MORRISON HERSHFIELD

October 4, 2019 MH Ref: 1905729.00

Mr. Patrick Lucas
CEO
R-Stud LLC
P.O. Box 692
Donald, OR 97020 email: patrick@rstud.com

Dear Patrick:

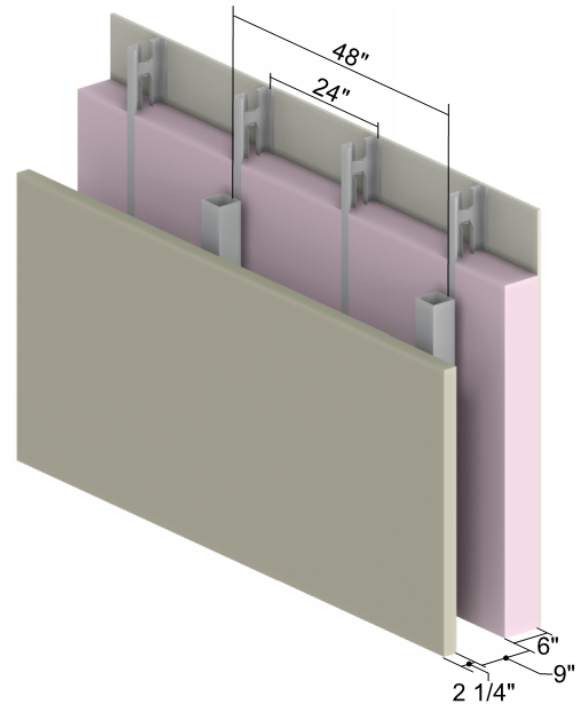
Re: R-Stud Thermal Analysis for Cal State Los Angeles, Los Angeles, CA

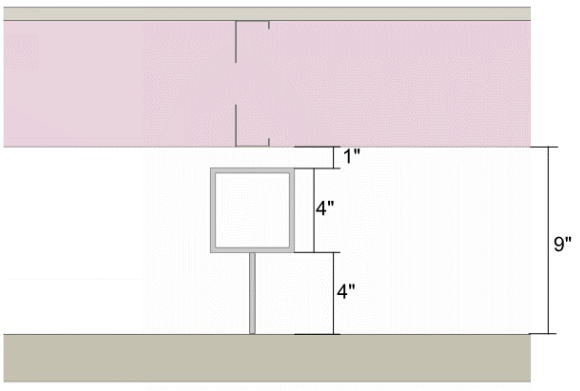
Morrison Hershfield Ltd. (MH) was retained by R-Stud LLC to analyze the proposed wall assemblies for Cal State Los Angeles, in Los Angeles, CA. This report is a summary of the analysis.

BACKGROUND INFORMATION

The proposed wall designs for Cal State Los Angeles consist of an R-Stud backup wall with batt insulation in the cavity and a Clark Composite Architectural Precast Panel (C-CAPP). The C-CAPP panel is attached to the structure at the intermediate slabs, spaced such that there is a minimum of 1 inch between the R-Stud flange and the panel frame.

The assembly geometry was based on correspondence the week of September 23, 2019 and the C-CAPP Panel System sheet dated September 2017 provided in Appendix A. Figure 1 illustrates the proposed wall assemblies. The material properties of the detail components are given in Appendix B.

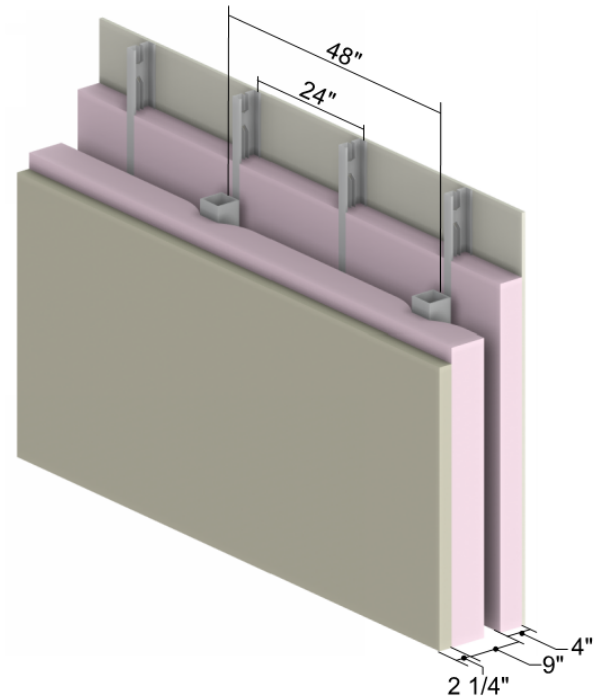


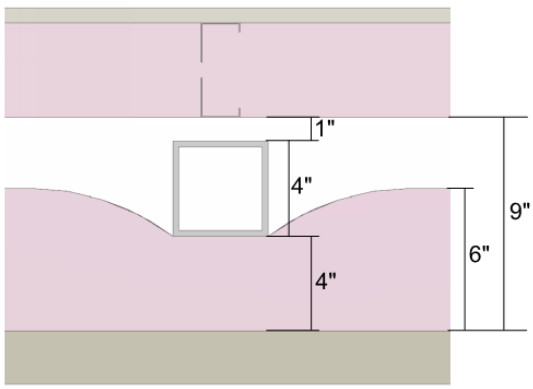


Top View

6 inch R-Stud Assembly

- 2 1/4 inch C-CAPP Skin
- 4 inch x 4 inch HSS Frame spaced 48 inches o.c., fastened with intermittent pins (not modelled)
- 1 inch gap between the HSS frame and R-Stud
- 6 inch R-Stud spaced 24 inches o.c. with R-21 batt insulation in cavity
- 5/8 inch interior gypsum





Top View

4 inch R-Stud Assembly

- 2 1/4 inch C-CAPP Skin
- 4 inch x 4 inch HSS Frame spaced 48 inches o.c., fastened with intermittent pins (not modelled)
- 6 inch nominal R-21 batt compressed to 4 inches outboard the HSS Frame
- 1 inch gap between the HSS frame and R-Stud
- 4 inch R-Stud spaced 24 inches o.c. with R-13 batt insulation in cavity
- 5/8 inch interior gypsum

Figure 1: Evaluated Wall Assemblies

THERMAL ANALYSIS

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.

The assembly U-Values and effective R-values are shown in Table 1. Example temperature profiles for each configuration are provided in Appendix C.

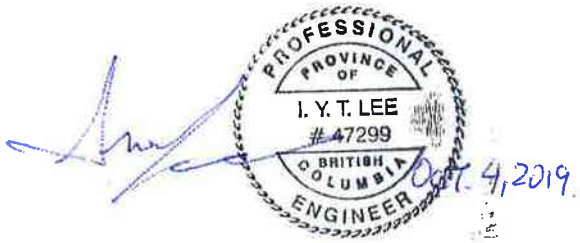
Table 2: Effective R-value of the Cal State Los Angeles Clear Wall with R-Studs

Scenario		R-Stud Size in	R-Stud Spacing in	U-Value Btu/h ft² °F (W/m² °K)	Effective R-Value ft² hr °F/Btu (m² °K/W)
1	6 inch R-Stud with R-21 Batt Insulation in Stud Cavity	6	24	0.062 (0.35)	R-16.2 (2.86)
2	4 inch R-Stud with R-13 Batt Insulation in Stud Cavity	4	24	0.031 (0.17)	R-32.5 (5.72)

We believe that this report meets your objectives for evaluating the thermal performance of the proposed assembly. If you have any questions or comments related to the above, please do not hesitate to contact the undersigned.

Yours truly,
MORRISON HERSHFIELD LIMITED

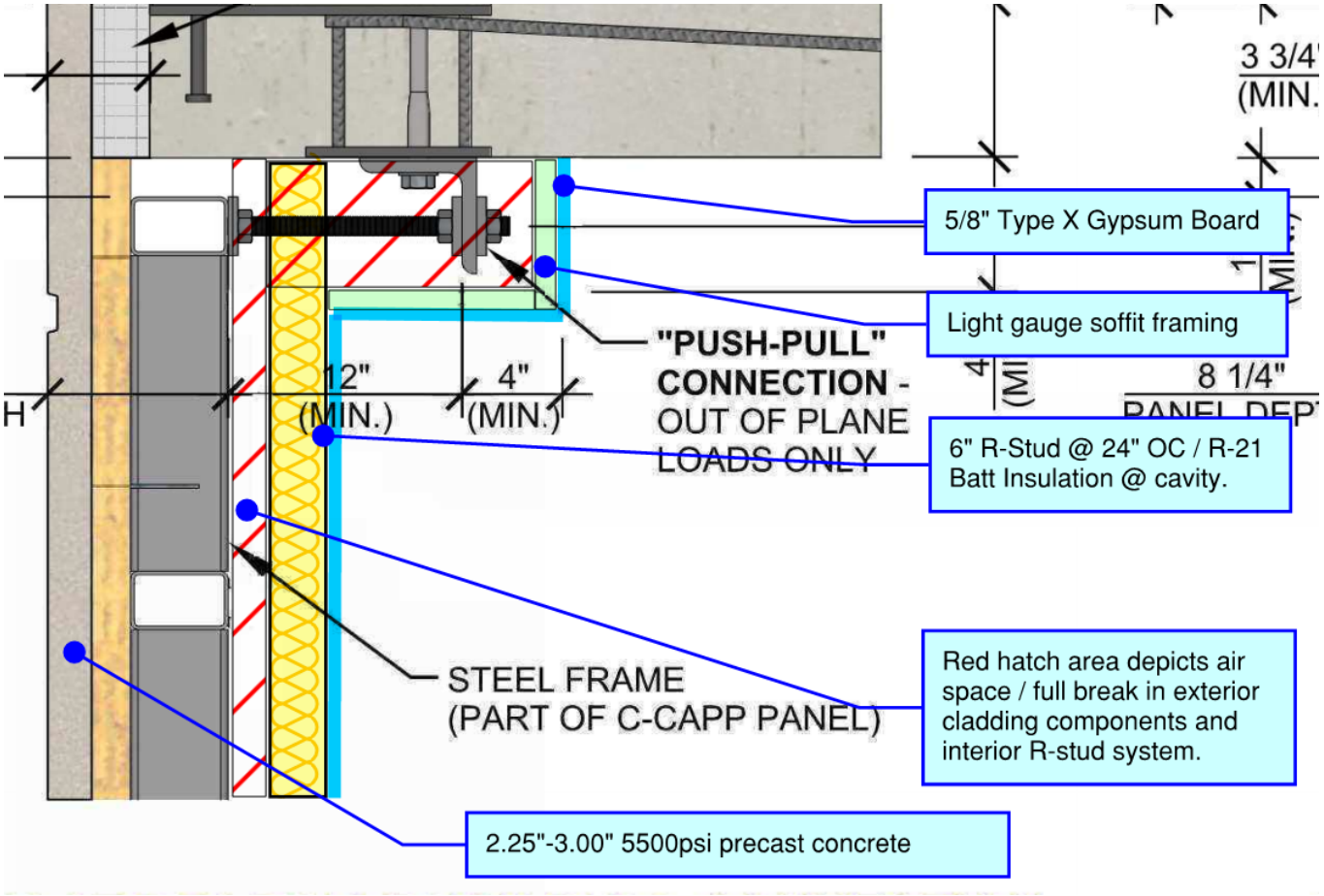
Katie Hay, P.Eng.
Building Science Consultant



Ivan Lee, P.Eng.
Building Science Consultant

[1] https://www.bchydro.com/thermalguide.

APPENDIX A: DETAIL DRAWINGS

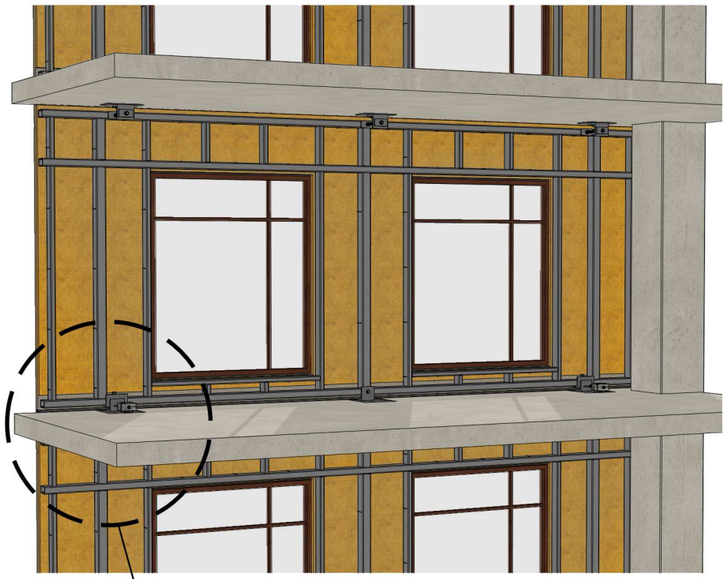


Panel System:

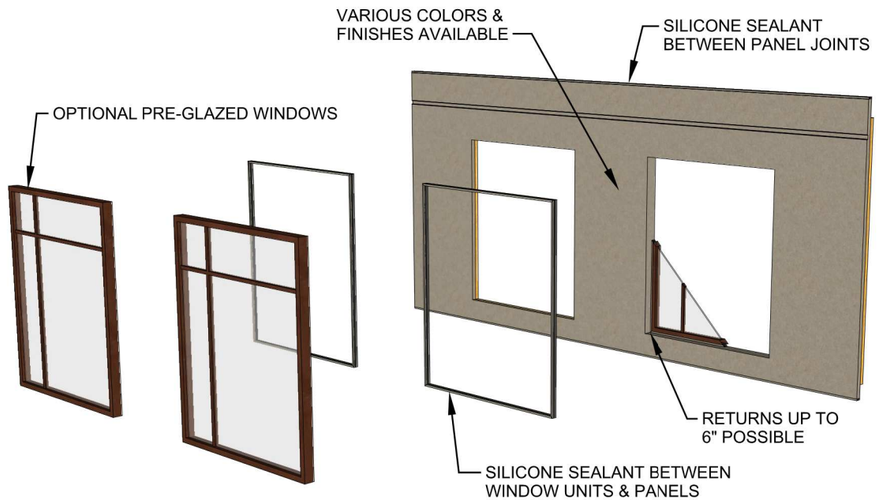
C-CAPP (Clark Composite Architectural Precast Panels) - Cast in Place Concrete Structure

Sheet: CCAPP.STND.CIP

Updated: September 2017

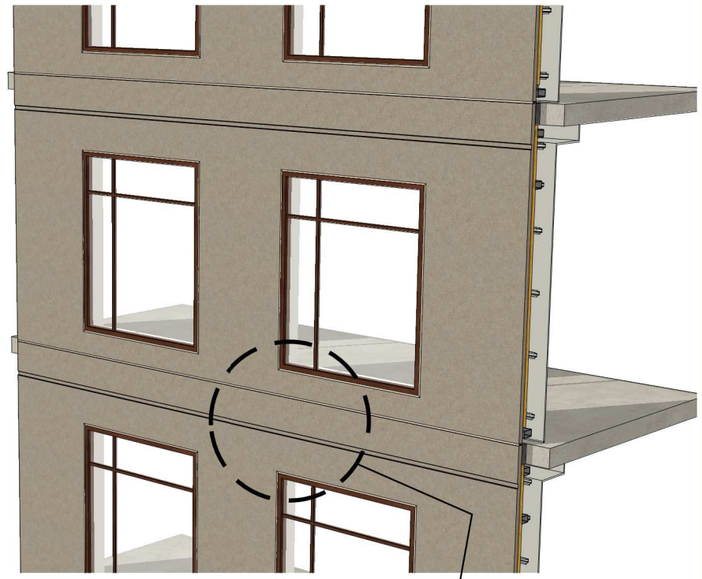


PANEL INTERIOR VIEW

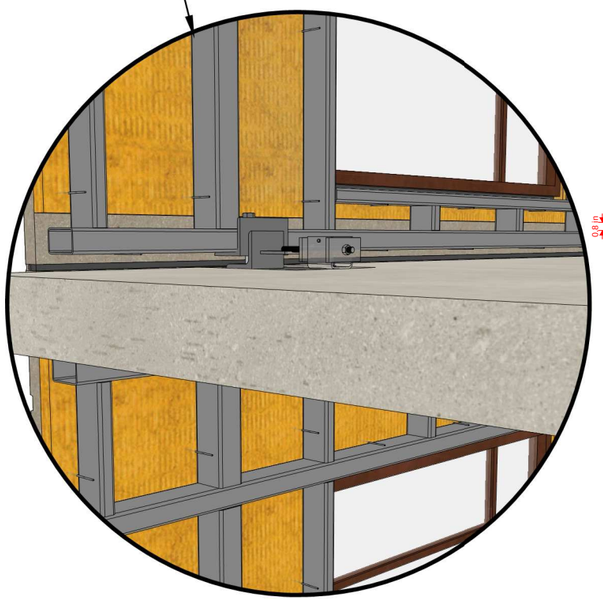


NOTE:
USE OF SPRAY FOAM REQUIRES AN "NFPA 285" AND/OR "ASTM E119" TESTED ASSEMBLY.
CONTACT CLARK PACIFIC FOR DETAILS ON OUR TESTED ASSEMBLIES.

EXPLODED VIEW (ASSEMBLY)

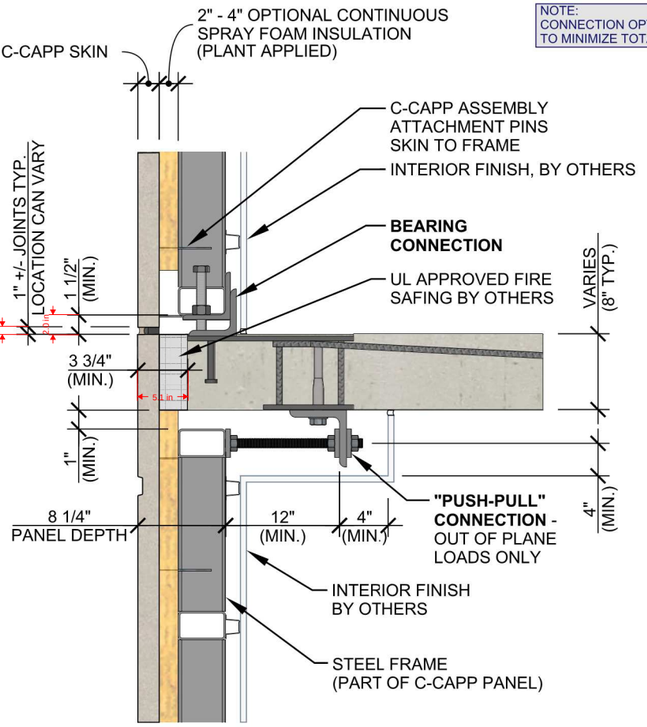


EXTERIOR VIEW

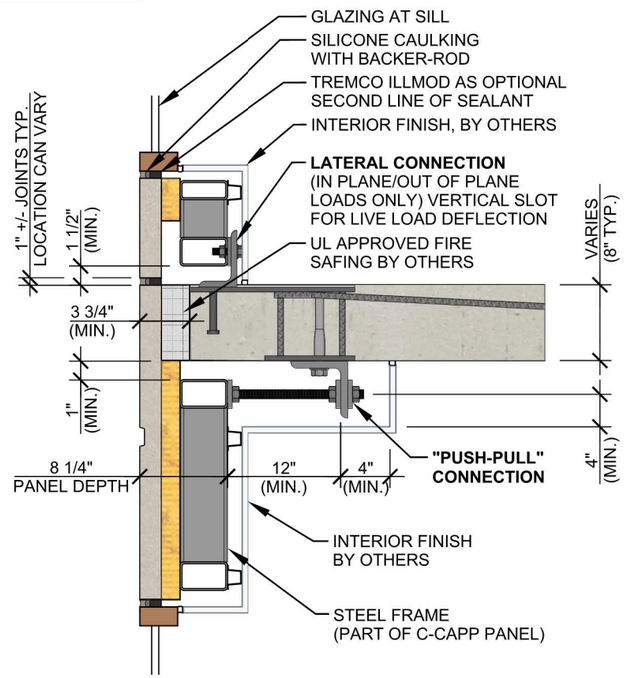


INTERIOR PERSPECTIVE VIEW

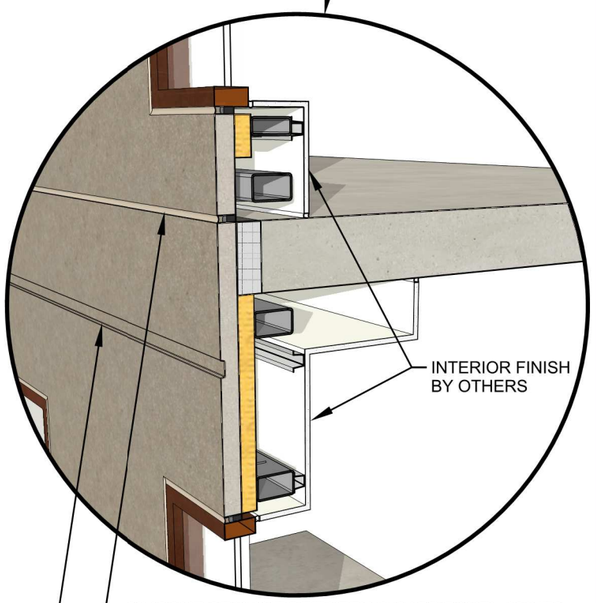
NOTE:
CONNECTION OPTIONS ARE AVAILABLE TO MINIMIZE TOTAL ASSEMBLY DEPTH.



SECTION AT BEARING/PUSH PULL CONNECTION



SECTION AT MID-SPAN LATERAL/PUSH PULL CONNECTION



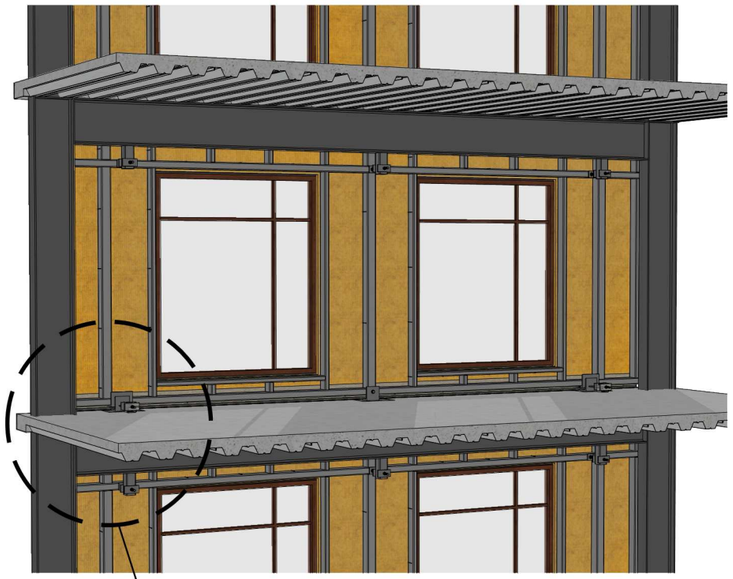
INSTALLED PERSPECTIVE VIEW

Panel System:

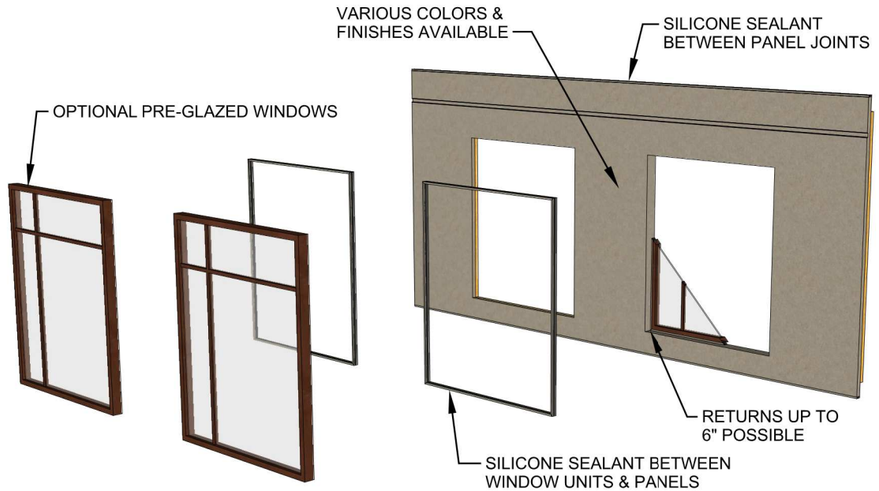
C-CAPP (Clark Composite Architectural Precast Panels) - Steel Structure

Sheet: CCAPP.STND.STL

Updated: September 2017



PANEL INTERIOR VIEW



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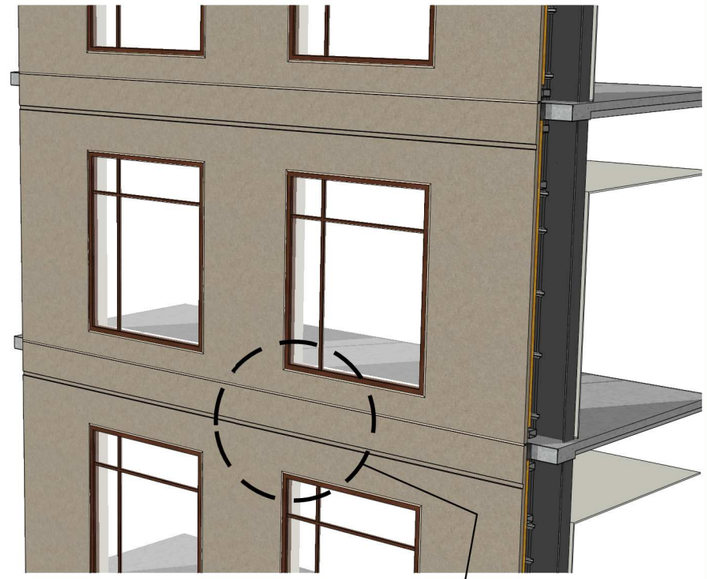
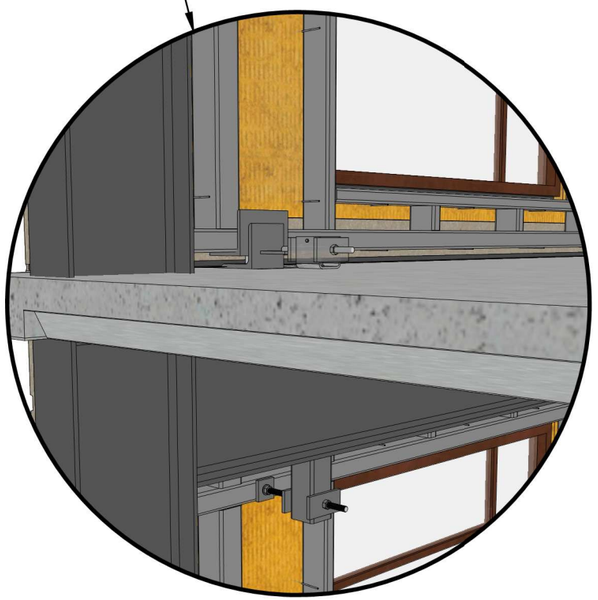


EXTERIOR VIEW



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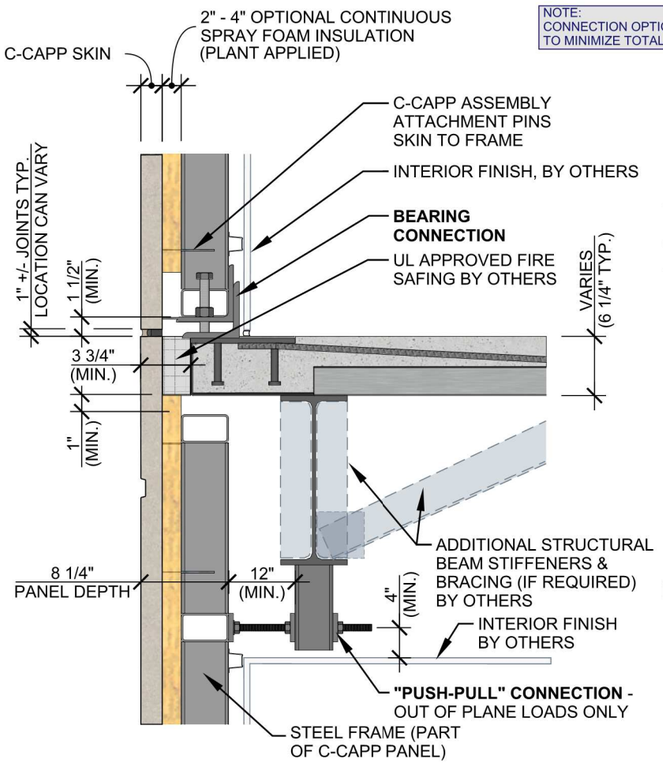
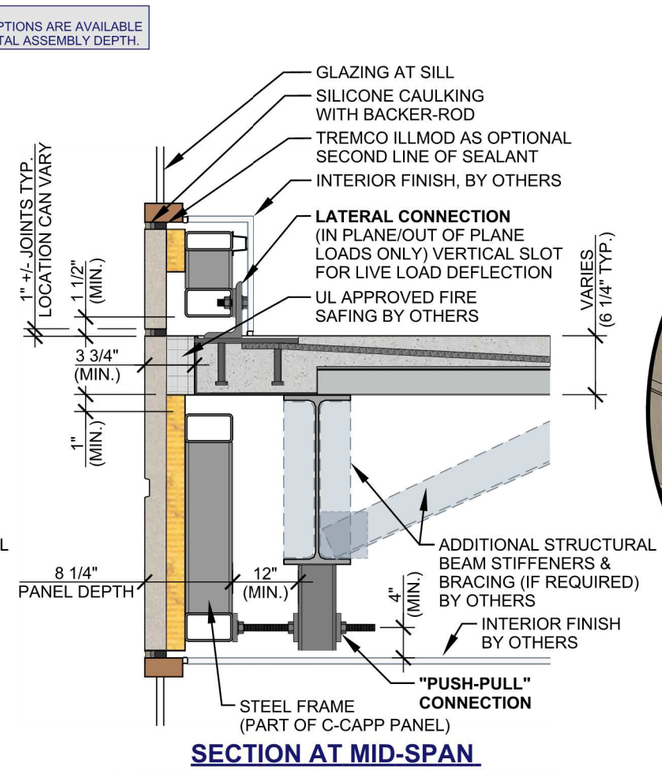
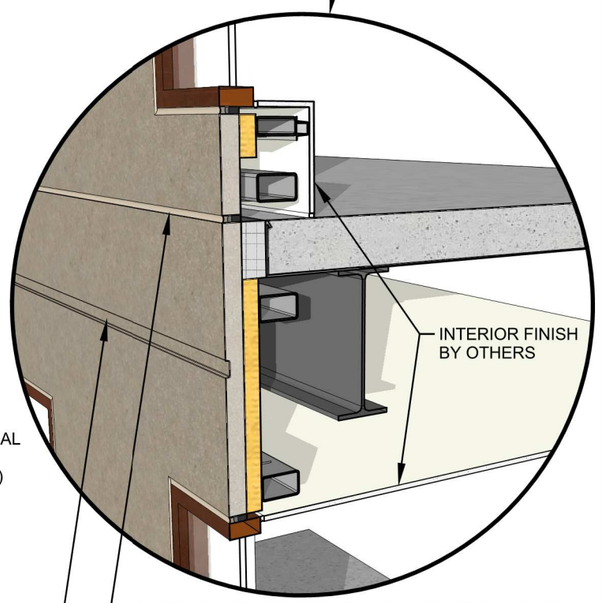


SECTION AT BEARING/PUSH PULL CONNECTION



SECTION AT MID-SPAN LATERAL/PUSH PULL CONNECTION



INSTALLED PERSPECTIVE VIEW

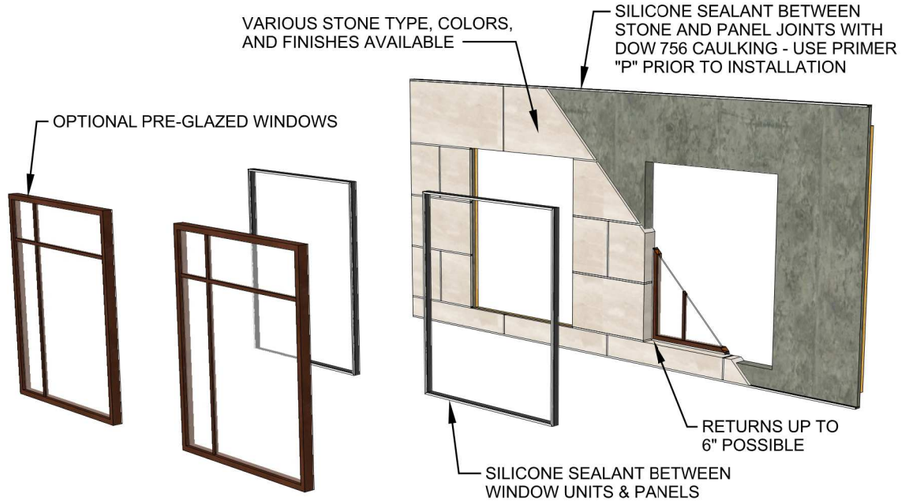
Panel System:

Stone on C-CAPP (Clark Composite Architectural Precast Panels) - Cast in Place Concrete Structure

Sheet: CCAPP.STONE.CIP

Updated: September 2017

PANEL INTERIOR VIEW



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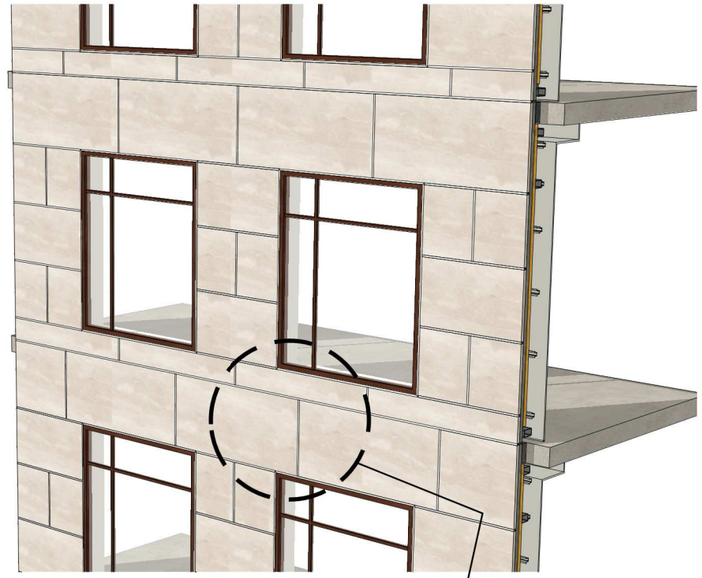
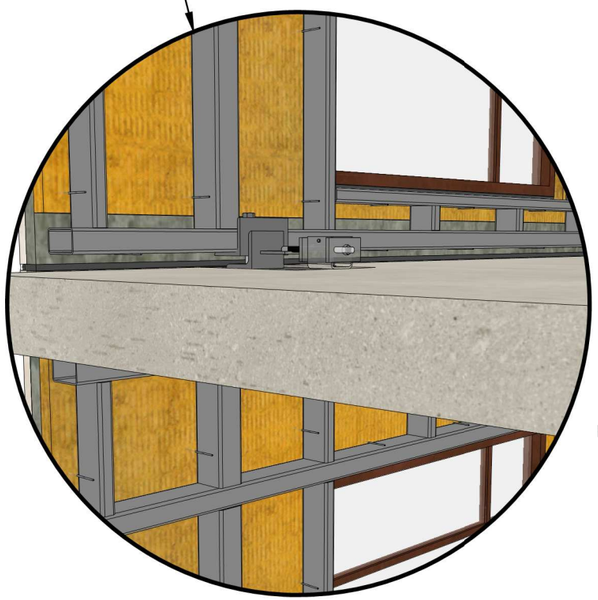


EXTERIOR VIEW



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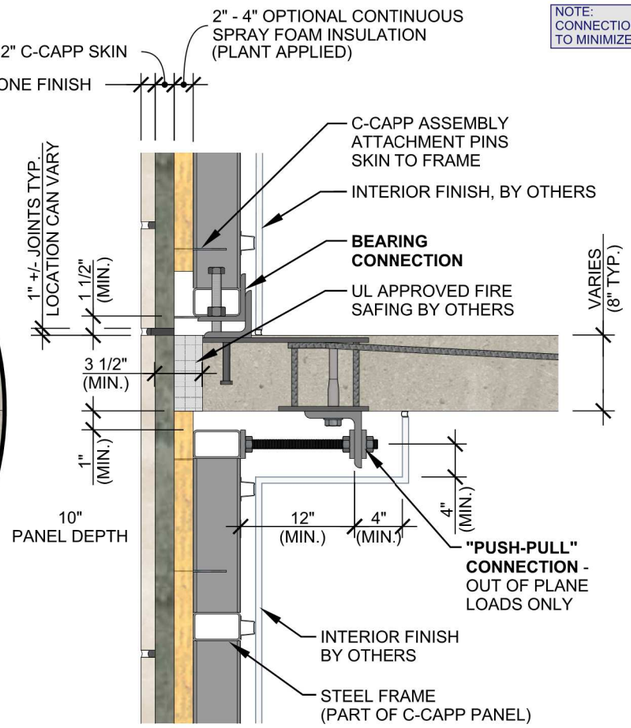

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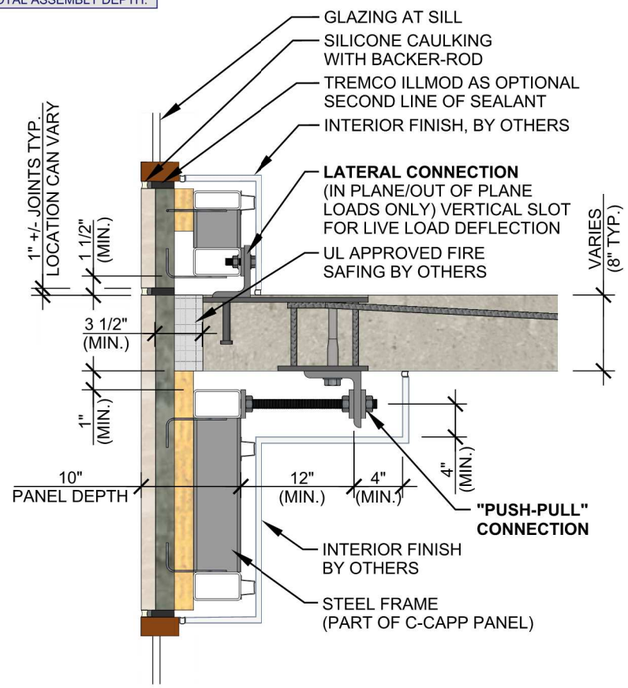
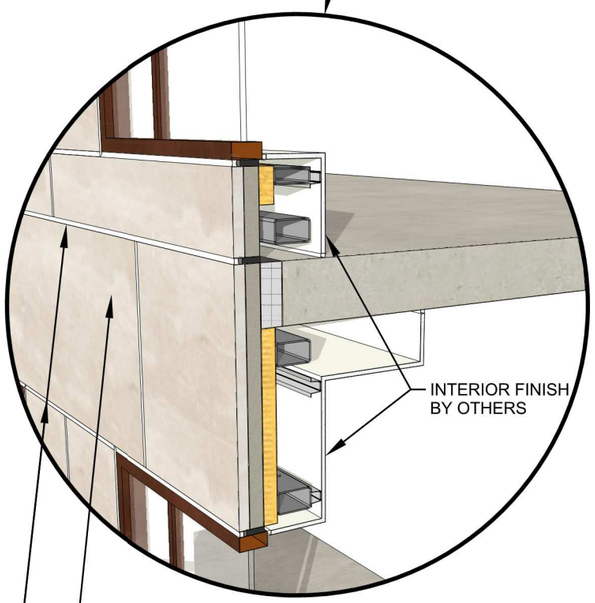


SECTION AT MID-SPAN LATERAL/PUSH PULL CONNECTION



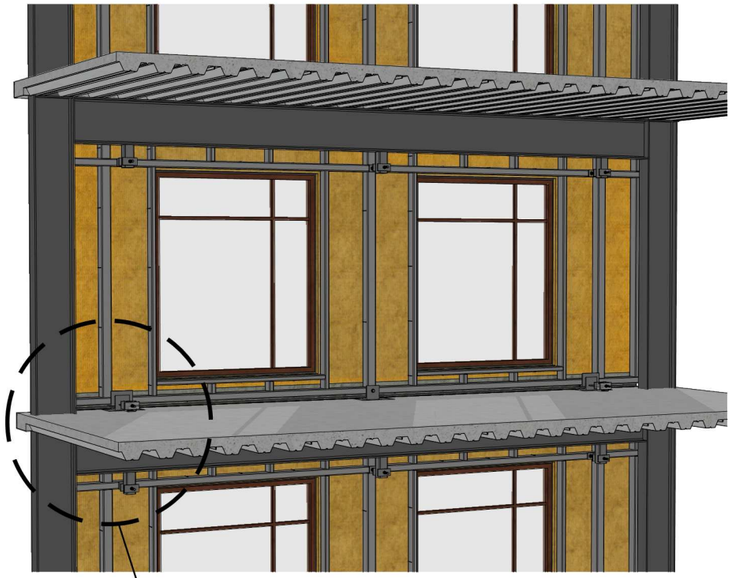
INSTALLED PERSPECTIVE VIEW

Panel System:

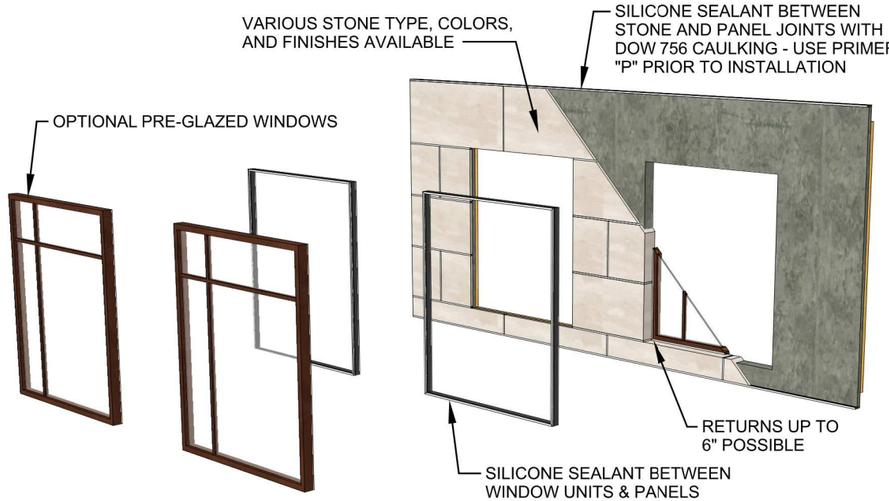
Stone on C-CAPP (Clark Pacific Architectural Precast Panels) - Steel Structure

Sheet: CCAPP.STONE.STL

Updated: September 2017



PANEL INTERIOR VIEW



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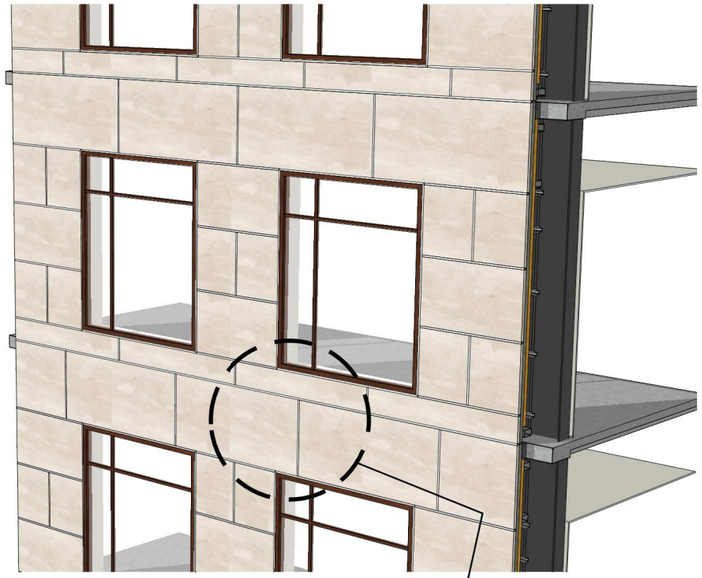

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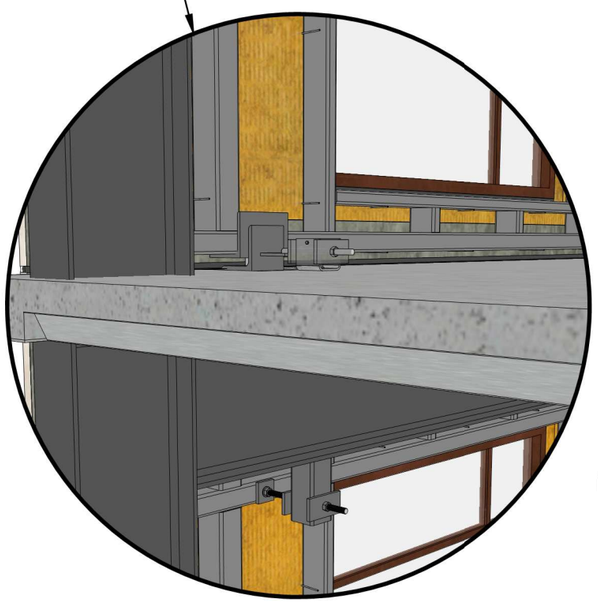
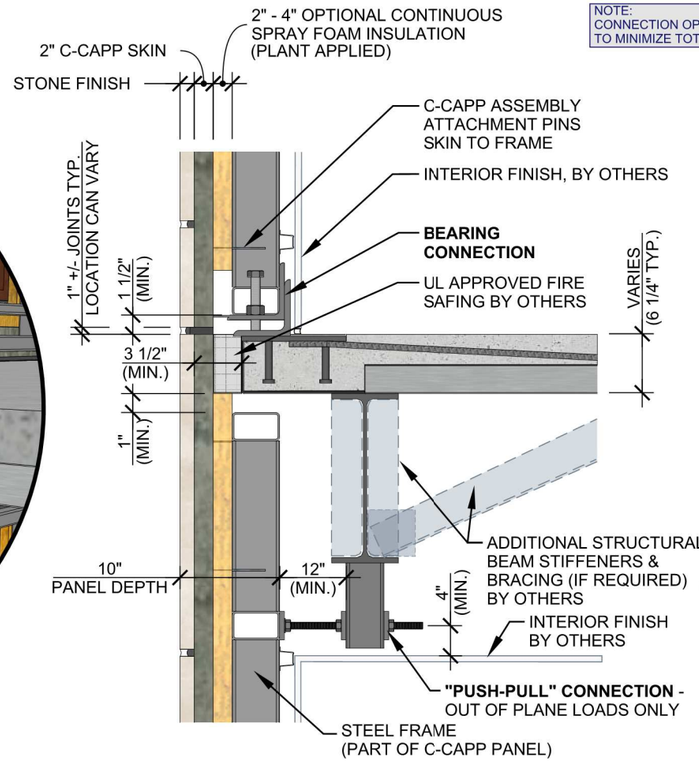


INTERIOR PERSPECTIVE VIEW



SECTION AT BEARING/PUSH PULL CONNECTION

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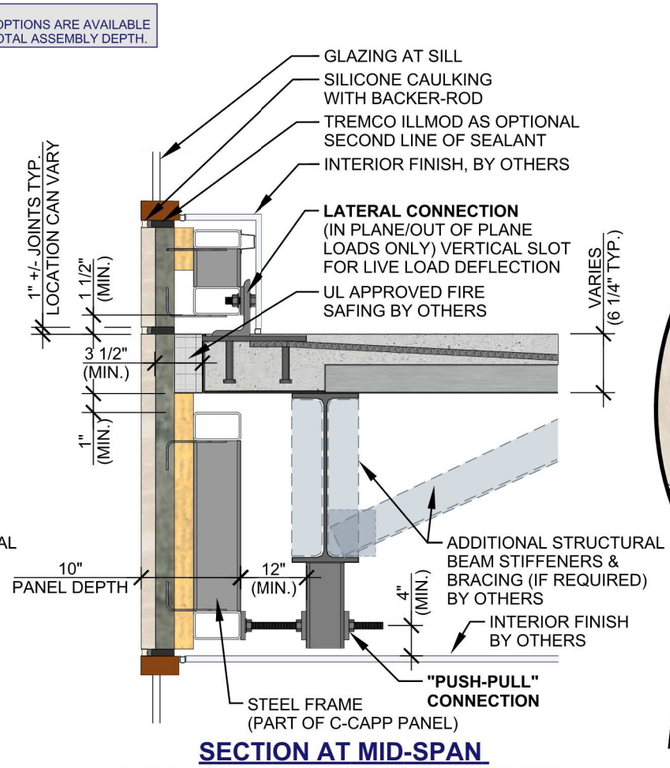
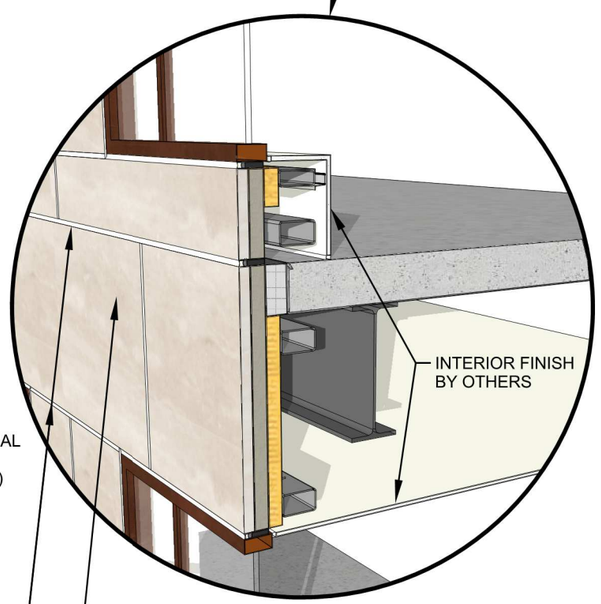


SECTION AT MID-SPAN LATERAL/PUSH PULL CONNECTION



INSTALLED PERSPECTIVE VIEW

APPENDIX B: MODELLING PARAMETERS AND ASSUMPTIONS

B.1 THERMAL MODELLING ASSUMPTIONS

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.
- Where the insulation is compressed, the R-value and conductivity of the insulation was determined using the methodology in ASHRAE 90.1-2013, Section A.9.4.3.
- The C-CAPP cavity insulation is compressed between the C-CAPP panel and the HSS frame. It was assumed that the insulation thus exhibits a parabolic curved cross-section until the insulation is fully uncompressed.
- Enclosed air spaces were modelled with an equivalent thermal conductivity of the air that include the impacts of convection and radiation within the enclosure. Calculations for this equivalent conductivity were based on ISO 10077.
- 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 windspeed of 15 mph.
- The exterior temperature was taken to be the 99% design temperature for Los Angeles, CA from 2017-ASHRAE Handbook of Fundamentals.
- 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 and HSS framing.

B.2 BOUNDARY CONDITIONS

Table B2.1: Boundary Conditions

Boundary Location	Surface Temperature °F	Combined Convective and Radiation Heat Transfer Coefficient BTU/hft²°F (W/m²K)
Exterior Surfaces	46.8	6.0 (34)
Interior Walls	68	1.5 (8.3)

B.3 MATERIAL PROPERTIES

B3.1: 6 inch R-Stud with R-21 in Stud Cavity

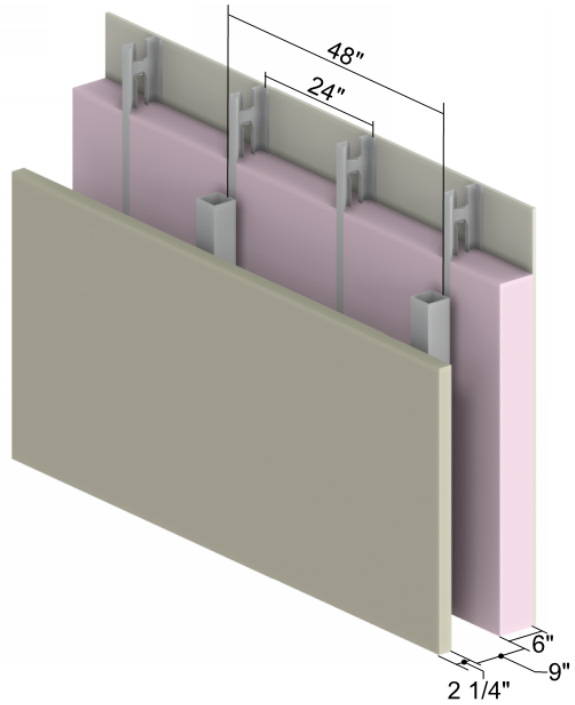


Table B3.1.1: Material Properties

Component	Material	Thickness In (mm)	Thermal Conductivity Btu in / ft² hr °F (W/m K)	Nominal Resistance ft² hr °F / Btu (m² K/W)
Interior Film	-	-	-	R-0.7 (0.12 RSI)
Gypsum	Gypsum	5/8 (16)	1.1 (0.16)	R-0.6 (0.10 RSI)
R-Stud	Galvanized Steel	18 Gauge	430 (62)	-
Stud Cavity	R-21 Batt Insulation	6 (152)	0.29 (0.041)	R-21 (3.7 RSI)
Framing Airspace	Air	-	-	R-0.9 (0.16 RSI)
HSS Frame	Steel	1/4 (6.4)	347 (50)	-
Precast Concrete Panel	Precast Concrete	2 1/4 (89)	12.5 (1.8)	R-0.18 (0.032 RSI)
Air Spaces[1]	Air	Varies	Varies	-
Exterior Film	-	-	-	R-0.2 (0.03 RSI)
Overall Assembly 1D	-	-	-	R-23.5 (4.1 RSI)

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

B3.2: 4 inch R-Stud with R-13 in Stud Cavity

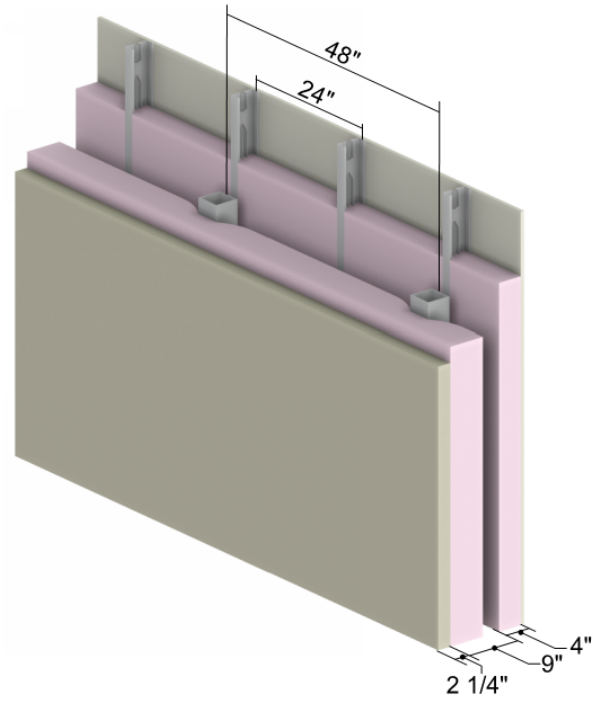


Table B3.2.1: Material Properties

Component	Material	Thickness In (mm)	Thermal Conductivity Btu in / ft² hr °F (W/m K)	Nominal Resistance ft² hr °F / Btu (m² K/W)
Interior Film	-	-	-	R-0.7 (0.12 RSI)
Gypsum	Gypsum	5/8 (16)	1.1 (0.16)	R-0.6 (0.10 RSI)
R-Stud	Galvanized Steel	18 Gauge	430 (62)	-
Stud Cavity	R-13 Batt Insulation	4 (102)	0.31 (0.044)	R-13 (2.9 RSI)
HSS Frame	Steel	1/4 (6.4)	347 (50)	-
C-CAP Frame Airspace	Air	Varies	-	R-0.9 (0.16 RSI)
C-CAPP Frame Cavity	R-21 Batt Insulation	Varies	-	R-21 (3.7 RSI)
Precast Concrete Panel	Precast Concrete	2 1/4 (89)	12.5 (1.8)	R-0.18 (0.032 RSI)
Air Spaces[1]	Air	Varies	Varies	-
Exterior Film	-	-	-	R-0.2 (0.03 RSI)
Overall Assembly 1D	-	-	-	R-36.5 (6.4 RSI)

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

APPENDIX C: SIMULATED TEMPERATURE PROFILES

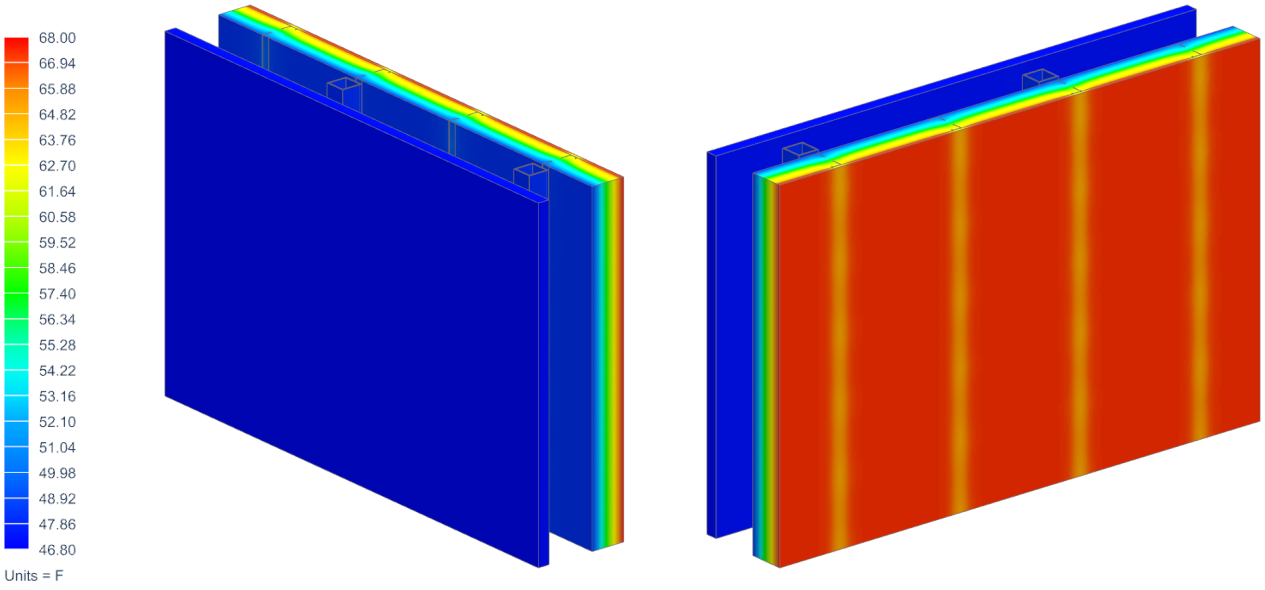


Figure C1.1: 6 inch R-Stud Spaced 24 inches o.c. with R-21 Batt Insulation in Stud Cavity: Isometric view from exterior and interior

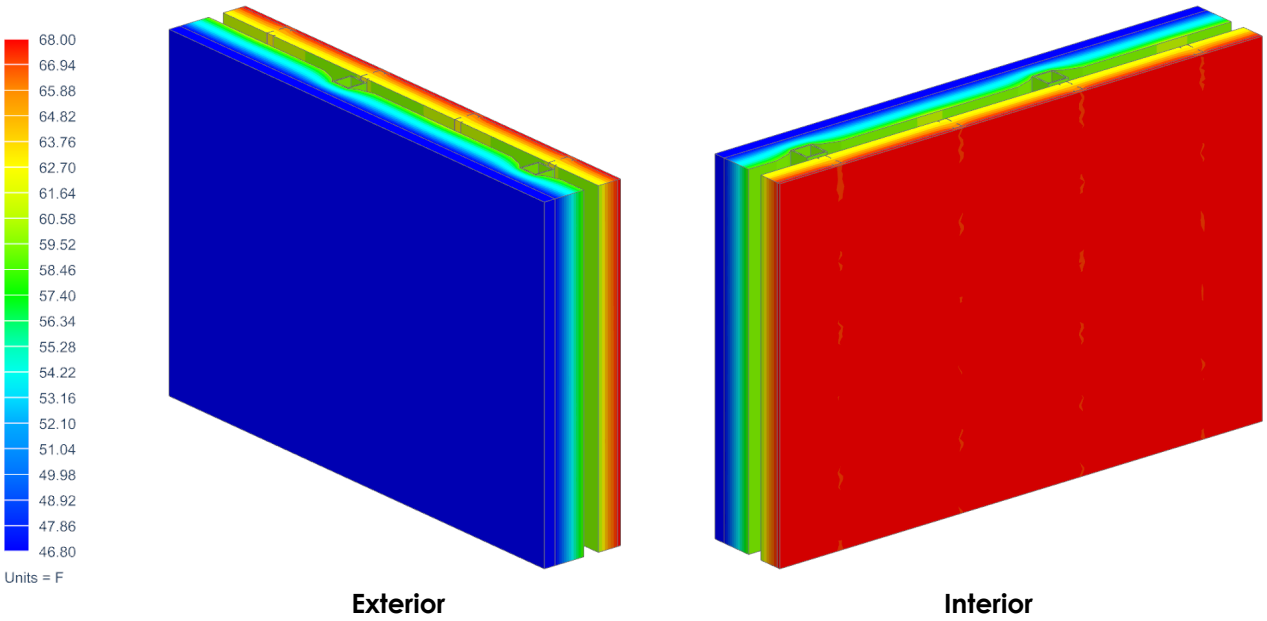


Figure C1.2: 4 inch R-Stud Spaced 24 inches o.c. with R-13 Batt Insulation in Stud Cavity: Isometric view from exterior and interior