Thermal Analysis of Northstar Exterior Wall System

Presented to:

Paul Inglese
CEO, Northstar Technologies Group Inc.

July 6, 2021

EVOKE
Sensible building solutions

Contents

Introduction

Evoke Buildings Engineering Inc. (Evoke) was contracted by Northstar Technologies Group. (Northstar) for the thermal analysis of the Northstar Exterior Wall Panel system. Evoke evaluated the wall system to determine the clear field thermal transmittance (U-value) and assembly effective R-value for various insulation scenarios.

The Northstar Exterior Wall Panel system has an ¼ inch balastic armor plate sheathing bonded to 6-inch fiber reinforced polymer framing. Mineral wool insulation (R-4.2/inch) is installed in the 6-inch stud cavity. The evaluated clear field wall assembly includes repetitive fiberglass studs at 24" o.c. and perimeter panel joints for a 48"x96" panel size. Figure 1 outlines the Northstar Exterior Wall Panel system.

Components

1. 6" x 1 5/8" fiberglass channel top and bottom track
2. 4 to 6 inches of mineral wool insulation (R-4.2/inch)
3. ¼" ballistic armor plate sheathing
4. 6" x 1 5/8" fiberglass channel Stud at 24" o.c.
5. 2" x 5 ½" fiberglass angle at stud to track connection

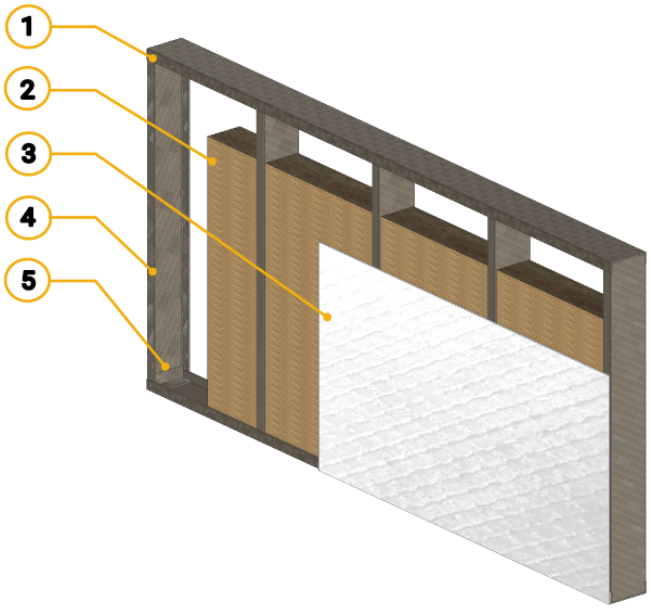

Figure 1: Northstar Exterior Wall Panel System

The Northstar Exterior Wall Panel system was evaluated to determine the U-value and effective R-value for 4, 5, and 6 inches of mineral wool insulation in the fiberglass framing. The assembly was evaluated with and without ½ inch gypsum interior drywall. The geometry of the components and panel size is based on drawings provided by Northstar as provided in Appendix A.

Methodology

The thermal analysis was done using 3D thermal simulation using the Simcenter 3D software package from Siemens, which is a general-purpose computer aided design (CAD) and finite element analysis (FEA) package. The thermal solver and modeling procedures utilized for this

evaluation were extensively calibrated and validated to within +/- 5% of hotbox testing[1,2,3]. The thermal analysis utilized steady-state conditions, published thermal data for materials, and information provided by Northstar. Additional assumptions for the thermal analysis are provided in Appendix B.

Thermal Results

The clear field thermal transmittances and assembly effective R-value of the Northstar Exterior Wall Panel system for a panel size of 48"x96" is presented in Table 1. Example temperature profiles are provided in Appendix C.

Table 1. Thermal Transmittance of Northstar Exterior Wall Panel System

Cavity Insulation Thickness	Cavity Insulation R-value	Without Interior Drywall		With Interior Drywall	
		Thermal Transmittance Btu/ft^2·hr·°F (W/m^2 K)	Assembly Effective R-Value ft^2·hr·°F/Btu (m^2 K/W)	Thermal Transmittance Btu/ft^2·hr·°F (W/m^2 K)	Assembly Effective R-Value ft^2·hr·°F/Btu (m^2 K/W)
4-inch	R-16.8	0.071 (0.401)	R-14.2 (2.50)	0.063 (0.360)	R-15.8 (2.78)
5-inch	R-21.0	0.058 (0.330)	R-17.2 (3.03)	0.053 (0.302)	R-18.8 (3.31)
6-inch	R-25.2	0.049 (0.280)	R-20.3 (3.58)	0.048 (0.272)	R-20.9 (3.68)

Closing

We believe that this report meets your request for the thermal evaluation of the Northstar Exterior Wall Panel system. Please do not hesitate to contact us with any questions regarding this evaluation.

Evoke Buildings Engineering Inc.

Patrick Roppel, P.Eng.
Building Science Specialist

Derek Budde, P.Eng.
Building Envelope Engineer

[1] ASHARE Research Project 1365-RP, Thermal Performance of Building Envelope Details for Mid- and High-Rise Construction, 2011
[2] AISI Research Report RP18-1, Thermal Analysis of Cold-Formed Steel Wall Assemblies, 2018
[3] Building Envelope Thermal Bridging Guide, Version 1.5, 2020

Appendix A: Detail Drawings and Datasheets

NORTHSTAR

TECHNOLOGIES

NORTHSTAR EXTERIOR WALL PANEL SYSTEM

A FIBER REINFORCED POLYMER EXTERIOR WALL PANEL WITH A 1/4" THICK FIBER REINFORCED POLYMER BALLISTIC ARMOR PLATE SHEATHING BONDED TO A 6" FIBER REINFORCED POLYMER FRAME ASSEMBLY

HVHZ
DESIGN PRESSURE: +75 / -85 PSF
MISSILE IMPACT: LEVEL D
DEFLECTION LIMIT: L/180

NON-HVHZ
DESIGN PRESSURE: +90 / -85 PSF
MISSILE IMPACT: LEVEL D
DEFLECTION LIMIT: L/120

NORTHSTAR TECHNOLOGIES GROUP INC
365 FIFTH AVE S.
NAPLES, FLORIDA 34102
239.850.6253

PINGLESE@NORTHSTARTGI.COM

NORTHSTARTGI.COM

ENGINEER
Scott Wolters
FL PE# 62354

Wolters Engineering
(COA# 27194)
15211 97th Road N.
West Palm Beach, FL 33412
561.225.1982

SCOTT WOLTERS LICENSE No 62354 STATE OF FLORIDA PROFESSIONAL ENGINEER DEC 18 2020

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1	12.14.20	PI	PI

COVER PAGE

NORTHSTAR EXTERIOR WALL PANEL SYSTEM

GENERAL NOTES:

1. THIS SYSTEM MEETS ALL OF THE REQUIREMENTS OF THE 6TH EDITION (2017) FLORIDA BUILDING CODE, INCLUDING THE HVHZ PROVISIONS.

2. THIS SYSTEM HAS BEEN TESTED PER TAS 201, 202, & 203. IT LARGE AND SMALL MISSILE IMPACT RESISTANT. SHUTTERS ARE NOT REQUIRED.

3. THIS SYSTEM HAS BEEN DESIGNED AND TESTED AS A WALL CLADDING SYSTEM ONLY. IF USED IN A LOAD BEARING APPLICATION THE ENGINEER MUST ADD ADDITIONAL FIBER REINFORCED POLYMER FRAMING COMPONENTS TO DESIGN THE MAIN WIND FORCE RESISTING SYSTEM.

4. THIS SYSTEM HAS BEEN TESTED PER ASTM E84 & E2768, AND MEETS THE REQUIREMENTS OF FBC SECTIONS 2613.5 AND 2603.5.4. FIRE RATINGS OR FIRE RESISTANCE IS NOT A PART OF THIS REVIEW.

5. ALL ANCHORS SECURING THE SYSTEM TO PRESSURE TREATED WOOD SHALL BE CAPABLE OF RESISTING CORROSION CAUSED BY THE CHEMICALS IN THE WOOD.

6. MATERIALS INCLUDING BUT NOT LIMITED TO STEEL/METAL SCREWS THAT COME INTO CONTACT WITH OTHER DISSIMILAR MATERIALS SHALL BE PROTECTED PER FBC REQUIREMENTS.

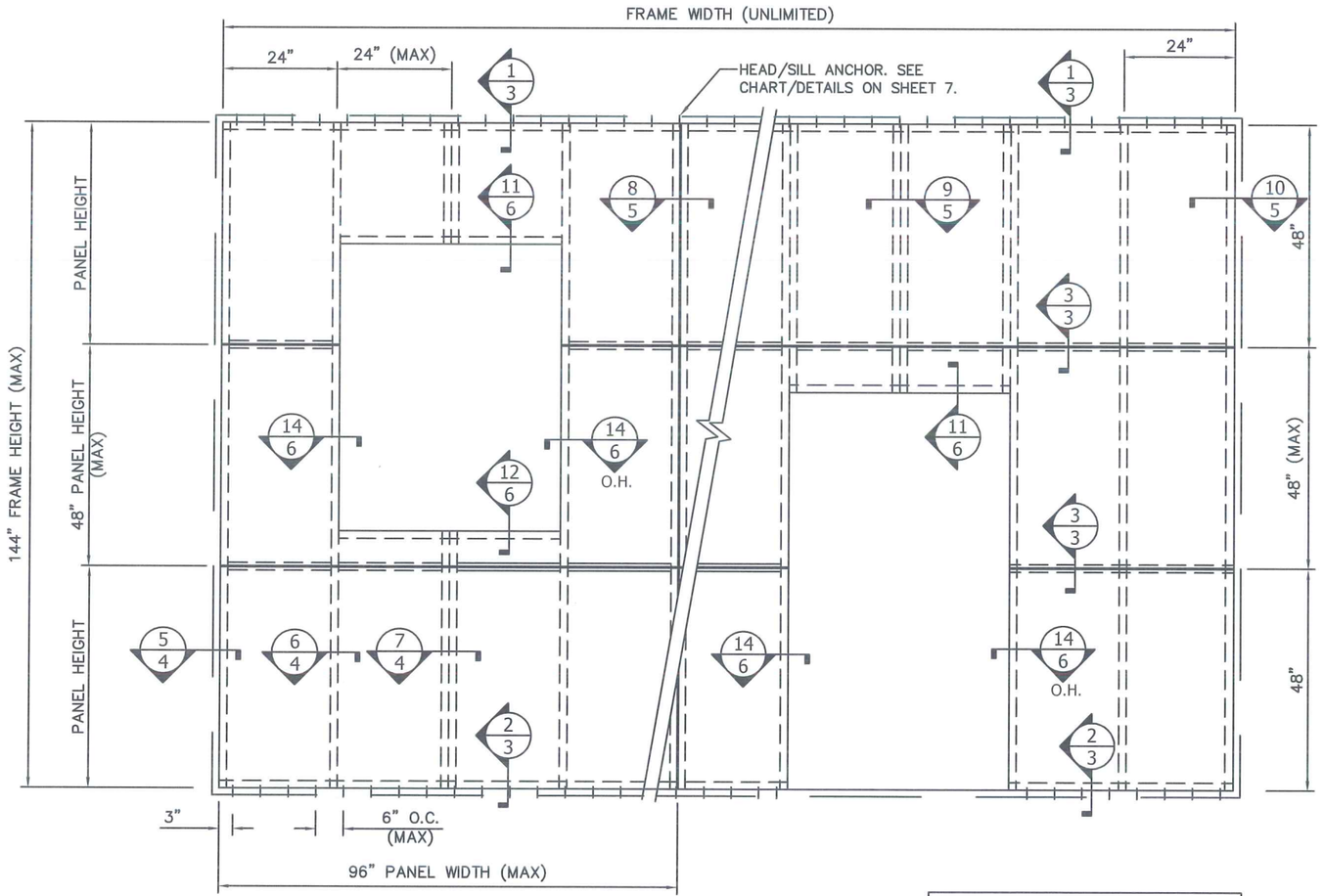
7. NO INCREASE IN ALLOWABLE STRESS HAS BEEN USED IN THE DESIGN OF THIS PRODUCT. Cd=1.6 WAS USED FOR WOOD SCREWS ONLY.

MANUFACTURING NOTES:

1. INTERMEDIATE VERTICAL STUDS ARE INSTALLED 24" O.C, ALTERNATING BETWEEN SINGLE AND DOUBLE STUDS, EXCEPT DOUBLE STUDS ARE USED AT CENTER OF DOOR OR WINDOW OPENINGS GREATER THAN 24" WIDE. THE STUDS ARE NOTCHED AT EACH END TO FIT INTO THE HEAD/SILL TRACKS, WHICH ARE CONTINUOUS.

2. INTERMEDIATE HORIZONTAL STUDS ARE INSTALLED 48" MAX. O.C, AND ARE NOTCHED TO FIT INTO THE VERTICAL STUDS WHERE REQUIRED.

3. AN 1/8" BEAD OF 3M SCOTCH-WELD MULTI-MATERIAL COMPOSITE URETHANE EPOXY IS APPLIED TO ALL THE VERTICAL AND HORIZONTAL STUDS TO BOND WITH THE STRONGWELL HS ARMOR FIBERGLASS PANELS AND APPLIED TO ALL VERTICAL AND HORIZONTAL JOINTS AND SCREW HEADS AS A SEALANT.



STANDARD ELEVATION
(EXTERIOR VIEW)

DESIGN PRESSURE
+75 / -85 psf (HVHZ)
+90 / -85 psf (Non-HVHZ)

NORTHSTAR TECHNOLOGIES

NORTHSTAR TECHNOLOGIES GROUP INC
365 FIFTH AVE S.
NAPLES, FLORIDA 34102
239.850.6253

PINGLESE@NORTHSTARTGI.COM

NORTHSTARTGI.COM

ENGINEER

Scott Wolters
FL PE# 62354

Wolters Engineering
(COA# 27194)
15211 97th Road N.
West Palm Beach, FL 33412
561.225.1982

SCOTT WOLTERS LICENSE No 62354 STATE OF FLORIDA PROFESSIONAL ENGINEER
DEC 18 2020

JOB NUMBER: 2020121

DATE: 12.14.2020

DRAWN BY: P Inglese

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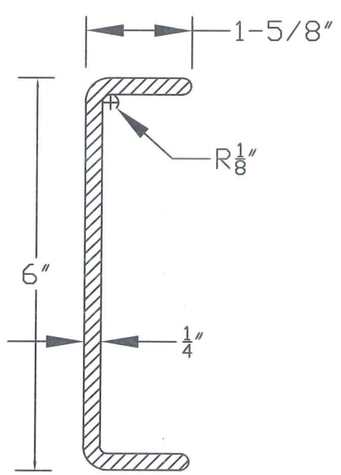
NORTHSTAR EXTERIOR WALL PANEL SYSTEM

BILL OF MATERIALS			
PART #	DESCRIPTION	MANUFACTURER	NOTES
1	6" X 1-5/8" FIBERGLASS CHANNEL	STRONGWELL	EXTREN 500 OR 525 PE POLYESTER RESIN
2	2" X 2" X 5-1/2" FIBERGLASS ANGLE	STRONGWELL	EXTREN 500 OR 525 PE POLYESTER RESIN
3	#14 X 1-1/2" SS FH TEK SCREW	ITW BUILDEX	FRONT AND BACK OF STUD AT HEAD / SILL
4	#14 X 1-1/2" SS FH TEK SCREW	ITW BUILDEX	1-1/4" FROM END OF STUDS AND 12" MAX O.C.
5	#14 X 1-1/2" SS FH TEK SCREW	ITW BUILDEX	(4) FASTENERS PER CLIP ANGLE
6	$\frac{1}{4}$" BALLISTIC ARMOR PLATE SHEATHING	STRONGWELL	BONDED TO FRAMING WITH 3M SCOTCH-WELD EPOXY
7	PERIMETER SEALANT AND BACKER ROD	PER ARCHITECTS SPECIFICATION	SUPPLIED BY OTHERS



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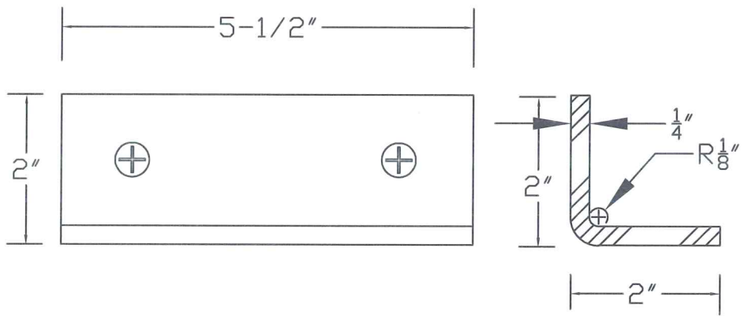

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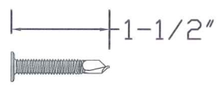

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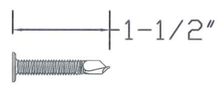

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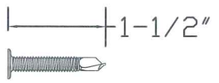

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NORTHSTAR TECHNOLOGIES GROUP INC
365 FIFTH AVE S.
NAPLES, FLORIDA 34102
239.850.6253

PINGLESE@NORTHSTARTGI.COM

NORTHSTARTGI.COM

ENGINEER
Scott Wolters
FL PE# 62354
Wolters Engineering
(COA# 27194)
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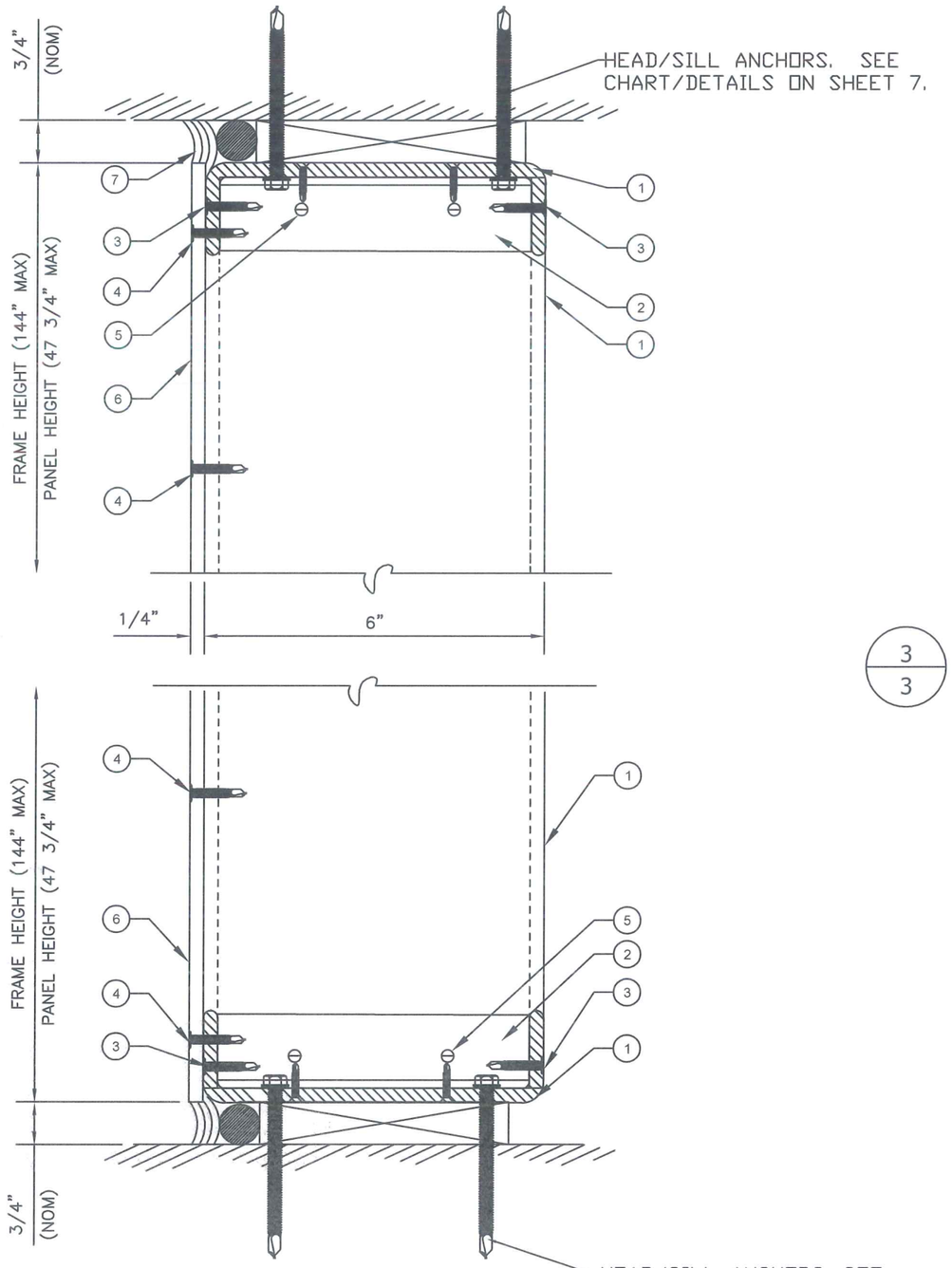

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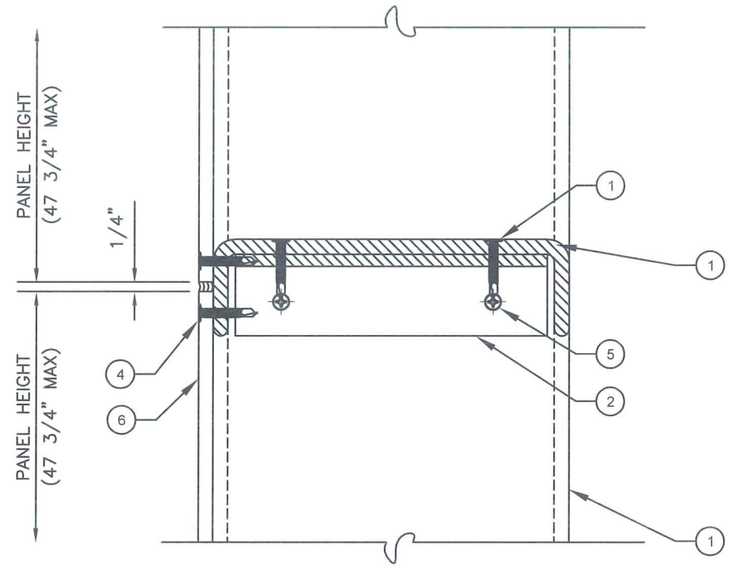

NORTHSTAR TECHNOLOGIES GROUP INC
365 FIFTH AVE S.
NAPLES, FLORIDA 34102
239.850.6253

PINGLESE@NORTHSTARTGI.COM

NORTHSTARTGI.COM

ENGINEER

Scott Wolters
FL PE# 62354

Wolters Engineering
(COA# 27194)
15211 97th Road N
West Palm Beach, FL 33412
561.225.1982

SCOTT WOLTERS GENERAL No 62354 STATE OF FLORIDA PROFESSIONAL ENGINEER

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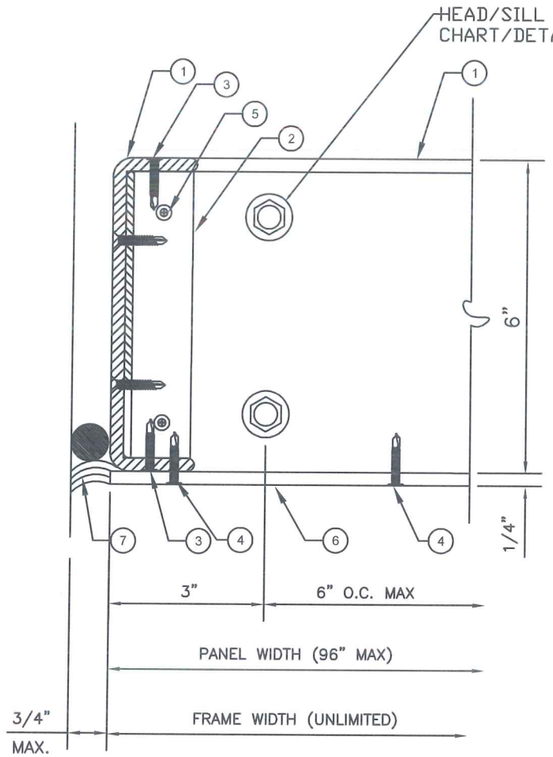

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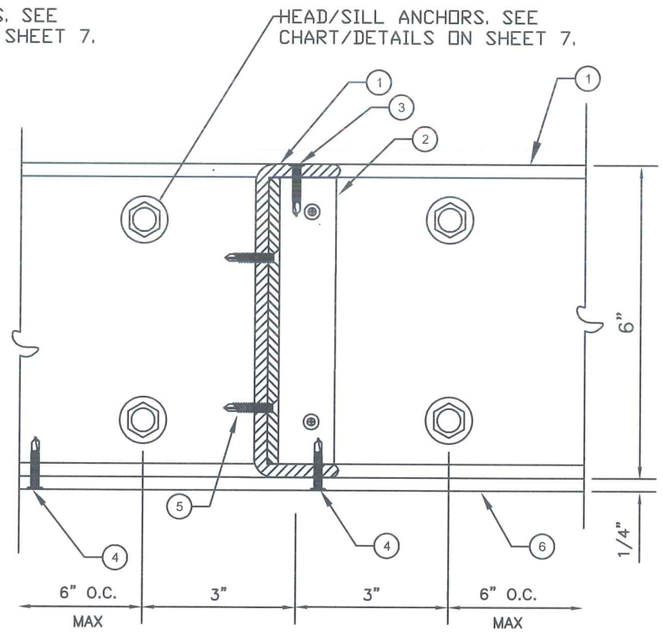

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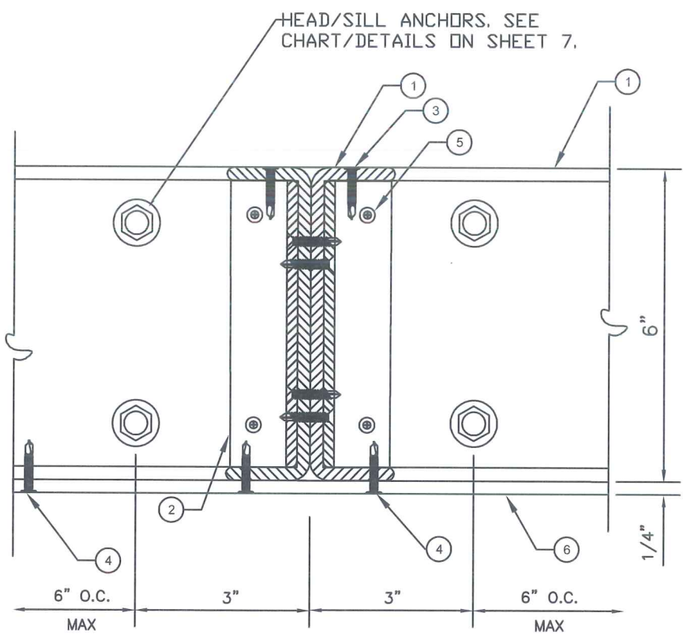

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NORTHSTAR TECHNOLOGIES GROUP INC
365 FIFTH AVE S.
NAPLES, FLORIDA 34102
239.850.6253

PINGLESE@NORTHSTARTGI.COM

NORTHSTARTGI.COM

ENGINEER

Scott Wolters
FL PE# 62354

Wolters Engineering
(COA# 27194)
15211 47th Road N.
West Palm Beach, FL 33411
561.225.1982

SCOTT WOLTERS LICENSE No 62354 STATE OF FLORIDA PROFESSIONAL ENGINEER

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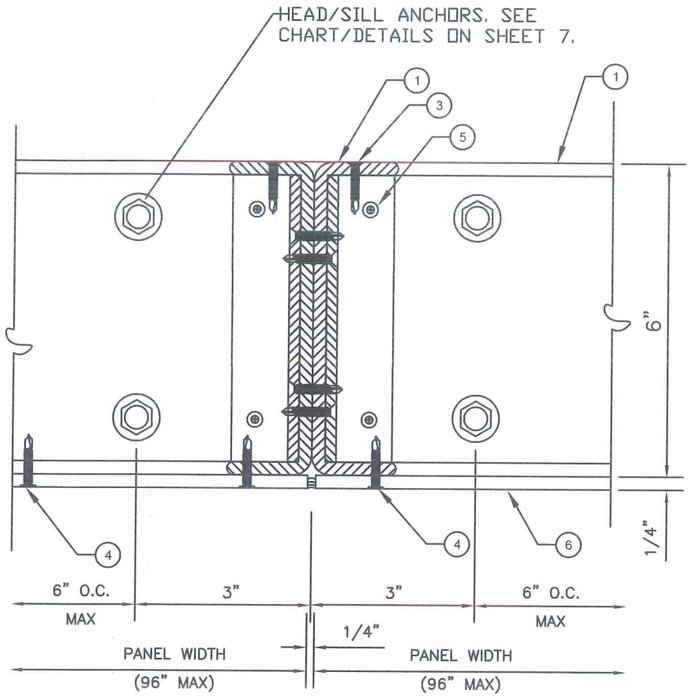

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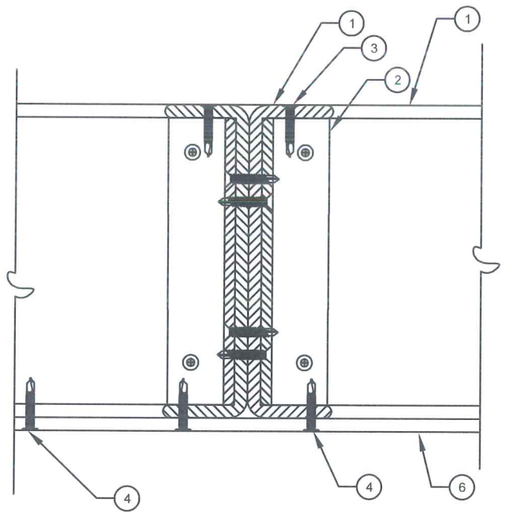

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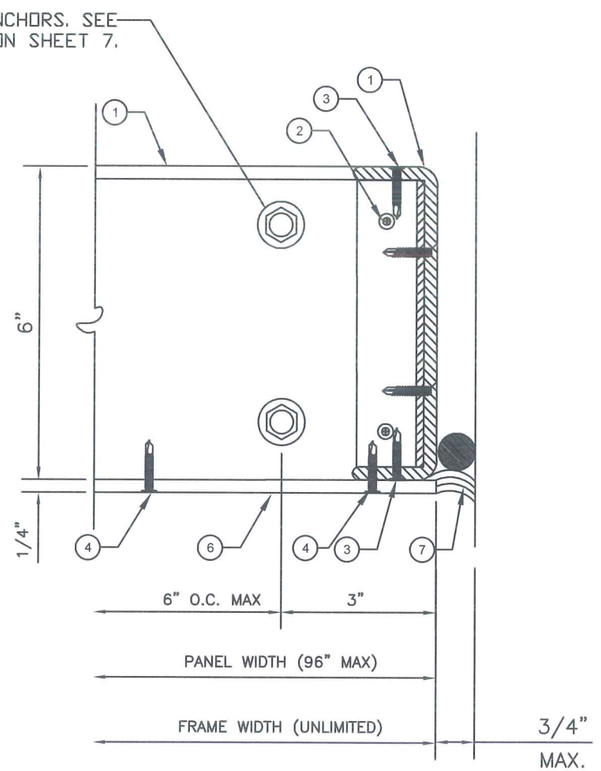

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NORTHSTAR TECHNOLOGIES GROUP INC
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NAPLES, FLORIDA 34102
239.850.6253

PINGLESE@NORTHSTARTGI.COM

NORTHSTARTGI.COM

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Scott Wolters
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Wolters Engineering
(COA# 27194)
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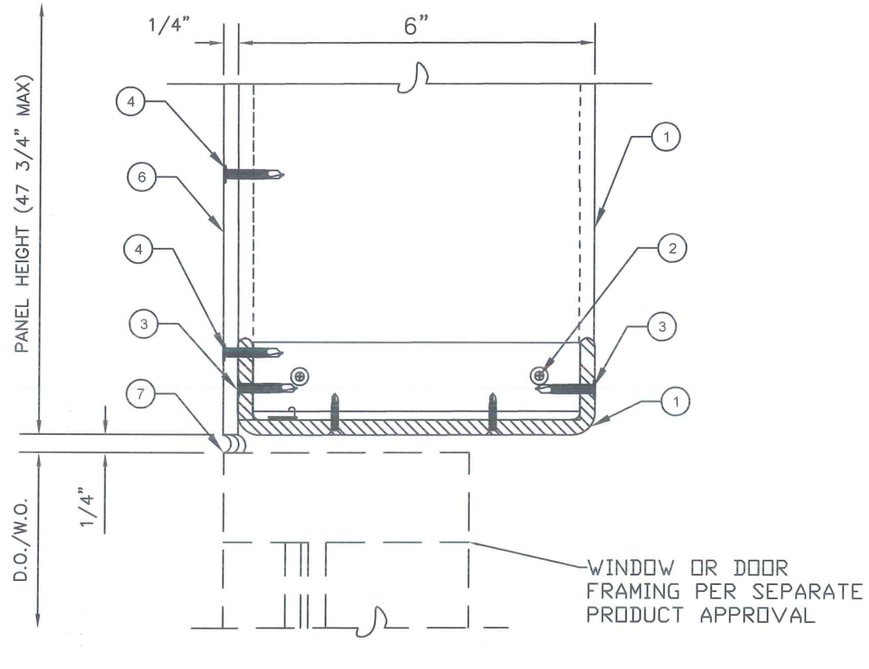

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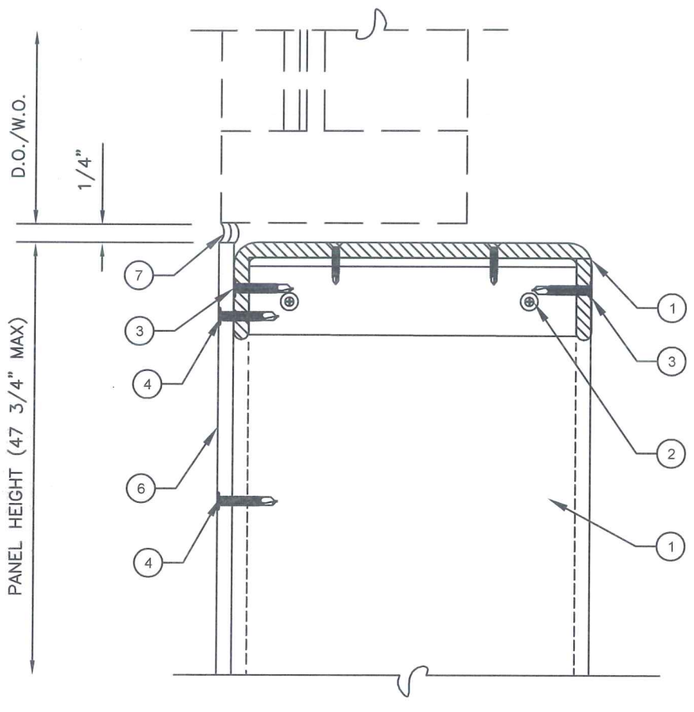

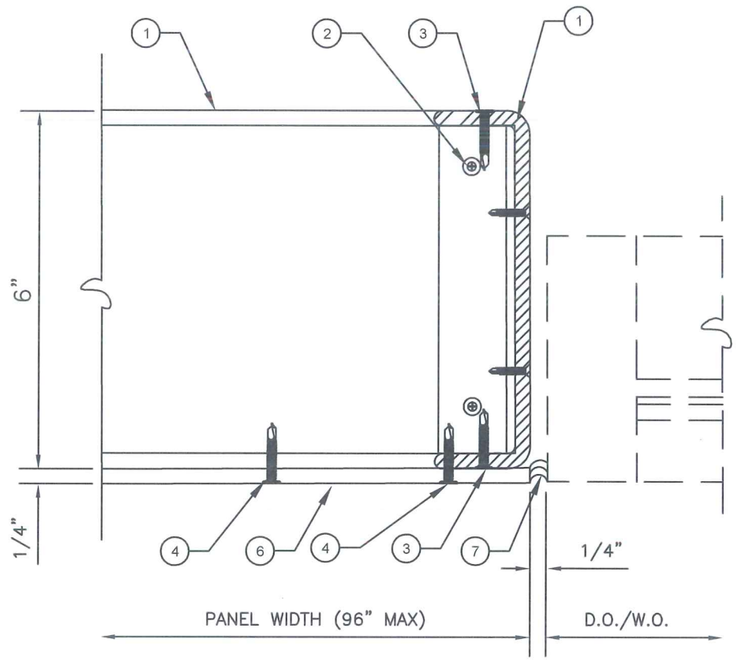

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NORTHSTAR TECHNOLOGIES GROUP INC
365 FIFTH AVE S.
NAPLES, FLORIDA 34102
239.850.6253

PINGLESE@NORTHSTARTGI.COM

NORTHSTARTGI.COM

ENGINEER

Scott Wolters
FL PE# 62354

Wolters Engineering
(COA# 27194)
15211 57th Road N.
West Palm Beach, FL 33412
561.225.1982

SCOTT WOLTERS LICENSE No 62354 STATE OF FLORIDA PROFESSIONAL ENGINEER
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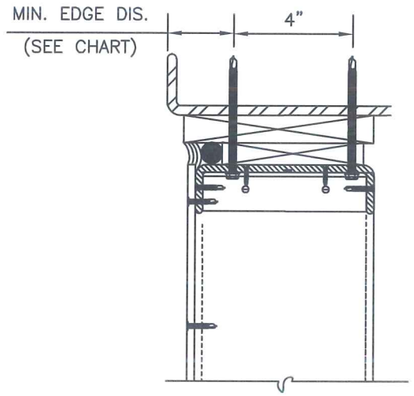
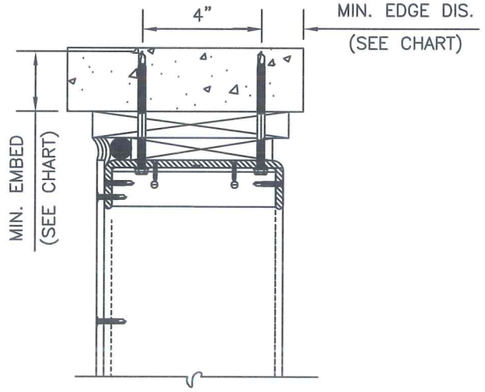
NORTHSTAR EXTERIOR WALL PANEL SYSTEM



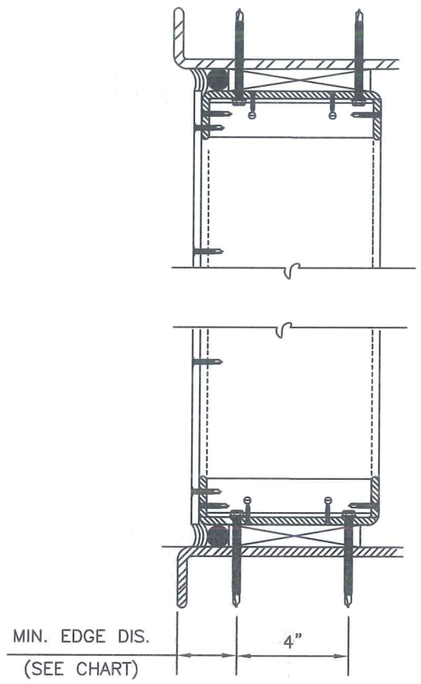
STEEL WITH OPTIONAL WOOD BUCK



CONCRETE WITH OPTIONAL WOOD BUCK

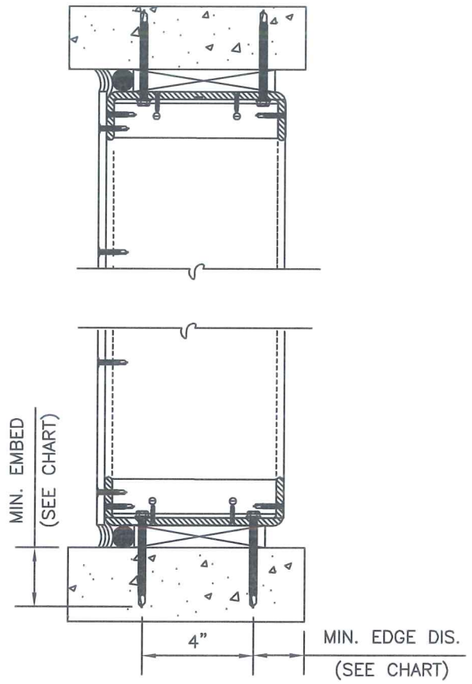
HEAD/SILL ANCHOR REQUIREMENTS			
SUBSTRATE TYPE	ANCHOR TYPE	MINIMUM EMBEDMENT	MINIMUM EDGE DISTANCE
CONCRETE (2.85 ksi MIN)	5/16" DIA. ELCO ULTRACON	1 3/4"	1 3/4"
2X P.T. WOOD (S.G.=0.5, MIN)	5/16" DIA. ELCO ULTRACON	1 1/2"	1"
STEEL (1/8", 46 ksi MIN)	5/16" DIA. ITW TEKS SELF-DRILLING SCREW	FULL++	1/2"

++ FULLY PENETRATES METAL WITH 3 THREADS BEYOND



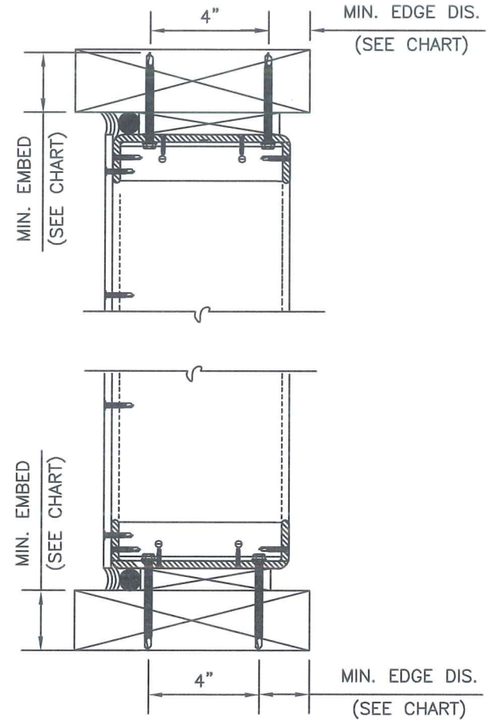
DIRECTLY TO STEEL

(1/8", 46 ksi MIN)



DIRECTLY TO CONCRETE

(2846 psi MIN)



DIRECTLY TO WOOD

(2X, S.G. = 0.5 MIN)

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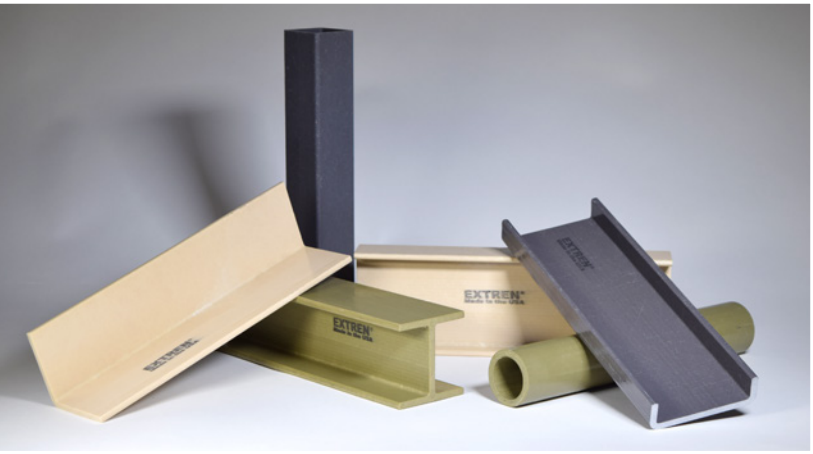
STRONGWELL®

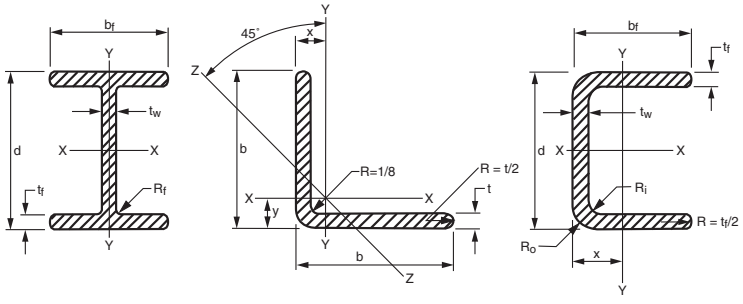
EXCLUSIVELY MADE IN THE USA

EXTREN®

FIBERGLASS STRUCTURAL SHAPES AND PLATE

- Corrosion Resistant
- High Strength-to-Weight
- Easy Installation
- Cost Effective
- Low Maintenance
- Low Conductivity
- Dimensionally Stable

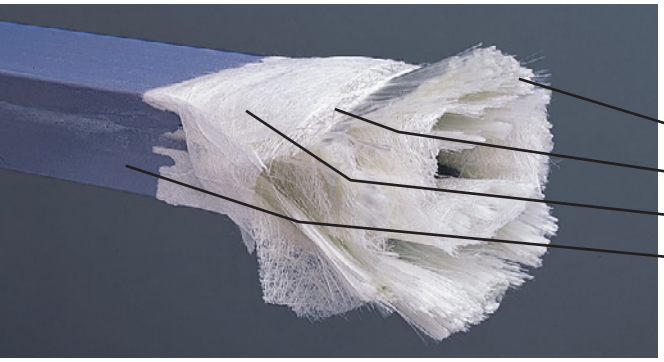




EXTREN® FIBERGLASS STRUCTURAL SHAPES AND PLATE

This entire rooftop structure was built using EXTREN®, to take advantage of its transparency to RF and cellular signals.

EXTREN® structural shapes have become an ideal alternative for traditional wood in cooling tower construction.



What is EXTREN®?

EXTREN® replaces steel, aluminum, and wood in a wide variety of structural applications. EXTREN® is a durable, lightweight, cost saving structural material. This brochure provides basic information about the EXTREN® product line and shows many examples of how EXTREN® provides solutions for end users in a variety of markets and applications.

EXTREN® is:

- Corrosion Resistant
- Structurally Strong
- Impact Resistant
- Lightweight
- Easy to Field Fabricate
- Low in Thermal and Electrical Conductivity

EXTREN® is manufactured by the pultrusion process. In its simplest terms, pultrusion is the process of pulling fiberglass (or other) reinforcements through a "bath" of thermosetting resin and into a heated forming-and-curing die to produce composite structural shapes. Reinforcement placement, resin formulation, catalyst levels, die temperature and pull speed are critical process parameters. Strongwell is world leader of the pultrusion process with more than 60 pultrusion machines in four plant locations across North America.

Why Use EXTREN®?

EXTREN® is the result of decades of experience in manufacture, design, and fabrication. EXTREN® offers the following advantages:

- **Corrosion Resistance** - Superior resistance to a broad range of chemicals. Unaffected by moisture or immersion in water when sealed. Will not rust like metal and will not rot like wood.
- **High Strength-to-Weight** - Pound-for-pound, EXTREN® pultruded fiberglass structural shapes are stronger than steel in lengthwise direction. Strongwell FRP weighs up to 75% less than steel and 30% less than aluminum - ideal when maximum performance is required but every pound counts.
- **Easy Installation** - Can be field fabricated using simple carpenter tools and is easily lifted into place during installation with less equipment or specialized labor vs. steel.
- **Cost Effective** - Because installation of Strongwell FRP is much simpler and quicker than steel, structures built using Strongwell's pultruded products can cost as much as 15% less than carbon steel, 30% less than galvanized steel, and as much as 50% less than stainless steel.
- **Virtually Maintenance Free** - Will not permanently deform under impact. Corrosion resistance eliminates need for constant painting and upkeep. Provides long-term, cost effective solutions with lower life cycle costs.
- **Durability & Weatherability** - Resists impact, non-denting and hard to break. Pigmented resin, surfacing veil, and UV-Inhibitors prevent moisture absorption, warping, fiber bloom, and delays fading.

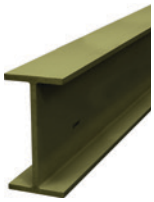
Materials of Construction

EXTREN® is an engineered composite consisting of:

- Fiberglass rovings for increased strength
- Continuous strand mat for crosswise strength and imact resistance
- Synthetic surfacing veil for corrosion and UV protection
- Resin (specified by Series)

THE EXTREN® SERIES

EXTREN® is pultruded structural composite profiles and plate produced exclusively by Strongwell with the EXTREN® logo embedded in the surfacing veil. It meets or exceeds the minimum published mechanical, physical, electrical, flammability, and corrosive properties of the respective Series published in the *Strongwell Design Manual*.



EXTREN® Series 500

Premium Polyester Resin, UV inhibitor added
Standard Color: olive green
A general purpose resin with excellent corrosion properties

EXTREN® Series 525

Premium Polyester Resin, UV inhibitor added, Flame retardant additives
Standard Color: slate gray
A general purpose resin with excellent corrosion properties and improved fire performance

EXTREN® Series 600

Premium Vinyl Ester Resin, UV inhibitor added
Standard Color: light gray
For harsher corrosive environments and higher temperature applications

EXTREN® Series 625

Premium Vinyl Ester Resin, UV inhibitor added, Flame retardant additives
Standard Color: beige
For harsher corrosive environments, higher temperature applications, with improved fire performance

EXTREN® Series 900

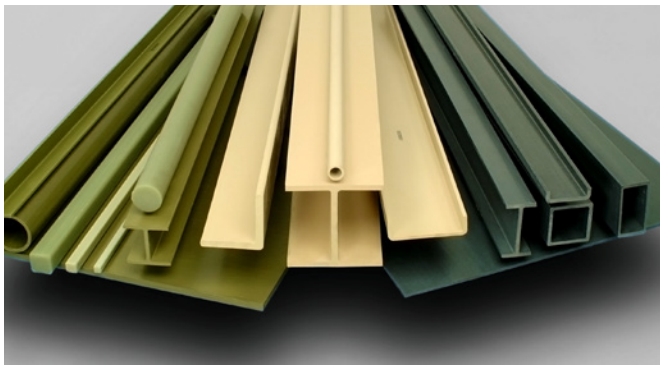
In addition to the above EXTREN® products, Strongwell manufactures custom pultrusions. These pultrusions vary from EXTREN® in either shape, resin type, or reinforcement (type, amount, location and/or orientation). Designers may choose to vary one or all of these parameters to improve strength, temperature resistance, corrosion resistance, machinability, or some other characteristic. Consult Strongwell with specific needs or questions.

E23

All standard EXTREN® products meet and/or exceed the structural requirements of E17 European standards. EXTREN® can be manufactured upon request to meet the mechanical and physical properties of BS EN 13706 (E23) European standards.

NSF International

Most Strongwell products can be manufactured to meet NSF-61 certification upon request. Contact Strongwell for details.



EXTREN® Series: (left to right) 500, 625, and 525.

EXTREN® structural shapes were used in a SXEW copper refinery because of the highly corrosive environment.

A 63' (19.2m) high freestanding fiberglass stair tower at Ft. Story Army Base, Virginia Beach, Virginia.

PROPERTIES

	ASTM TEST METHOD	UNITS/ VALUE	SERIES 500/525 SHAPES	SERIES 600/625 SHAPES	SERIES 500/525 PLATE ④ 1/8" 3.175mm	SERIES 500/525 PLATE ④ 3/16" - 3/8" 4.76-9.5mm	SERIES 500/525 PLATE ④ 1/2" - 1" 9.5-25.4mm	SERIES 600/625 PLATE ④ 1/8" 3.175mm	SERIES 600/625 PLATE ④ 3/16" - 1/4" 4.76-6.35mm	SERIES 600/625 PLATE ④ 3/8" - 1" 9.5-25.4mm
MECHANICAL										
Tensile Stress, LW	D638	psi	30,000	30,000	20,000	20,000	20,000	20,000	20,000	20,000
		N/mm²	207	207	138	138	138	138	138	138
Tensile Stress, CW	D638	psi	7,000	7,000	7,500	10,000	10,000	7,500	10,000	10,000
		N/mm²	48.3	48.3	51.7	68.9	68.9	51.7	68.9	68.9
Tensile Modulus, LW	D638	10^6 psi	2.5	2.6	1.8	1.8	1.8	1.8	1.8	1.8
		10^3N/mm²	17.2	17.9	12.4	12.4	12.4	12.4	12.4	12.4
Tensile Modulus, CW	D638	10^6 psi	0.8	0.8	0.7	0.9	1.0	1.0	1.0	1.0
		10^3N/mm²	5.52	5.52	4.83	6.21	6.89	6.89	6.89	6.89
Compressive Stress, LW	D695	psi	30,000	30,000	24,000	24,000	24,000	24,000	24,000	24,000
		N/mm²	207	207	165	165	165	165	165	165
Compressive Stress, CW	D695	psi	15,000	16,000	15,500	16,500	20,000	16,500	17,500	17,500
		N/mm²	103	110	107	114	138	114	121	121
Compressive Modulus, LW	D695	10^6 psi	2.5	2.6	1.8	1.8	1.8	1.8	1.8	1.8
		10^3N/mm²	17.2	17.9	12.4	12.4	12.4	12.4	12.4	12.4
Compressive Modulus, CW	D695	10^6 psi	0.8	0.8	0.7	0.9	1.0	1.0	1.0	1.0
		N/mm²	5.52	5.52	4.83	6.21	6.89	6.89	6.89	6.89
Flexural Stress, LW	D790	psi	30,000	30,000	24,000	24,000	24,000	24,000	24,000	24,000
		N/mm²	207	207	165	165	165	165	165	165
Flexural Stress, CW	D790	psi	10,000	10,000	10,000	13,000	17,000	10,000	13,000	17,000
		N/mm²	68.9	68.9	68.9	89.6	117	68.9	89.6	117
Flexural Modulus, LW	D790	10^6 psi	1.6	1.6	1.1	1.1	1.4	1.1	1.1	1.4
		10^3N/mm²	11.0	11.0	7.58	7.58	9.65	7.58	7.58	9.65
Flexural Modulus, CW	D790	10^6 psi	0.8	0.8	0.8	0.8	1.3	0.8	0.9	1.3
		10^3N/mm²	5.52	5.52	5.51	5.51	8.96	5.51	6.21	8.96
Modulus of Elasticity ①	full section	10^6 psi	2.6	2.8	LW: 2.0 CW: 0.8	2.0 0.8	2.0 1.3	2.0 0.8	2.0 0.9	2.0 1.3
		10^3N/mm²	17.9	19.3	LW: 13.7 CW: 5.51	13.7 5.51	13.7 8.96	13.7 5.51	13.7 6.21	13.7 8.95
Modulus of Elasticity: W & I shapes > 4"	full section	10^6 psi	2.5	2.5	-	-	-	-	-	-
W & I shapes > 102mm		10^3N/mm²	17.2	17.2	-	-	-	-	-	-
Shear Modulus, LW ②⑧	D5379	10^6 psi	0.425	0.425	-	-	-	-	-	-
		10^3N/mm²	2.93	2.93	-	-	-	-	-	-
Short Beam Shear, LW ⑦⑧	D2344	psi	4,500	4,500	-	-	-	-	-	-
		N/mm²	31.0	31.0	-	-	-	-	-	-
Ultimate Bearing Stress, LW	D953	psi	30,000	30,000	32,000	32,000	32,000	32,000	32,000	32,000
		N/mm²	207	207	221	221	221	221	221	221
Poisson's Ratio, LW ⑧	D3039	in/in	0.33	0.33	0.31	0.31	0.31	0.32	0.32	0.32
		mm/mm	0.33	0.33	0.31	0.31	0.31	0.32	0.32	0.32
Poisson's Ratio, CW ⑧	D3039	in/in	-	-	0.29	0.29	0.29	0.24	0.24	0.24
		mm/mm	-	-	0.29	0.29	0.29	0.24	0.24	0.24
Notched Izod Impact, LW	D256	ft-lbs/in	25	25	15	10	10	15	10	10
		J/mm	1.33	1.33	0.801	0.533	0.533	0.801	0.533	0.533
Notched Izod Impact, CW	D256	ft-lbs/in	4	4	5	5	5	5	5	5
		J/mm	0.214	0.214	0.267	0.267	0.267	0.267	0.267	0.267

	ASTM TEST METHOD	UNITS/ VALUE	SERIES 500/525 SHAPES	SERIES 600/625 SHAPES	SERIES 500/525 PLATE ④ 1/8" 3.175mm	SERIES 500/525 PLATE ④ 3/16" - 3/8" 4.76-9.5mm	SERIES 500/525 PLATE ④ 1/2" - 1" 9.5-25.4mm	SERIES 600/625 PLATE ④ 1/8" 3.175mm	SERIES 600/625 PLATE ④ 3/16" - 1/4" 4.76-6.35mm	SERIES 600/625 PLATE ④ 3/8" - 1" 9.5-25.4mm
PHYSICAL*										
Barcol Hardness	D2583	-	45	45	40	40	40	40	40	40
24 hr Water Absorption ⑥	D570	% Max	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Density	D792	lbs/in^3	0.062-0.070	0.062-0.070	0.060-0.068	0.060-0.068	0.060-0.068	0.060-0.068	0.060-0.068	0.060-0.068
		10^{-3} g/mm^3	1.72-1.94	1.72-1.94	1.66-1.88	1.66-1.88	1.66-1.88	1.66-1.88	1.66-1.88	1.66-1.88
Coefficient of Thermal Expansion, LW ⑧	D696	10^{-6} in/in/°F	7	7	8	8	8	8	8	8
		10^{-6} mm/mm/°C	12	12	14.5	14.5	14.5	14.5	14.5	14.5
Coefficient of Thermal Expansion, CW ⑧	D696	10^{-6} in/in/°F	16	16	-	-	-	-	-	-
		10^{-6} mm/mm/°C	28.8	28.8	-	-	-	-	-	-
Thermal Conductivty ⑧	C177	BTU-in/ft²/hr/°F	4	4	-	-	-	-	-	-
		W(m * °K)	0.58	0.58	-	-	-	-	-	-
**All values are minimum ultimate properties from coupon tests except as noted.*										
ELECTRICAL										
Arc Resistance, LW ⑧	D495	seconds	120	120	-	-	-	-	-	-
Dielectric Strength, LW ⑧	D149	KV/in	35	35	35	35	35	35	35	35
		KV/mm	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38
Dielectric Strength, PF ⑧	D149	volts/mil	200	200	200	-	-	250	-	-
FLAMMABILITY ⑤										
Flammability Classification	UL 94	V-0								
Tunnel Test	E84	25 Max								
NBS Smoke Chamber	E662	650-700 (Typical)								
Flammability	D635	Self Extinguishing								
UL Thermal Index	Generic	266°F								
		130°C								
British Fire Test	BS 476-7	Class 1								

① This value is determined from full section simple beam bending of EXTREN® structural shapes.

② The Shear Modulus value has been determined from tests with full sections of EXTREN® structural shapes. (See Strongwell's *Design Manual* for further information.)

③ Value would be 50 if the surfacing veil were not there.

④ Plate compressive stress/modulus measured edgewise and flexural stress/modulus measured flatwise.

⑤ Values apply to Series 525 and 625 (≥ 1/8" thickness).

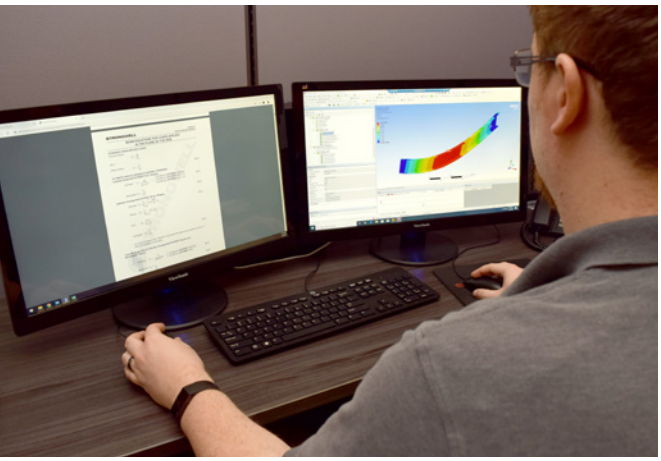
⑥ Measured as a percentage maximum by weight.

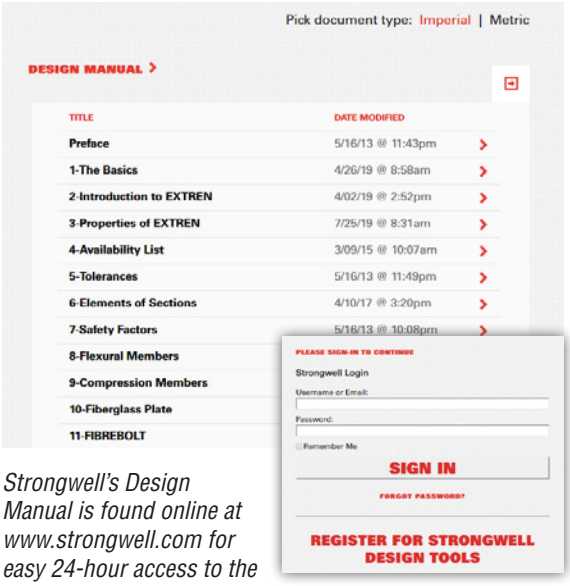
⑦ Span to depth ratio of 3:1; EXTREN® angles will have a minimum value of 4000 psi and the I/W shapes are tested in the web.

⑧ Typical values.

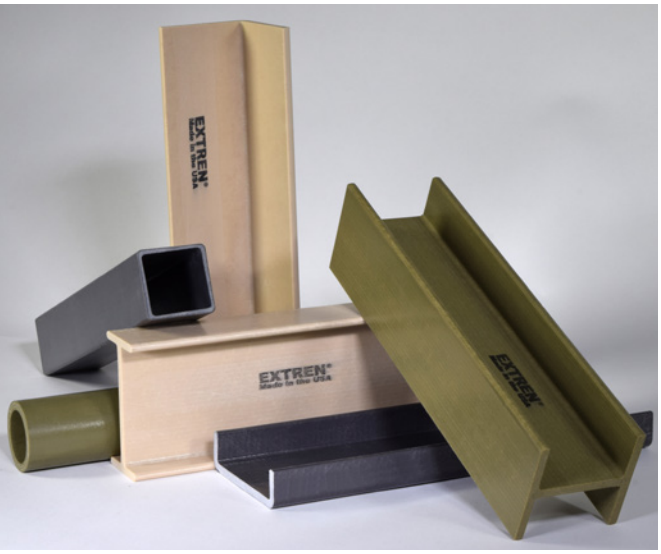
LW - Lengthwise
CW - Crosswise
PF - Perpendicular to laminate face

DESIGNING WITH EXTREN®





Strongwell's Design Manual is found online at www.strongwell.com for easy 24-hour access to the most up-to-date design information. Register your email address and information; you'll receive access immediately via email.



Design By Strongwell

Strongwell has on-staff registered Professional Engineers experienced in the design of fiberglass structures and systems for custom design requirements. Strongwell's extensive experience in fabrication procedures, joint design and stress analysis of composite assemblies, when combined with the use of Strongwell fiberglass products, results in structures of superior, cost-effective design and structural integrity. Strongwell provides drawings of any of its designed-in-house structures for approval before fabrication begins.

Design It Yourself

The Strongwell Design Manual, developed by Strongwell, is the most complete reference guide in the industry for designing FRP structures and is used by more engineers and architects than any other FRP engineering guide. With more than 400 pages of engineering data, the Design Manual includes properties of materials, beam and column load tables, empirical design equations and sample calculations, connection details, and FRP product and fabrication specifications. Strongwell's Design Manual can be found online at www.strongwell.com. It is based upon years of extensive product testing and experience in monitoring applications of EXTREN® fiberglass structural shapes, fiberglass grating, handrail and other proprietary pultruded products.

WARNING!

Fiberglass reinforced thermoset plastic composites are non-homogenous materials (i.e., their strengths and behavior are dependent upon the design of the composite and reinforcement). Other fiberglass structural shapes with a similar exterior appearance to EXTREN® shapes are likely not equal in any other way to EXTREN®, including glass content, glass placement, glass type, wet out, resin mixture or pull speed. Do not use the *Strongwell Design Manual* to design a structure unless only EXTREN® structural materials are used.

EXTREN® Product Logo

Since July 1, 1993, all EXTREN® fiberglass structural shapes and plate have been imprinted with the "EXTREN® Made in the USA" logo every three feet down the length of the part. Square and round tubes have the logo imprinted inside the shape. Small and unobtrusive, the logo assures customers that they are getting EXTREN® properties backed by corrosion, mechanical, and structural testing, as conducted by Strongwell.

Fabrication

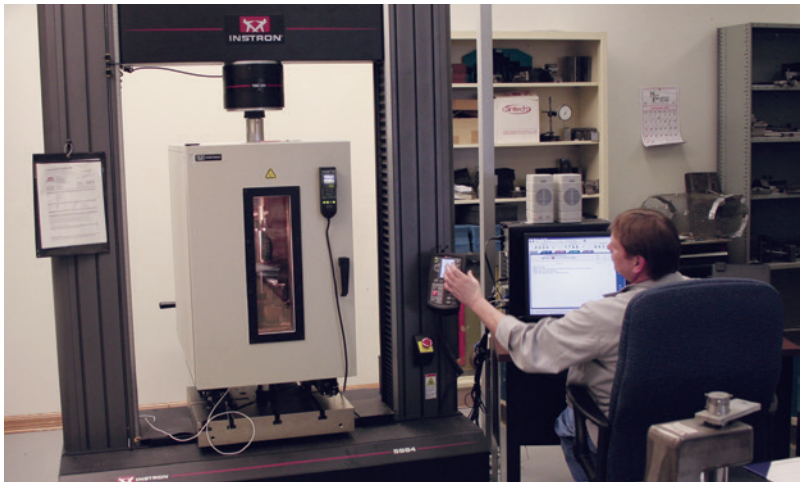
Working with EXTREN® is somewhat similar to working with wood, but there are some differences in cutting and fastening. These differences are presented in detail in the *EXTREN® Fabrication and Repair Manual*. This manual also presents the cleaning, inspection, maintenance, and repair of EXTREN® structural shapes.

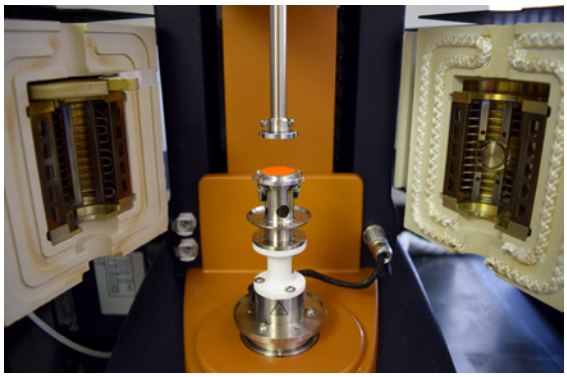
QUALITY AND AVAILABILITY

Strongwell manufacturing facilities are ISO 9001 certified. This ensures the highest quality standards for every piece of EXTREN® used in the field. A "first article" series of tests on each EXTREN® production run assures that the structural members meet or exceed published minimum criteria.

With a 10,000 square-foot on-site R&D laboratory and full-time R&D staff, Strongwell can perform most testing procedures, material qualifications, and quality experiments in house. These resources provide Strongwell, its customers, and suppliers unmatched technical expertise.

Strongwell maintains a large inventory of many commonly-used EXTREN® structural shapes and plate. Refer to the *Strongwell Availiabilty List* for more details.





Clockwise from Above: *Strongwell's Instron 5984 Materials Testing Machine with Environmental Chamber is a state-of-the-art piece of equipment.*

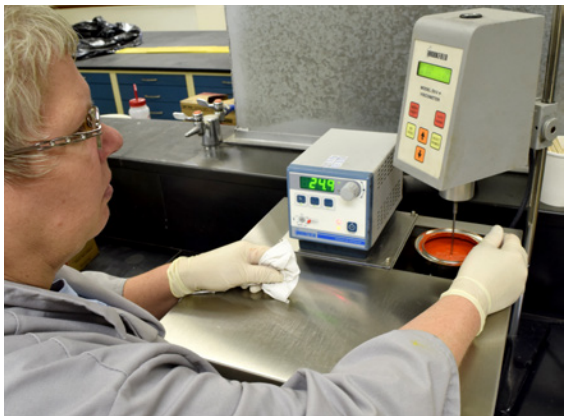
Strongwell's laboratory and research facility is large, well-equipped, and professionally staffed.

Rheology/DMA to determine glass transition temperature and other viscoelastic properties of resin mixes as well as solid composites.

Strongwell can perform incoming resin tests to verify the suppliers' conformance to specified requirements.

Differential Scanning Calorimetry (DSC) for profiling the cure characteristics of resin mixes.

Below: *Strongwell maintains a large intentory of many commonly-used EXTREN® structural shapes and plate. Refer to the* Strongwell Availability List *for more details.*



MARKETS

Strongwell works every day to provide solutions to tough engineering and design challenges like the examples shown here. As engineers become aware of the features and benefits of pultrusion, the range of applications for composite materials continues to grow.

Architectural

Strongwell manufactures numerous products used in the architectural market, including walkways and handrail, to fully customized shapes like the one above, Strongwell's fiberglass pultrusions are strong, lightweight, corrosion resistant, and durable.

Building / Construction

The EXTREN® line includes over 100 standard shapes, and Strongwell manufactures hundreds of other profiles used in building and construction, which have been used to save weight, increase corrosion resistance, provide aesthetic beauty, and reduce maintenance costs.

Cellular

EXTREN® is often an ideal material for building anywhere that electro-magnetic (EMI) or radio frequency interference (RFI) is a concern. Strongwell FRP has been used extensively for applications ranging from architectural screening to entire structures - FRP is nearly invisble to cellular and radio frequencies.

Coastal / Marine

Fiberglass handrail, pultruded grating, decking, and EXTREN® from Strongwell offer an attractive, low-maintenance and long-lasting alternative to steel and wood in corrosive marine and freshwater environments.

Electric Utility

The high strength to weight ratio, low electrical conductivity and proven durability of Strongwell's FRP make it an attractive option for electric utilities seeking to upgrade or install new materials.

Hotel / Motel

Constant maintenance at hotel and motel facilities have driven many operators to select Strongwell FRP to replace traditional materials, especially in exterior handrail, stairways, walkways, and water play areas.

Chemical Processing

The superior corrosion resistance of Strongwell FRP makes it an excellent choice around most harsh chemicals in a variety of environments. In addition, Strongwell offers a vast Corrosion Resistance Guide to help end users determine the expected performance of FRP in their application(s).

Infrastructure

Strongwell is actively involved in the advancement of FRP technology for civil infrastructure applications. These efforts include the research and development of new products as well as in the establishment of engineering and performance standards.

Transportation

Incorporating FRP into structures and designs reduces the overall structure weight and foundational requirements. Installation can also be much faster and less complicated, reducing congestion in work zones and improving safety.

Mining

Engineers and end users are replacing traditional materials with FRP in corrosive mining environments. FRP provides lower life cycle costs, offers outstanding performance and provides superior quality.

Air Pollution Control

Odor control covers made with traditional materials weigh significantly more than those made with FRP. Strongwell's odor control covers weigh up to 75% less than steel and 30% less than aluminum, and offer superior corrosion resistance in the chemical-laden wastewater processing setting.

Food & Beverage

The processing of many foods and beverages creates significant corrosion and food safety challenges for end users. Many Strongwell products can be manufactured to meet NSF-61 certification for hot and cold, while offering exceptional corrosion performance in most food processing environments.

Water / Wastewater

Strongwell offers a wide range of fiberglass products for the water and wastewater treatment industries, including NSF compliant structures for use in potable water systems. For example, EXTREN® structural shapes are often used with FRP baffles for an all-FRP system.

Oil & Gas

Strongwell's structural composites have proven to be an effective long-term solution in the Oil and Gas market. Weight savings, durability, and resistance to salt air and seawater are just a few of the benefits which fiberglass composites provide over steel.

Parks & Recreation

Strongwell's pultruded fiberglass materials can replace wood and metal to help reduce maintenance costs, reduce downtime and increase the beauty of parks and recreational areas, especially in areas which currently require frequent maintenance.

STRONGWELL

ISO 9001 Quality Certified Manufacturing Plants

MADE IN THE USA

BRISTOL LOCATION
400 Commonwealth Ave.
Bristol, VA 24201 USA
(276) 645-8000

HIGHLANDS LOCATION
26770 Newbanks Road
Abingdon, VA 24210 USA
(276) 645-8000

www.strongwell.com

ST0720

Appendix B: Simulation Assumptions and Material Properties

General Assumptions

Steady-state simulations were utilized for the thermal evaluation outlined in this report with the following assumptions:

1. Material properties were taken from the 2017 ASHARE Handbook – Fundamentals for common materials, information provided by Northstar Technologies Group for the system components, and Strongwell datasheets for the EXTREN fiberglass framing.
2. Interior and exterior heat transfer coefficients were taken from table 10 on page 26.21 of the 2017 ASHRAE Handbook – Fundamentals. Lightweight claddings have an insignificant impact on the overall thermal resistance of insulated wall assemblies, other than shielding the insulation or sheathing from direct wind exposure. The cladding and secondary structure outboard of the sheathing were not explicitly modeled. The impact of lightweight cladding was incorporated into the exterior heat transfer coefficient per ASHRAE 1365-RP so that the results can directly apply to any climate.
3. Contact resistances between the sheathing and drywall to the framing and insulation were simulated per ASHARE 1365-RP and varied between R-0.057 (0.010 m^2 K/W) and R-0.17 (0.030 0.010 m^2 K/W) depending on the materials and interfaces.
4. Insulation is assumed to be installed tight to the framing and sheathing.
5. The thermal transmittances and effective R-values included uniform thermal bridges from the fiberglass framing as outlined in the evaluation report.

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 per the following equation:

$$T_i = \frac{T_{suface} - T_{outside}}{T_{inside} - T_{outside}}$$

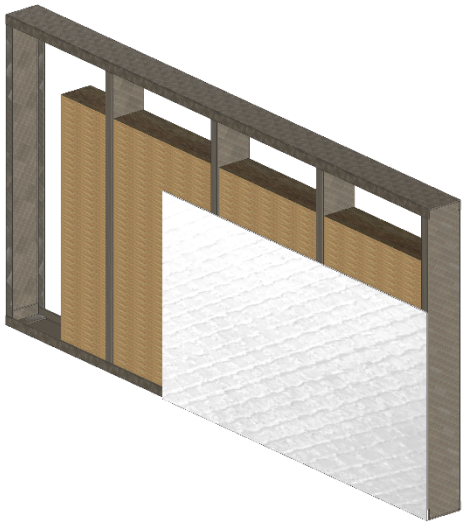
This formula can be rearranged for $T_{surface}$ to determine the surface temperatures for any climate once the temperature index is known for a critical location to evaluate the condensation risk. The temperature indices shown in the temperature profiles in Appendix C are for general information and not intended to predict in-service temperatures subject to transient conditions, variable heating systems, and/or obstructions that restrict heat getting to the wall system. Refer to ASHRAE 1365-RP for a full discussion on the limitations of using steady-state temperature indices for evaluating condensation risk.

Boundary Conditions

Table B-1. Boundary Conditions

Boundary Condition	Combined Convective and Radiative Heat Transfer Coefficient Btu/ft²· hr·°F (W/m² K)
Exterior wall surface with generic cladding	1.5 (8.3)
Interior surface	1.5 (8.3)

Material Properties

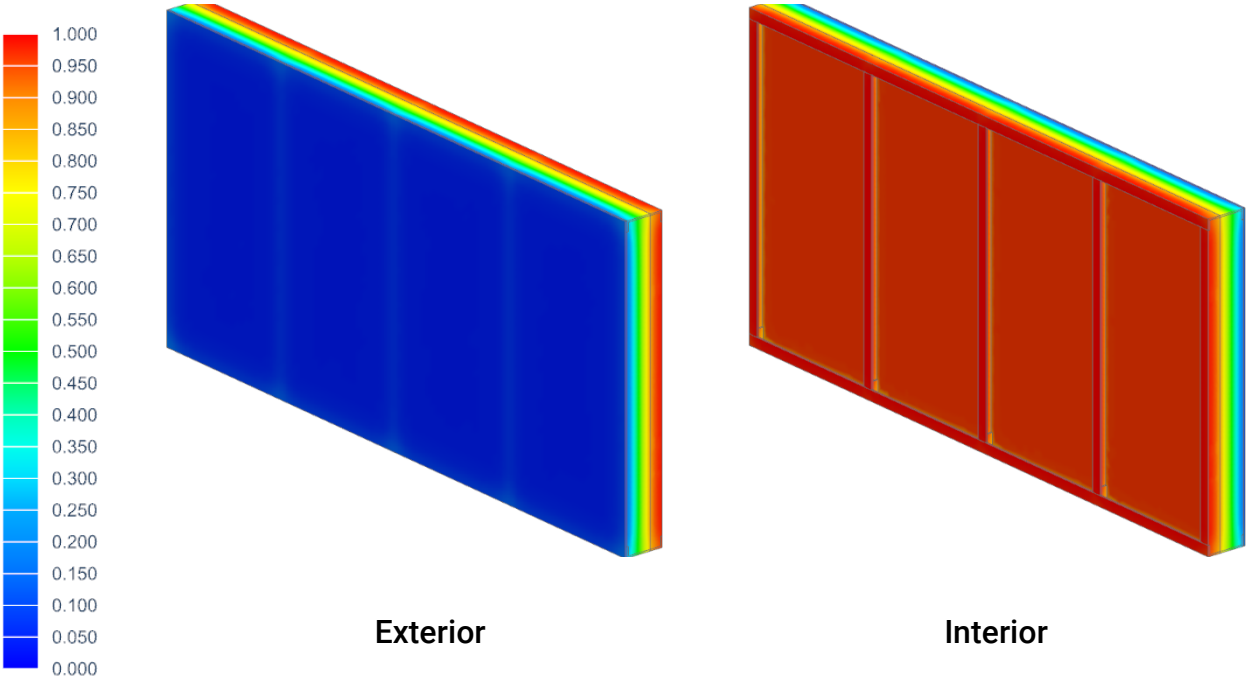


Component	Material	Thermal Conductivity Btu · in/ft² · hr·°F (W/m K)
6" x 1 5/8" channel	Strongwell EXTREN 500 or 525 Fiberglass with PE Polyester Resin	4.0 (0.58)
2" x 5 ½" angle	Strongwell EXTREN 500 or 525 Fiberglass with PE Polyester Resin	4 .0 (0.58)
¼" ballistic armor plate sheathing	Strongwell fiberglass	4 .0 (0.58)
Insulation	Mineral wool	0.24 (0.034)
1- inch air space in stud cavity	Air	1.1 (0.16)
2-inch air space in stud cavity	Air	2.2 (0.32)
Interior Drywall	Gypsum	1.1 (0.16)

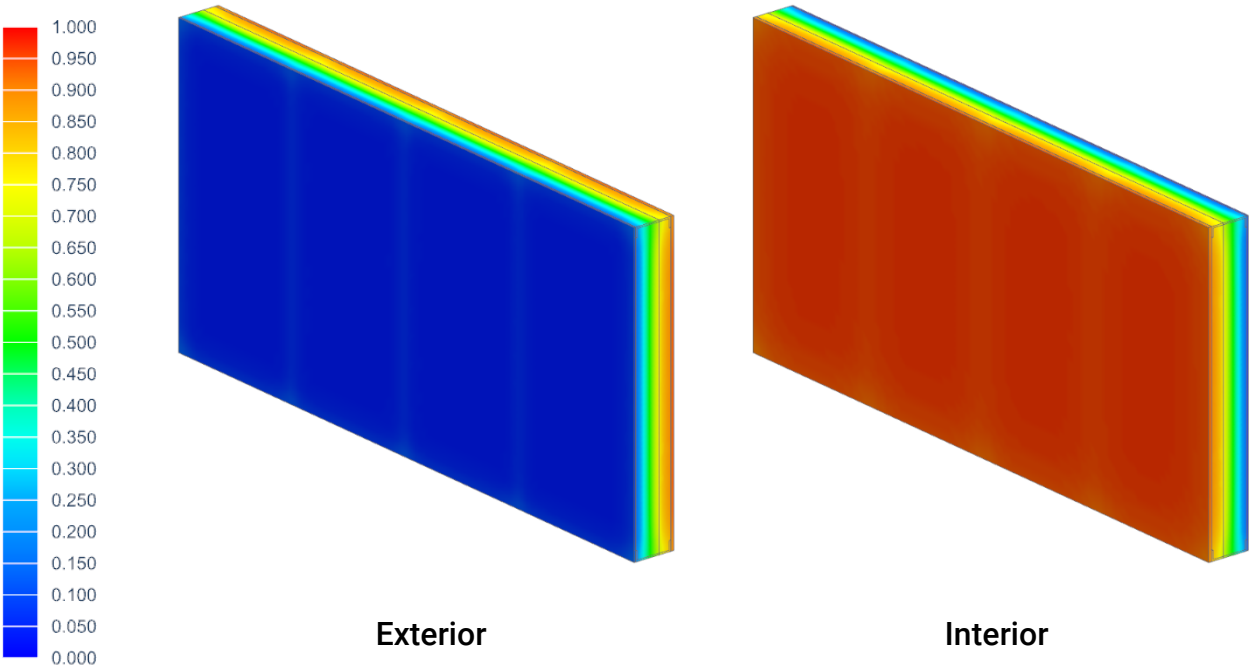
Appendix C: Simulated Temperature Profiles

The following figures illustrate the temperature distribution for the Northstar Exterior Wall system for select insulation scenarios. The profiles are presented as a temperature index (between 0 and 1). See Appendix B for more discussion.

4-Inch Cavity Insulation without Interior Drywall



4-Inch Cavity Insulation with Interior Drywall



6-Inch Cavity Insulation with Interior Drywall