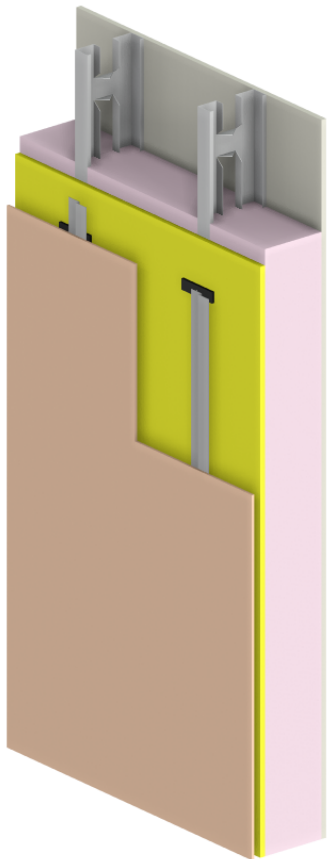




MORRISON HERSHFIELD

R-Stud Thermal Analysis



Presented to:

Mr. Patrick Lucas CEO

R-Stud LLC

3200 Park Center Dr 14th Floor
Costa Mesa, CA 92626 (updated)

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1. INTRODUCTION

Morrison Hershfield was retained by R-Stud LLC (R-Stud) to evaluate the thermal performance of the R-Stud steel studs and compare to standard steel studs for a variety of wall assembly configurations. This report is a summary of the analysis.

The evaluated wall assemblies and their components are shown below in Table 1.1.

Table 1.1: R-Stud and Standard Stud Evaluated Assemblies

<p>Scenario 1 Vertical Z-Bar with Fibrecement</p>	<p>Scenario 2 Horizontal Z-Bar with Fibrecement</p>	<p>Scenario 3 Stucco</p>	<p>Scenario 4 Ceraclad Clip with Ceraclad Panel</p>
<ul style="list-style-type: none"> • 1/4 inch fibrecement • Rainscreen cavity • 18ga. vertical z-bar • 1 inch x 4 inch x 1/4 inch polypropylene shim • 5/8 inch DensGlass sheathing • 6 inch x 1 5/8 inch steel R-Studs or standard studs with R-21 batt insulation or R-25.2 mineral wool insulation in stud cavity • 5/8 inch interior gypsum 	<ul style="list-style-type: none"> • 1/4 inch fibrecement • Rainscreen cavity • 18ga. horizontal z-bar • 1 inch x 4 inch x 1/4 inch polypropylene shim • 5/8 inch DensGlass sheathing • 6 inch x 1 5/8 inch steel R-Studs or standard studs with R-21 batt insulation or R-25.2 mineral wool insulation in stud cavity • 5/8 inch interior gypsum 	<ul style="list-style-type: none"> • Stucco • 5/8 inch DensGlass or plywood sheathing • 6 inch x 1 5/8 inch steel R-Studs or standard studs with R-21 batt insulation or R-25.2 mineral wool insulation in stud cavity • 5/8 inch interior gypsum 	<ul style="list-style-type: none"> • 1/2 inch Ceraclad panel • Rainscreen cavity • Ceraclad clip • 5/8 inch plywood sheathing • 6 inch x 1 5/8 inch steel R-Studs or standard studs with R-21 batt insulation or R-25.2 mineral wool insulation in stud cavity • 5/8 inch interior gypsum

In addition to the scenarios described in Table 1.1 above, all of the R-Stud assemblies were evaluated with the same materials and dimensions as Table 1.1 with the following modifications:

- R-28.8 GPS foam insulation in the stud cavity, and
- 1/2 inch interior gypsum

2. MODELLING PROCEDURES

The thermal performance of the different assembly scenarios was evaluated by 3D thermal modelling using the Nx software package from Siemens, which is a general purpose computer aided design (CAD) and finite element analysis (FEA) package. The thermal solver and modelling procedures utilized for this study were extensively calibrated and validated to within +/- 5% of hotbox testing for *ASHRAE Research Project 1365-RP Thermal Performance of Building Envelope Details for Mid- and High-Rise Construction and for the Building Envelope Thermal Bridging Guide*¹. The thermal analysis utilized steady-state conditions, published thermal properties of materials and information provided by R-Stud. Additional assumptions for the thermal analysis are listed in Appendix B. Further assembly information, including dimensions and materials are given in Appendix C.

For the R-Stud assemblies, the ratio of metal in the web of the stud to batt insulation in the stud cavity may impact the results. The geometry of the R-stud web knockouts were assumed to be consistent for all stud heights, therefore if the backup wall changed in height the R-values of the assemblies may not be directly comparable. Thus, for all scenarios the assemblies were modelled with the same height.

1 <https://www.bchydro.com/thermalguide>

3. THERMAL RESULTS

The U-values and effective R-values with R-21 batt insulation in the stud cavity are shown in Table 3.1. Results for scenarios with R-25.2 mineral wool insulation in the stud cavity are shown in Table 3.2, and results for the R-Stud assemblies with R-28.8 GPS foam insulation in the stud cavity are shown in Table 3.3. Example temperature profiles for each configuration are provided in Appendix D.

Table 3.1: Effective R-values of the Evaluated Wall Assemblies with R-21 Batt Insulation

Scenario		Stud Spacing in	Z-Bar / Clip Spacing in	R-Stud		Standard Stud	
				U-Value Btu/h ft ² °F (W/m ² °K)	Effective R-Value ft ² · hr °F/Btu (m ² °K/W)	U-Value Btu/h ft ² °F (W/m ² °K)	Effective R-Value ft ² · hr °F/Btu (m ² °K/W)
1A	Vertical Z-Bar with Fibre cement	16	16	0.065 (0.37)	R-15.3 (2.70)	0.082 (0.46)	R-12.2 (2.15)
1B		24	24	0.058 (0.33)	R-17.4 (3.06)	0.069 (0.39)	R-14.5 (2.56)
2A	Horizontal Z-Bar with Fibre cement	16	32	0.065 (0.37)	R-15.4 (2.71)	0.081 (0.46)	R-12.3 (2.17)
2B		24	32	0.057 (0.33)	R-17.5 (3.07)	0.068 (0.39)	R-14.7 (2.59)
3A	Stucco with DensGlass Sheathing	16	--	0.068 (0.39)	R-14.7 (2.59)	0.087 (0.49)	R-11.5 (2.02)
3B		24	--	0.060 (0.34)	R-16.7 (2.95)	0.073 (0.41)	R-13.8 (2.43)
3C	Stucco with Plywood Sheathing	16	--	0.066 (0.38)	R-15.1 (2.66)	0.083 (0.47)	R-12.0 (2.11)
4	Ceraclad Clip with Ceraclad Panel	24	18	0.056 (0.32)	R-18.0 (3.17)	0.065 (0.37)	R-15.3 (2.70)

Table 3.2: Effective R-values of the Evaluated Wall Assemblies with R-25.2 Mineral Wool Insulation

Scenario		Stud Spacing in	Z-Bar / Clip Spacing in	R-Stud		Standard Stud	
				U-Value Btu/h ft ² °F (W/m ² °K)	Effective R-Value ft ² · hr °F/Btu (m ² °K/W)	U-Value Btu/h ft ² °F (W/m ² °K)	Effective R-Value ft ² · hr °F/Btu (m ² °K/W)
1A	Vertical Z-Bar with Fibre cement	16	16	0.059 (0.34)	R-16.9 (2.97)	0.076 (0.43)	R-13.2 (2.32)
1B		24	24	0.051 (0.29)	R-19.4 (3.42)	0.063 (0.36)	R-16.0 (2.81)
2A	Horizontal Z-Bar with Fibre cement	16	32	0.059 (0.33)	R-17.0 (2.99)	0.075 (0.43)	R-13.3 (2.34)
2B		24	32	0.051 (0.29)	R-19.5 (3.44)	0.062 (0.35)	R-16.2 (2.85)
3A	Stucco with DensGlass Sheathing	16	--	0.062 (0.35)	R-16.2 (2.85)	0.083 (0.47)	R-12.1 (2.13)
3B		24	--	0.053 (0.30)	R-18.7 (3.30)	0.066 (0.37)	R-15.2 (2.67)
3C	Stucco with Plywood Sheathing	16	--	0.059 (0.34)	R-16.8 (2.96)	0.077 (0.44)	R-13.0 (2.28)
4	Ceraclad Clip with Ceraclad Panel	24	18	0.050 (0.28)	R-20.1 (3.54)	0.059 (0.34)	R-16.9 (2.97)



Table 3.3: Effective R-values of the Evaluated R-Stud Wall Assemblies with R-28.8 GPS Foam Insulation

Scenario		Stud Spacing in	Z-Bar / Clip Spacing in	U-Value Btu/h ft ² °F (W/m ² °K)	Effective R-Value ft ² · hr °F/Btu (m ² °K/W)
1A	Vertical Z-Bar with Fibrecement	16	16	0.056 (0.32)	R-17.8 (3.13)
1B		24	24	0.048 (0.27)	R-20.8 (3.66)
2A	Horizontal Z-Bar with Fibrecement	16	32	0.056 (0.32)	R-17.9 (3.15)
2B		24	32	0.048 (0.27)	R-20.9 (3.68)
3A	Stucco with DensGlass Sheathing	16	--	0.059 (0.33)	R-17.1 (3.01)
3B		24	--	0.050 (0.29)	R-19.8 (3.49)
3C	Stucco with Plywood Sheathing	16	--	0.057 (0.32)	R-17.6 (3.10)
4	Ceraclad Clip with Ceraclad Panel	24	18	0.046 (0.26)	R-21.5 (3.79)

We believe that this report meets your objectives for evaluating the thermal performance of the R-Stud and standard stud assemblies. If you have any questions or comments related to the above, please do not hesitate to contact the undersigned.

Morrison Hershfield Limited



Katie Hay, P.Eng.
Building Science Consultant

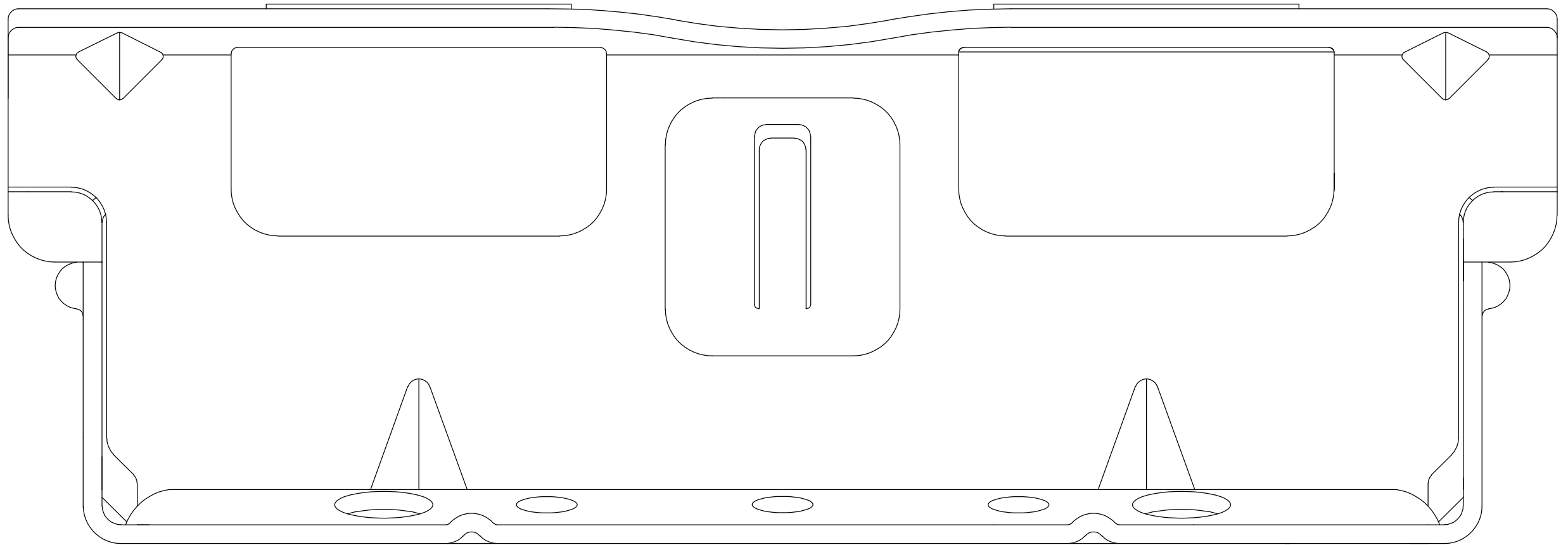


Ivan Lee, P.Eng.
Building Science Consultant

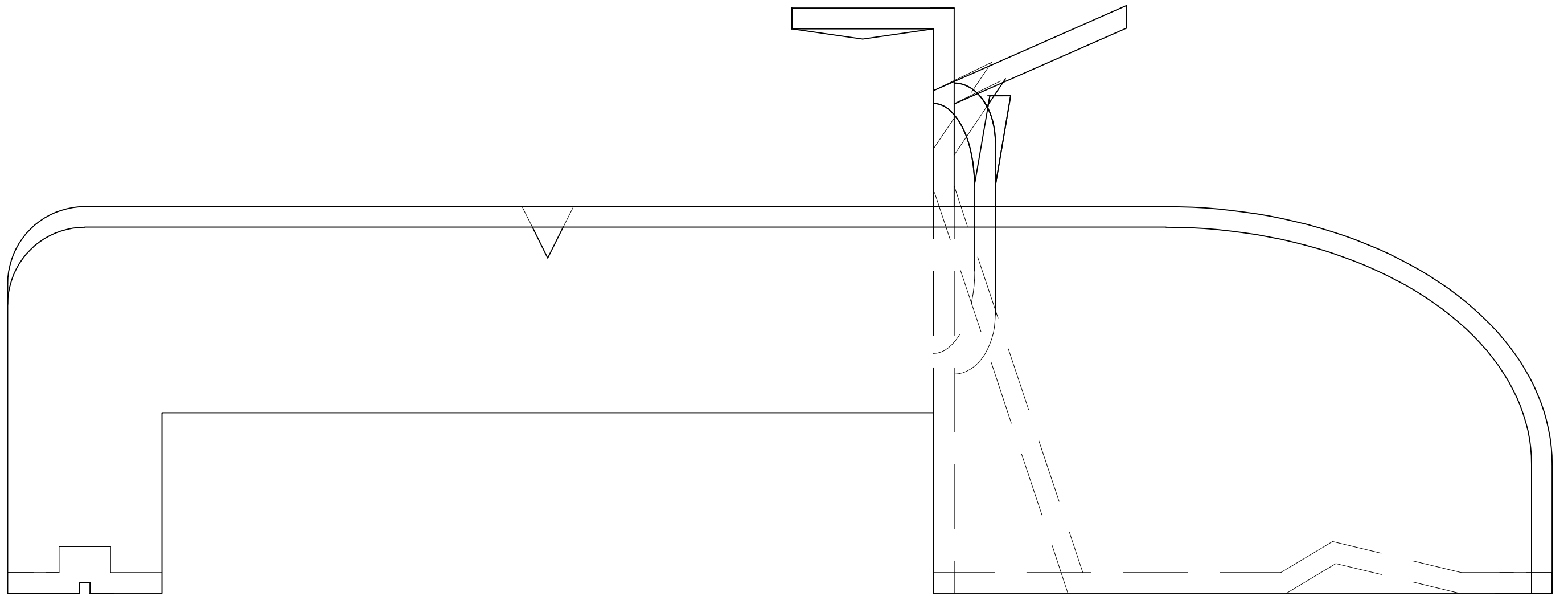


**APPENDIX A:
CERACLAD CLIP
DRAWINGS**





Ceraclad Clip: New Clip Drawing



Ceraclad Clip: New Clip Drawing
Side View

APPENDIX B: MODELLING PARAMETERS AND ASSUMPTIONS

1. GENERAL MODELLING APPROACH

For this report, a steady-state conduction model was used. The following parameters were also assumed:

- Material properties were taken from information provided by R-Stud LLC and ASHRAE Handbook – Fundamentals for common materials.
- Interior/exterior air films were taken from Table 1, p. 26.1 of 2009 ASHRAE Handbook – Fundamentals depending on surface orientation. The exterior air films were based on an exterior wind speed of 15 mph.
- From the calibration in 1365-RP, contact resistances between materials were modeled and varied between R-0.01 and R-0.2 depending on the materials and interfaces.
- Insulation and other components were considered tight to adjacent interfaces.
- The clear field transmittances included in this analysis include uniform thermal bridges such as studs, clips, and girts.

2. TEMPERATURE INDEX

The temperature index is the ratio of the surface temperature relative to the interior and exterior temperatures. The temperature index has a value between 0 and 1, where 0 is the exterior temperature and 1 is the interior temperature. If T_i is known, Equation 1 can be rearranged for $T_{surface}$. This arrangement allows the modelled surface temperatures to be applicable to any climate.

$$T_i = \frac{T_{surface} - T_{outside}}{T_{inside} - T_{outside}} \quad \text{EQ 1}$$

Note, these indices shown in the temperature profiles for this analysis are for general information only and are not intended to predict in-service surface temperatures subject to transient conditions, variable heating systems, and/ or interior obstructions that restrict heating of the assembly. For full limitations of this modeling approach, see ASHRAE 1365-RP.

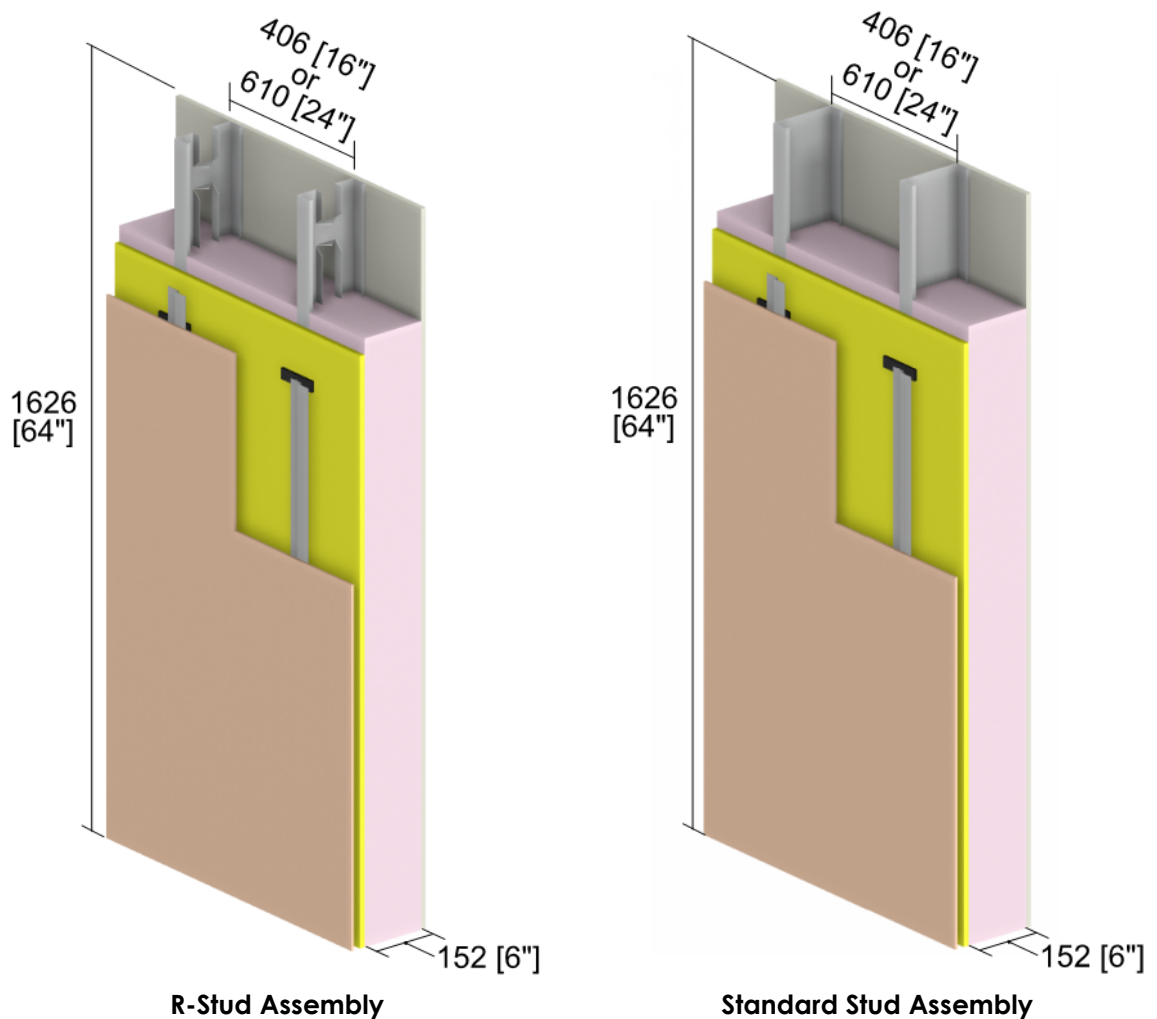
3. BOUNDARY CONDITIONS

Table B3.1: Boundary Conditions

Boundary Location	Heat Transfer Coefficient BTU/hft ² °F (W/m ² K)
Exterior Surfaces	6.0 (34)
Interior Walls	1.5 (8.3)

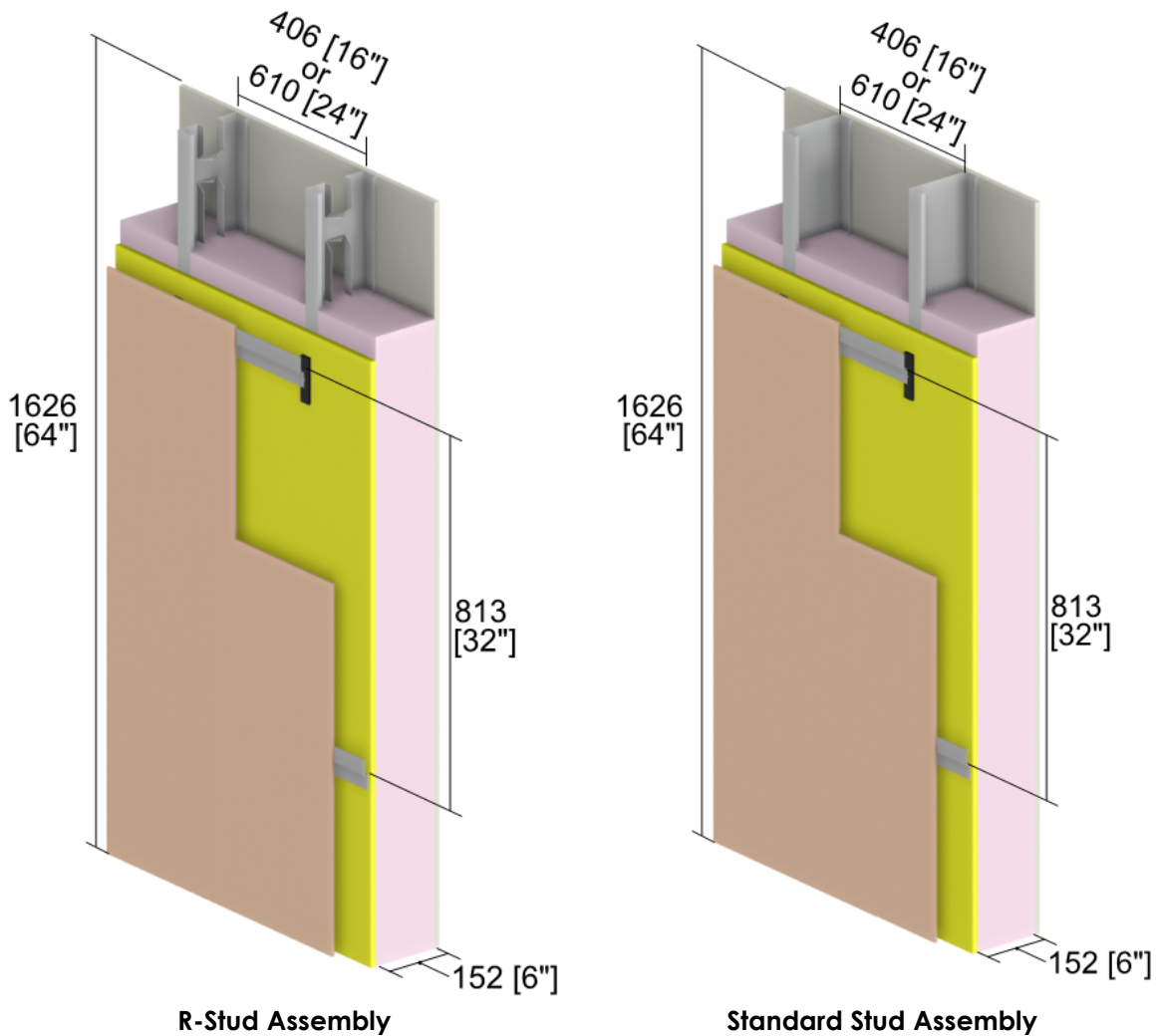
APPENDIX C: MATERIAL PROPERTIES

1. VERTICAL Z-BAR WITH FIBRECEMENT



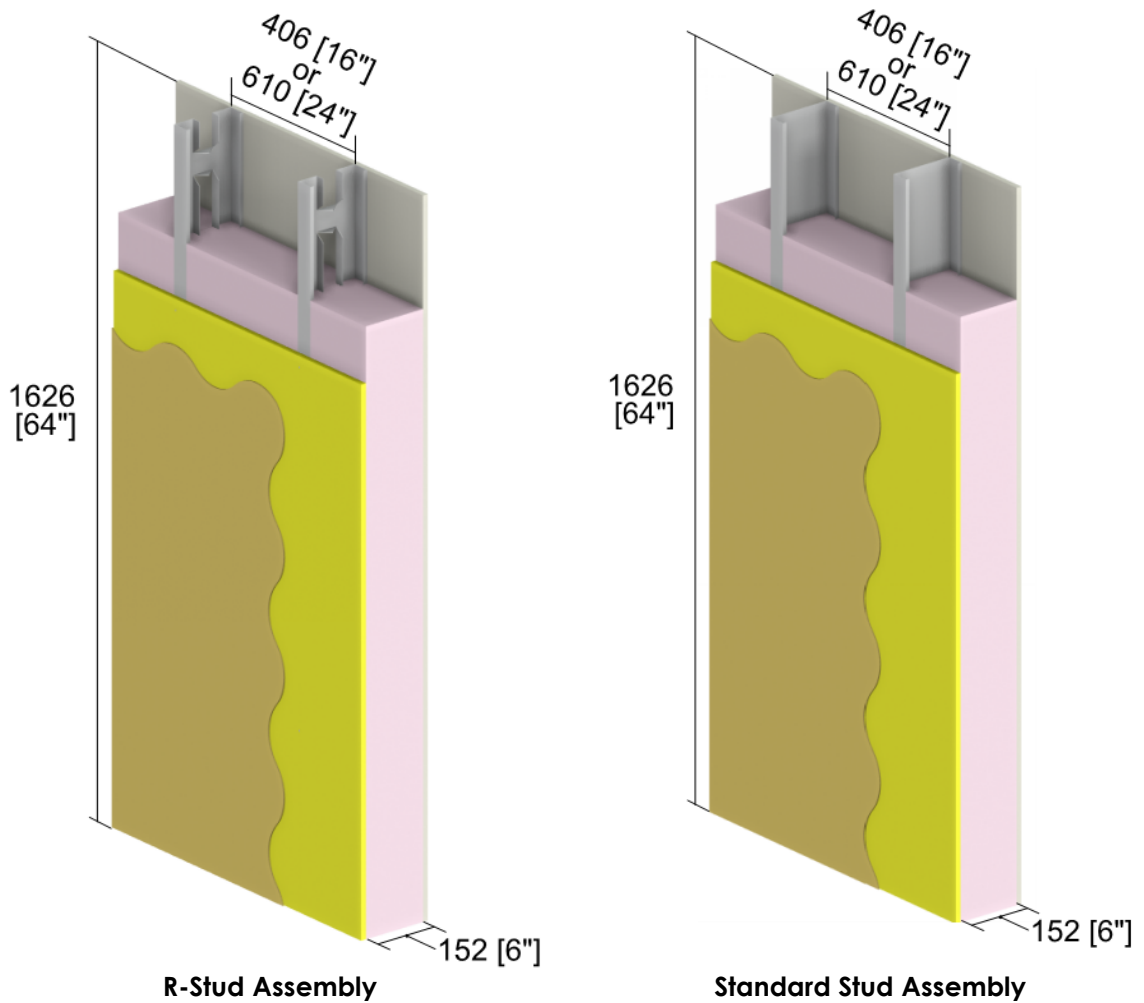
Component	Material	Thermal Conductivity Btu in / ft ² hr °F (W/m K)
Gypsum	Gypsum	1.1 (0.16)
Steel Stud	Galvanized Steel	430 (62)
Stud Cavity	R-21 Batt Insulation, or	0.29 (0.041)
	R-25.2 Mineral Wool Insulation, or	0.24 (0.034)
	R-28.8 GPS Foam Insulation	0.21 (0.030)
Sheathing	DensGlass	1.1 (0.16)
Rainscreen Cavity	Vented Air Gap	1.6 (0.23)
Z-Girt	Galvanized Steel	430 (62)
Shim	Polypropylene	1.5 (0.22)
Fastener	Steel	347 (50)
Fibrecement	Fibrecement	1.7 (0.25)

2. HORIZONTAL Z-BAR WITH FIBRECEMENT



Component	Material	Thermal Conductivity Btu in / ft ² hr °F (W/m K)
Gypsum	Gypsum	1.1 (0.16)
Steel Stud	Galvanized Steel	430 (62)
Stud Cavity	R-21 Batt Insulation, or	0.29 (0.041)
	R-25.2 Mineral Wool Insulation, or	0.24 (0.034)
	R-28.8 GPS Foam Insulation	0.21 (0.030)
Sheathing	DensGlass	1.1 (0.16)
Rainscreen Cavity	Vented Air Gap	1.6 (0.23)
Z-Girt	Galvanized Steel	430 (62)
Shim	Polypropylene	1.5 (0.22)
Fastener	Steel	347 (50)
Fibre cement	Fibre cement	1.7 (0.25)

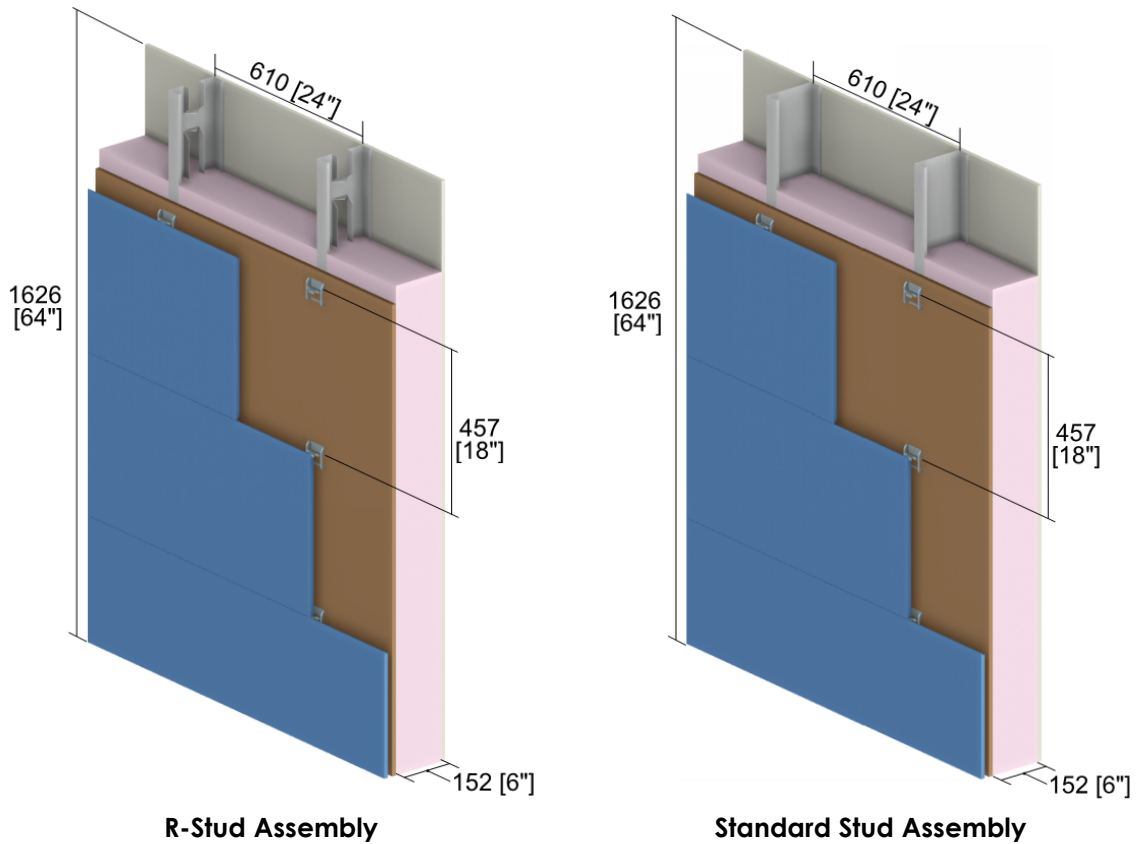
3. STUCCO ASSEMBLY



Component	Material	Thermal Conductivity Btu in / ft ² hr °F (W/mK)
16 inch o.c. and 24 inch o.c. Studs with DensGlass Sheathing		
Gypsum	Gypsum	1.1 (0.16)
Steel Stud	Galvanized Steel	430 (62)
Stud Cavity	R-21 Batt Insulation, or	0.29 (0.041)
	R-25.2 Mineral Wool Insulation, or	0.24 (0.034)
	R-28.8 GPS Foam Insulation	0.21 (0.030)
Sheathing	DensGlass	1.1 (0.16)
Stucco	Stucco	6.2 (0.90)
16 inch o.c. Studs with Plywood Sheathing		
Gypsum	Gypsum	1.1 (0.16)
Steel Stud	Galvanized Steel	430 (62)
Stud Cavity	R-21 Batt Insulation, or	0.29 (0.041)
	R-25.2 Mineral Wool Insulation, or	0.24 (0.034)
	R-28.8 GPS Foam Insulation	0.21 (0.030)
Sheathing	Plywood	0.69 (0.10)
Stucco	Stucco	6.2 (0.90)



4. CERACLAD CLIP WITH CERACLAD PANEL



Component	Material	Thermal Conductivity Btu in / ft ² hr °F (W/m K)
Gypsum	Gypsum	1.1 (0.16)
Steel Stud	Galvanized Steel	430 (62)
Stud Cavity	R-21 Batt Insulation, or	0.29 (0.041)
	R-25.2 Mineral Wool Insulation, or	0.24 (0.034)
	R-28.8 GPS Foam Insulation	0.21 (0.030)
Sheathing	Plywood	0.69 (0.10)
Rainscreen Cavity	Vented Air Gap	1.4 (0.20)
Ceraclad Clip	Steel	347 (50)
Fastener	Steel	347 (50)
Ceraclad Panel	Fibre cement	1.7 (0.25)

**APPENDIX D:
SIMULATED TEMPERATURE
PROFILES**

The following figures illustrate the temperature distribution for representative scenarios of the evaluated assemblies. The profiles presented are for the R-Stud assemblies spaced 24 inches o.c., and are presented as a temperature index (between 0 and 1). See Appendix B.2 for more information.

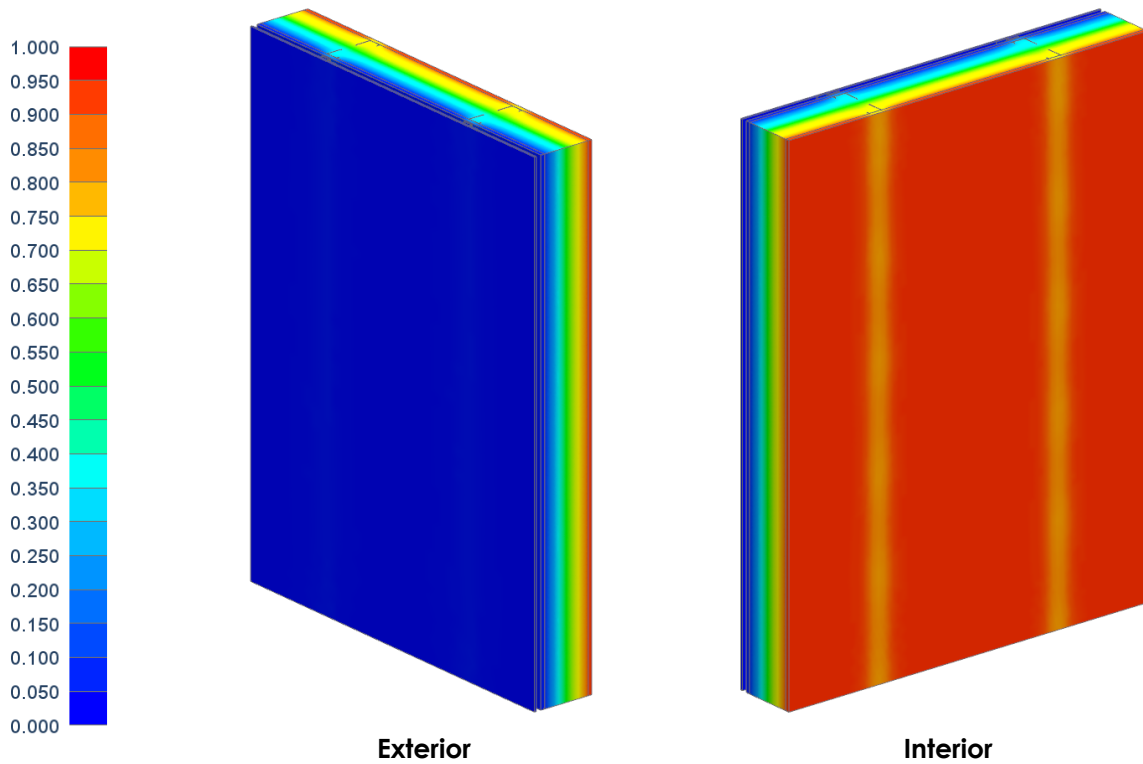


Figure D1: Temperature Profile of Vertical Z-Girt Assembly with R-Stud, spaced 24 inches o.c. (Scenario 1B)

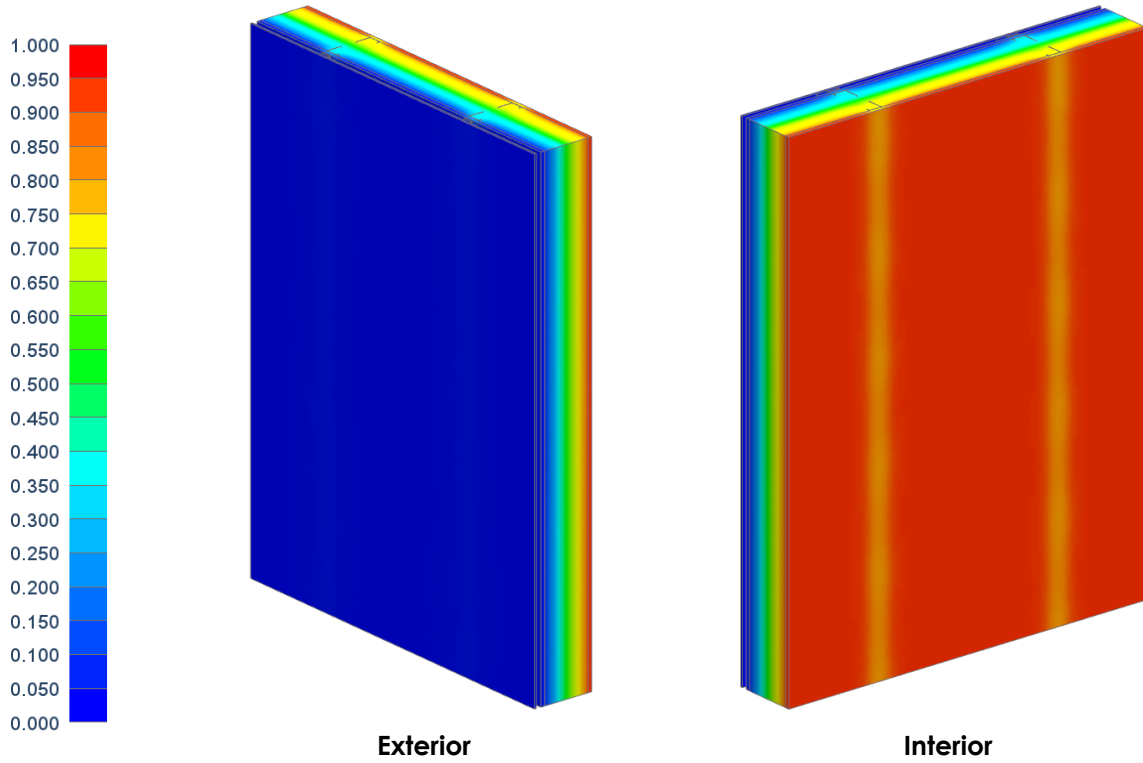


Figure D2: Temperature Profile of Horizontal Z-Girt Assembly with R-Stud, spaced 24 inches o.c. horizontally and 32 inches o.c. vertically (Scenario 2B)

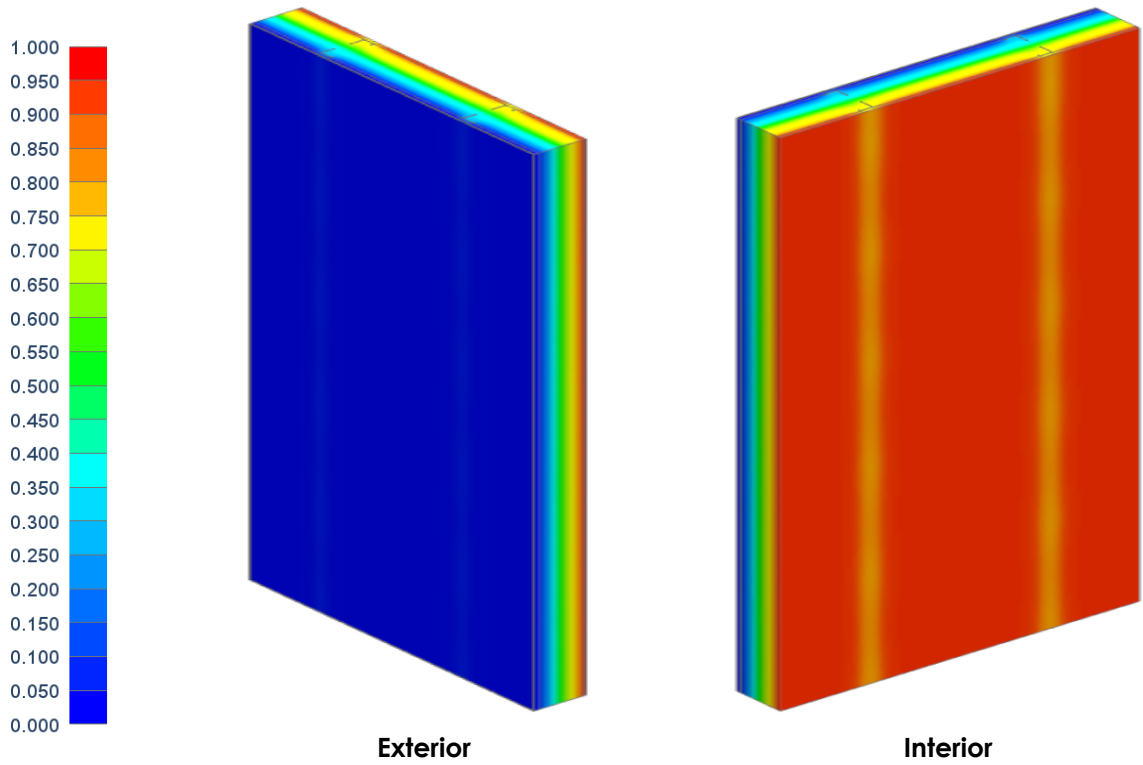


Figure D3: Temperature Profile of Stucco Assembly with DensGlass Sheathing and R-Stud, spaced 24 inches o.c. (Scenario 3B)

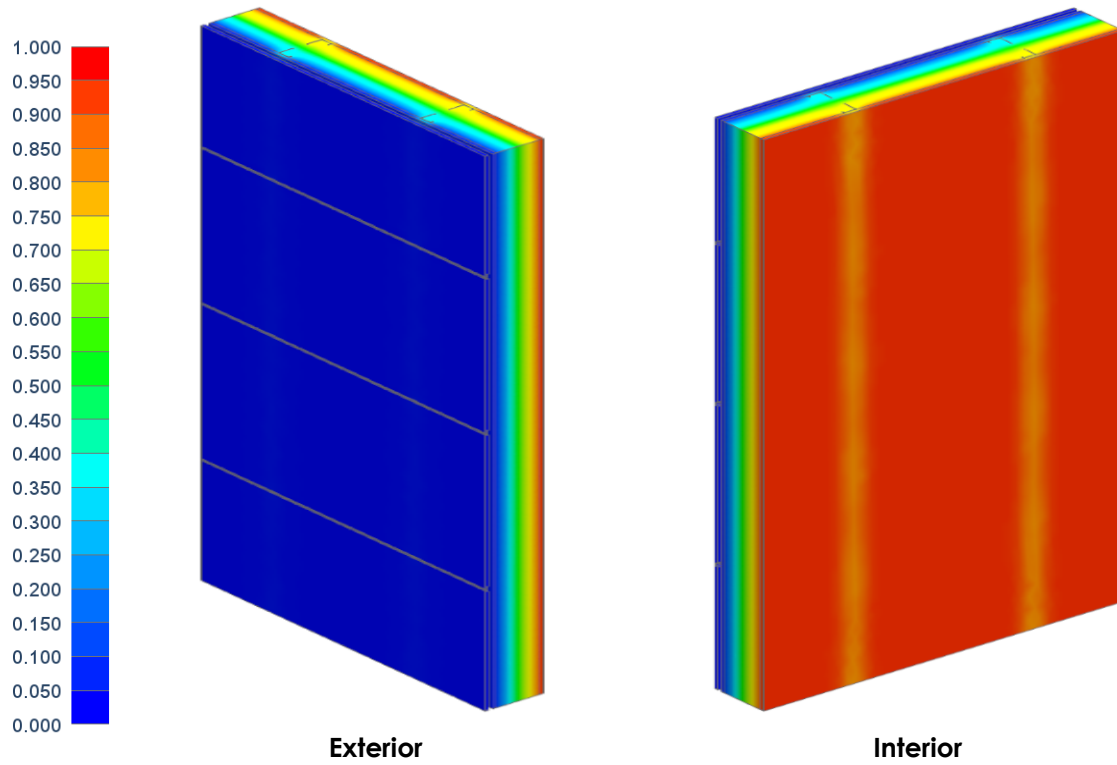


Figure D4: Temperature Profile of Ceraclad Clip Assembly with R-Stud, spaced 24 inches o.c. horizontally and 18 inches o.c. vertically (Scenario 4)