AND ASSESSED FOR THERMAL HEAT TRANSMITTANCE ONLY. THE DETAILS WERE NOT EVALUATED WITH RESPECT TO OTHER BUILDING ENCLOSURE FUNCTIONS SUCH AS MOISTURE CONTROL, AIR LEAKAGE, STRUCTURAL, OR DURABILITY. RDH AND ITS EMPLOYEES NEITHER ENDORSE NOR WARRANT THE SUITABILITY OF THE SIMULATED PRODUCTS.

PROJECT NAME:	CLIENT NAME: Sapphire
PRODUCT NAME: Sapphire Anchor System	PROJECT NO.:
DRAWING REFERENCE: R10041-G60-00-0_2D R10041-G25-00-0_2D	DATE: Mar 06, 2022
	DRAWN BY: BG
	CHECKED BY: NN

Vancouver



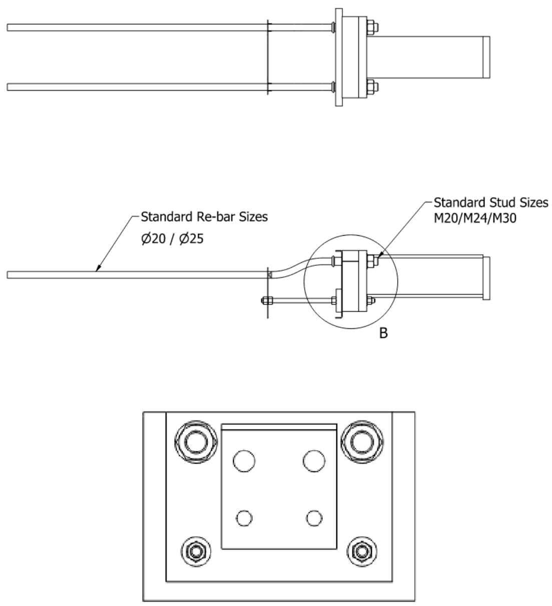
MODEL TYPE:

Sapphire Anchor Penetrating Exterior Insulated Steel Framed Wall (4" Exterior Insulation)

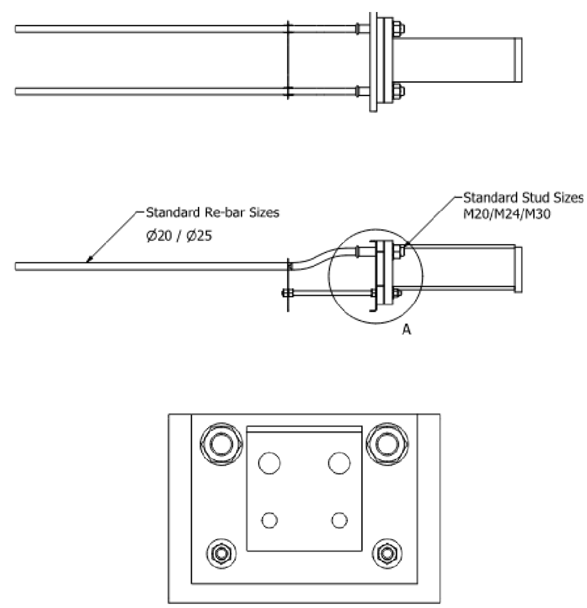
RDH		PROJECT NAME:	CLIENT NAME: Sapphire
4333 STILL CREEK DRIVE #400 WWW.RDH.COM BURNABY BC V5C 6S6 TEL 604 873 1181		PRODUCT NAME: Sapphire Anchor System	PROJECT NO.:
THE DETAILS WERE MODELED AND ASSESSED FOR THERMAL HEAT TRANSMITTANCE ONLY. THE DETAILS WERE NOT EVALUATED WITH RESPECT TO OTHER BUILDING ENCLOSURE FUNCTIONS SUCH AS MOISTURE CONTROL, AIR LEAKAGE, STRUCTURAL, OR DURABILITY. RDH AND ITS EMPLOYEES NEITHER ENDORSE NOR WARRANT THE SUITABILITY OF THE SIMULATED PRODUCTS.		DRAWING REFERENCE: R10041-G60-00-0_2D R10041_G25-00-0_2D	DATE: Mar 06, 2022 DRAWN BY: BG CHECKED BY: NN

Vancouver

MANUFACTURER'S DETAIL:

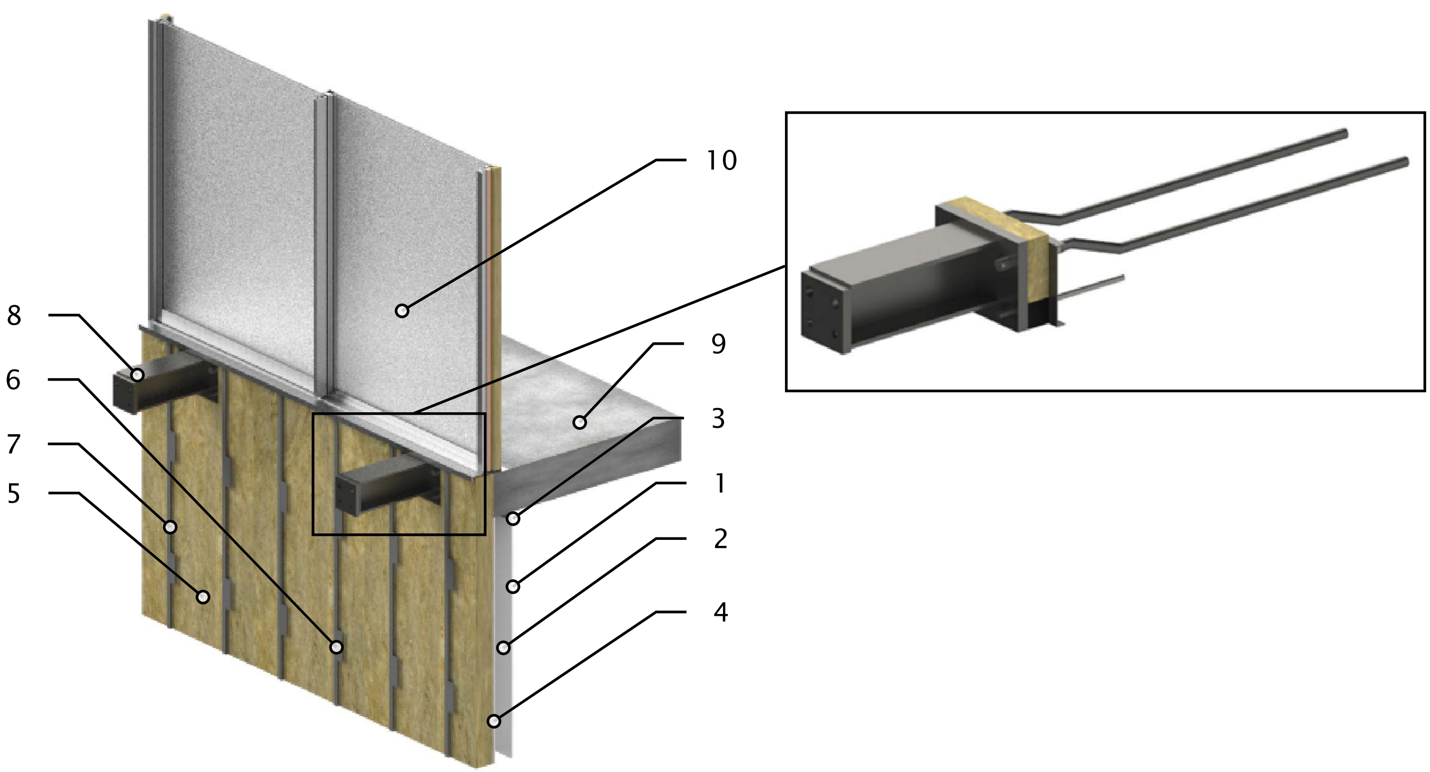


G60



G25

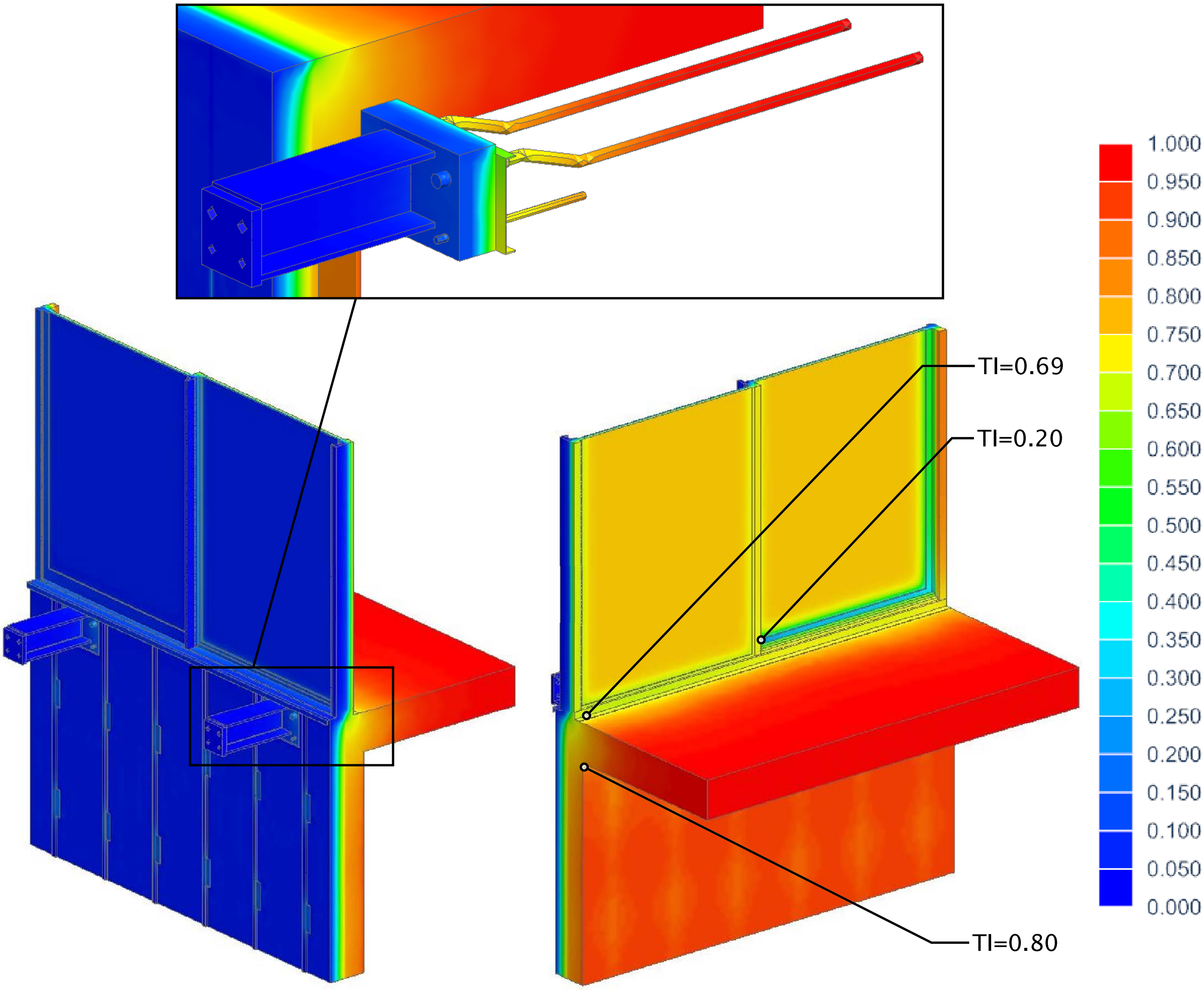
3D MODEL:



Sapphire Anchor Penetrating Exterior Insulated Steel Framed Wall with Sliding Glass Door

RDH 4333 STILL CREEK DRIVE #400 WWW.RDH.COM BURNABY BC V5C 6S6 TEL 604 873 1181		PROJECT NAME:	CLIENT NAME: Sapphire
		PRODUCT NAME: Sapphire Anchor System	PROJECT NO.:
THE DETAILS WERE MODELED AND ASSESSED FOR THERMAL HEAT TRANSMITTANCE ONLY. THE DETAILS WERE NOT EVALUATED WITH RESPECT TO OTHER BUILDING ENCLOSURE FUNCTIONS SUCH AS MOISTURE CONTROL, AIR LEAKAGE, STRUCTURAL, OR DURABILITY. RDH AND ITS EMPLOYEES NEITHER ENDORSE NOR WARRANT THE SUITABILITY OF THE SIMULATED PRODUCTS.		DRAWING REFERENCE: R10041-G60-00-0_2D R10041_G25-00-0_2D	DATE: Mar 06, 2022 DRAWN BY: BG CHECKED BY: NN

Vancouver



MODEL TYPE:

Sapphire Anchor Penetrating Exterior Insulated Steel Stud Wall with Sliding Door Above Slab (4" Exterior Insulation)

RDH

4333 STILL CREEK DRIVE #400 WWW.RDH.COM
BURNABY BC V5C 6S6 TEL 604 873 1181

THE DETAILS WERE MODELED AND ASSESSED FOR THERMAL HEAT TRANSMITTANCE ONLY. THE DETAILS WERE NOT EVALUATED WITH RESPECT TO OTHER BUILDING ENCLOSURE FUNCTIONS SUCH AS MOISTURE CONTROL, AIR LEAKAGE, STRUCTURAL, OR DURABILITY. RDH AND ITS EMPLOYEES NEITHER ENDORSE NOR WARRANT THE SUITABILITY OF THE SIMULATED PRODUCTS.

PROJECT NAME:	CLIENT NAME: Sapphire
PRODUCT NAME: Sapphire Anchor System	PROJECT NO.:
DRAWING REFERENCE: R10041-G60-00-0_2D R10041_G25-00-0_2D	DATE: Mar 06, 2022
	DRAWN BY: BG
	CHECKED BY: NN

Vancouver