REPORT

Structural Span Chart Report

ClarkDietrich & TruFast Walls

Presented to:

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1. INTRODUCTION

1.1 Purpose

Morrison Hershfield was retained by ClarkDietrich and Altenloh Brinck and Co. (corporate owner of TruFast Walls) to review a new cladding attachment system for use with continuous insulation applications. The purpose of this report is to present the structural span charts produced for the horizontal hat channel system and the vertical hat channel system.

1.2 Scope

We performed calculations for a hat channel system, installed horizontally and vertically, using the following variables:

- Cladding dead loads: 3, 4, 5, 6, 7, 8, 9, 10 and 15 psf
- Stud spacings of 16, 24, 32, and 48 inches horizontally, and:
  - For the horizontally aligned hat channel system (Figure 1), hat channels spaced vertically at 12, 16, 24, 36 and 48 inches with two screws at every stud crossing.
  - For the vertically aligned hat channel system (Figure 2), screws spaced vertically at 6, 12, 18 and 24 inches along each hat channel along each stud.
- Insulation thicknesses of 2 and 4 inches, using a minimum stiffness based on Rockwool Comfortboard 80 mineral wool insulation.
- Glass mat gypsum sheathing panels, with the minimum properties expressed in the standard ASTM C1177-17 as tested to ASTM C473-19 and a thickness of 5/8 inches.
- For wood studs only, a 5/8" thick plywood sheathing board is used instead of a glass mat reinforced gypsum panel.
- 6 stud types with flange widths of 1.625 inches, including:
  - Douglas fir or spruce-pine-fir stud (2" x 4" or deeper stud), with fastener embedment of 1.5 inches
  - 12 ga. (97 mil) Steel stud, using 50 ksi steel strength (standard). All steel studs have 1 5/8" flanges with a return lip, and a 3 5/8" web or deeper.
  - 14 ga. (68 mil) Steel stud, using 50 ksi steel strength (standard)
  - 16 ga. (54 mil) Steel stud, using 50 ksi steel strength (standard)
  - 18 ga. (43 mil) Steel stud, using 33 ksi steel strength (standard)
  - 20 ga. (33 mil) Steel stud, using 33 ksi steel strength (standard)

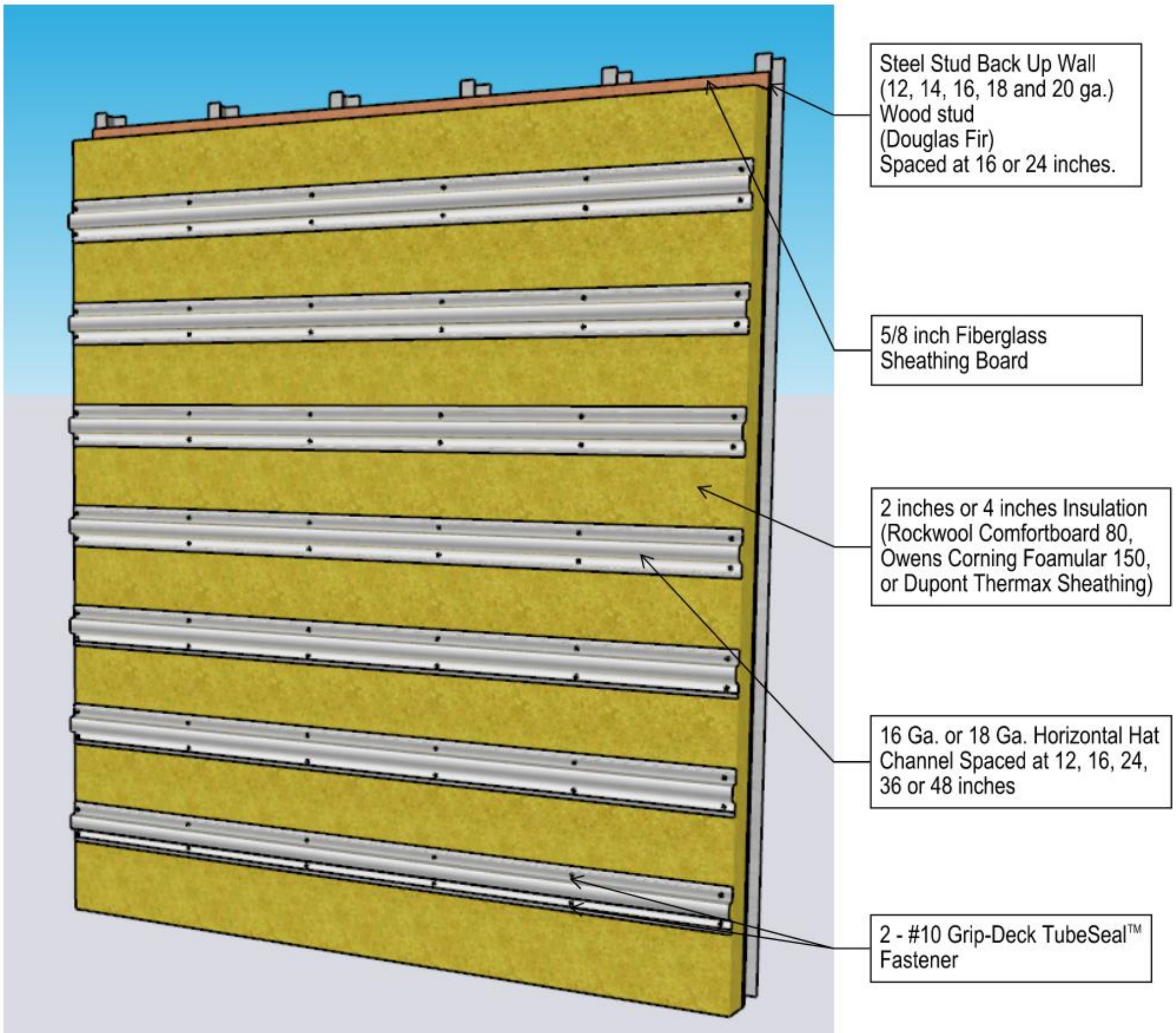
1.3 System Description

The ClarkDietrich/TruFast Walls Hat Channel system is a thermally and structurally efficient exterior wall cladding system that is intended to minimize penetrations through the insulation layer to hold an exterior rainscreen in place. This system is differentiated from other wall systems because it uses the Grip-Deck TubeSeal™ fastening system from TruFast Walls to seal the fastener penetrations against air and water leakage, and it does not use any clips, girts, or other large penetrations through the insulation to affix the rainscreen to the structure. The system is reliant on use of a sufficiently rigid insulation to provide stiffness to the overall assembly.

This system can be installed with the hat channel running horizontally or vertically. Figure 1 shows the horizontal system and Figure 2 shows the vertical system.

In the horizontally aligned hat channel system, the hat channel runs horizontally and bridges between the studs. The flanges of the hat channel are pressed up against the insulation, allowing for two fasteners to connect into each stud at each crossing. The pre-punched holes are at 1 inch spacing, allowing for spacing to be in multiples of 1 inch. In systems with 32 and 48 inch stud spacings, we assume that there are studs at 16 or 24 inches, but the system is tied back to the wall at every other stud.

In the vertically aligned hat channel system, the hat channel runs vertically along each stud with the top of the hat channel pressed up against the insulation. Pre-punched holes in the top of the hat are spaced at 6 inches, allowing for spacing of fasteners to be in multiples of 6 inches.



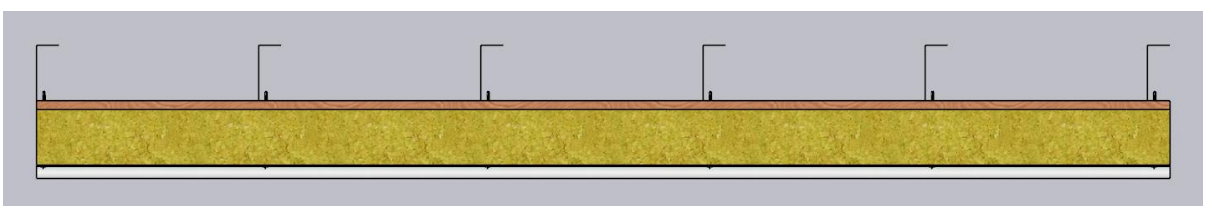
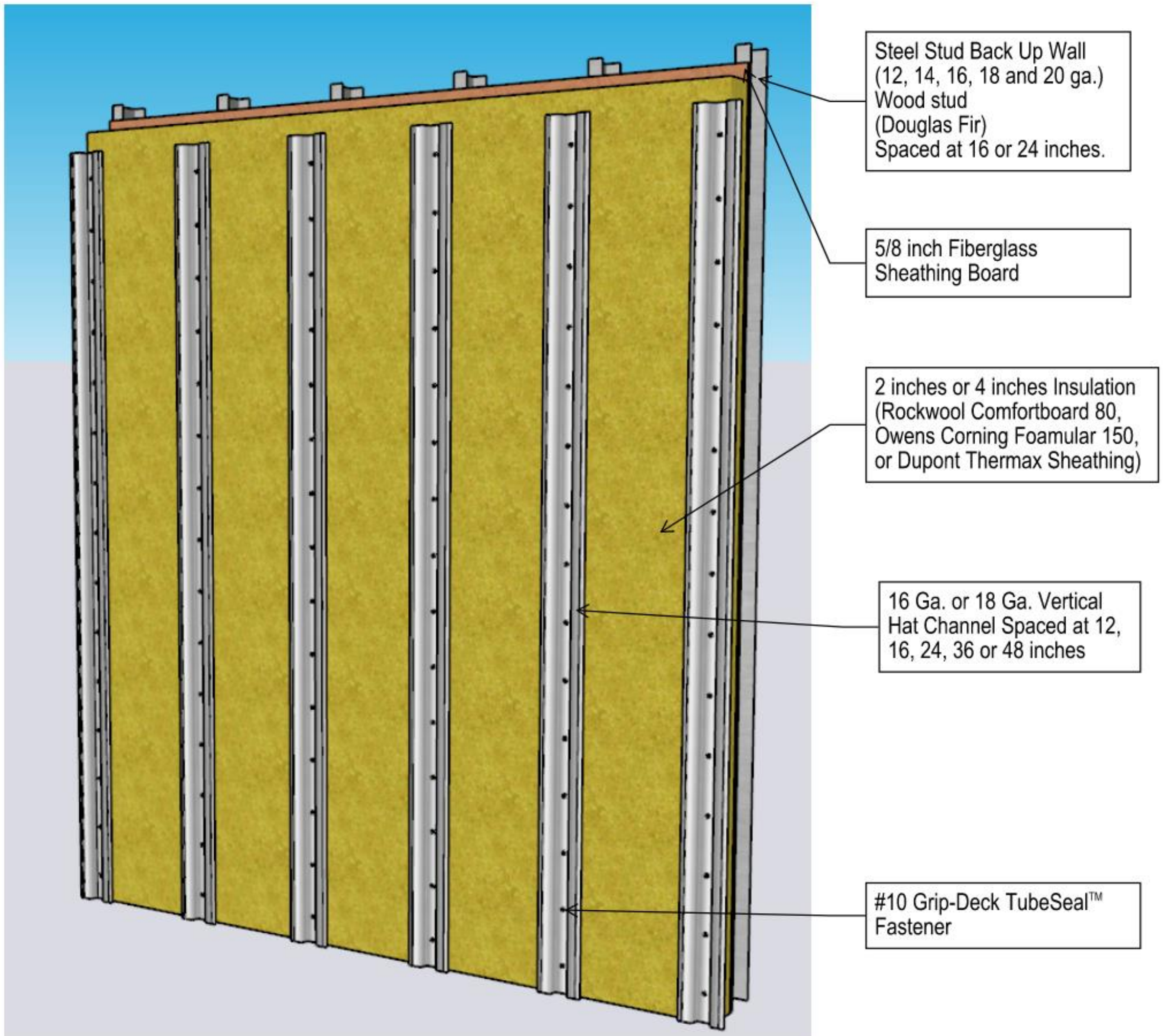


Figure 1. Horizontally aligned hat channel system on steel stud wall.



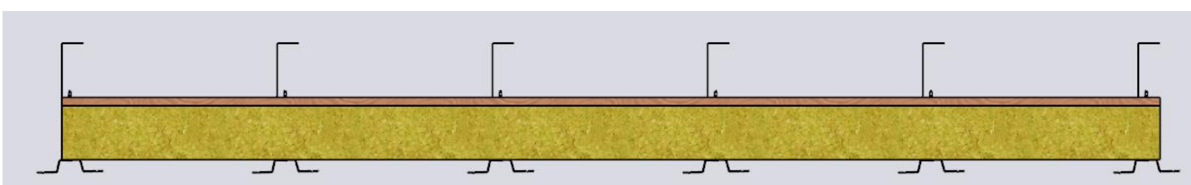


Figure 2: Vertically aligned hat channel system on steel stud wall

The figures above show the configuration and components of the two systems.

1.4 Component Descriptions

From interior to exterior, the wall system is composed of a wood or steel stud structural wall; a sheathing element in the form of glass mat reinforced gypsum panel or plywood, mineral wool insulation, and then a cladding system.

1.4.1 Hat Channel

This system uses an 18- or 16-gauge hat channel with pre-punched holes at regular spacings. The hat channel is shown in Figure 3 below.

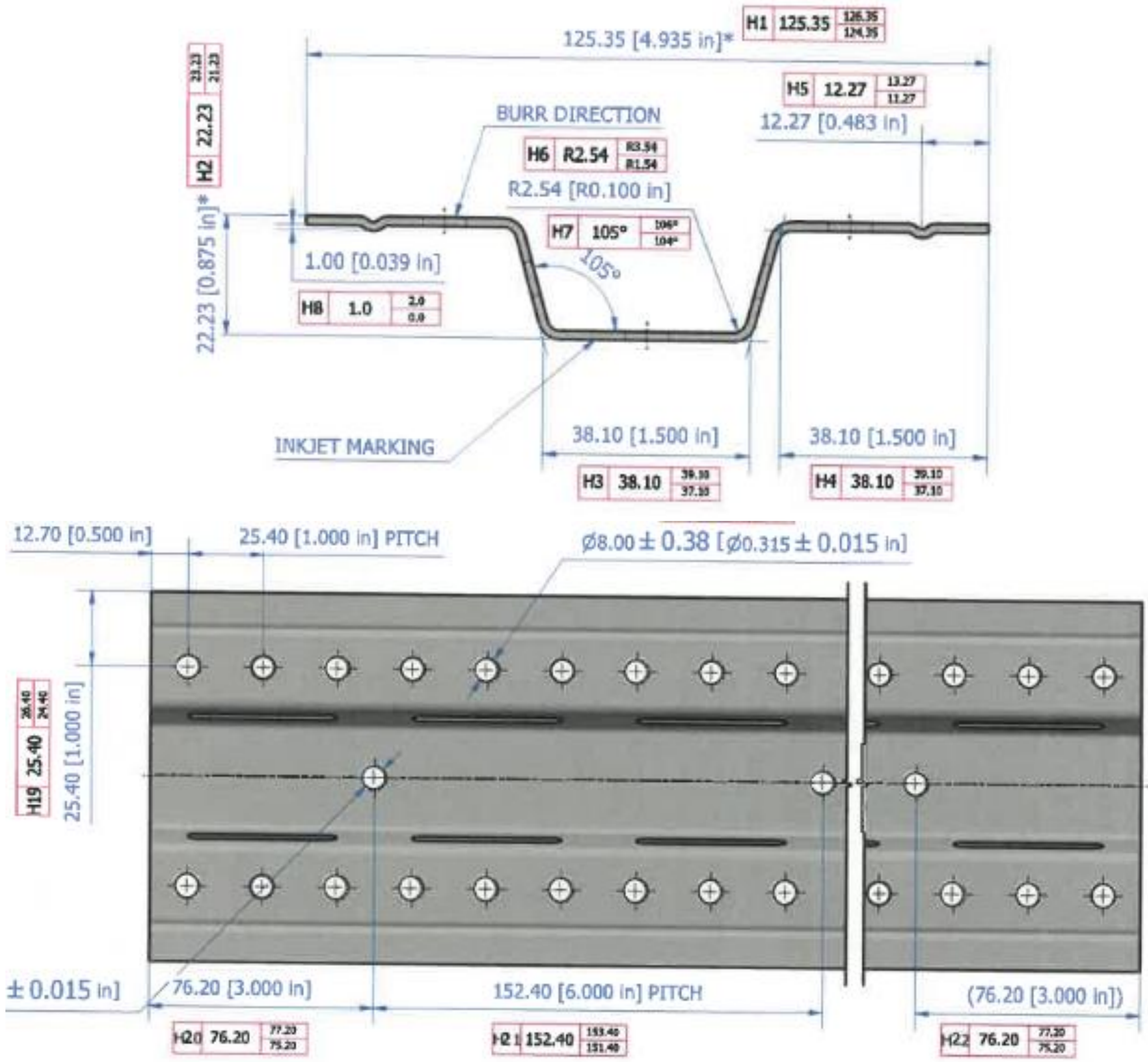


Figure 3. Dimensions of hat channel

The holes on the flanges are at 1 inch spacing, which allows for some variety in the screw spacings on horizontal systems. The holes in the web are at 6 inch spacing, which limits the screw spacings on vertical systems to multiples of 6 inches.

1.4.2 Fasteners

The hat channel is fastened through the insulation into sheathing and structural studs using the TruFast Walls Grip-Deck TubeSeal™ fastener system, composed of #10-16 Philips bugle head screws with a tek drilling tip or a pointed tip, sheathed in a polyurethane tube. This system minimizes thermal bridging by eliminating the need for clips and minimizing the size of the penetration, and also helps to seal the penetrations against air leakage and water penetration.

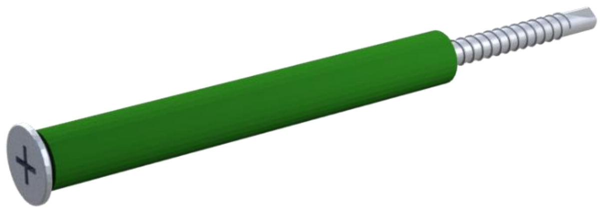


Figure 4. Grip-Deck TubeSeal Fastener by TruFast Walls

The #10 Grip-Deck TubeSeal fastener is assumed to have an ultimate strength and yield strength that exceeds its capacity for pull-over in 18-gauge steel and pull-out strength from wood or steel studs. While other requirements for this type of screw are specified in ASTM C1513, we have assumed a stainless-steel fastener with a grade of SS 2 CW2 as described in ASTM F593-17. Otherwise, its capacity depends on the substrate materials into which it engages. These capacities are as follows:

Table 1. Calculated Capacity of #10 screws in various substrates and failure modes

Capacity	Tension Capacity	Shear Capacity
Screw Capacity	405 lbf	230 lbf
Pull-over at head, 20-gauge steel	235 lbf	230 lbf
Pull-out at tip, 20 gauge 33 ksi steel	80 lbf	160 lbf
Pull-out at tip, 18 gauge 33 ksi steel	100 lbf	230 lbf
Pull-out at tip, 16 gauge 50 ksi steel	190 lbf	230 lbf
Pull-out at tip, 14 gauge 50 ksi steel	235 lbf	230 lbf
Pull-out at tip, 12 gauge 50 ksi steel	340 lbf	230 lbf
Pull-out at tip, Douglas Fir Stud	405 lbf	230 lbf

A sample calculation for the capacities as shown above was calculated to AISI S100 and is available in Appendix B. The capacity of the screwed c3onnection is limited, in all cases, to the pull-out at the tip of the fastener in each substrate. The wind load that this screw can handle is the tension capacity divided by the screw spacing in each direction, the number of fasteners at the connection point, and a prescribed safety factor. Therefore, for lighter studs, we expect to find lower wind load resistance compared to the same spacing with a thicker stud.

For wood connections, a wood screw is used, as shown in Figure 5 below, while for connections into steel stud, a screw with a drilling tip is used, per Figure 6 below:

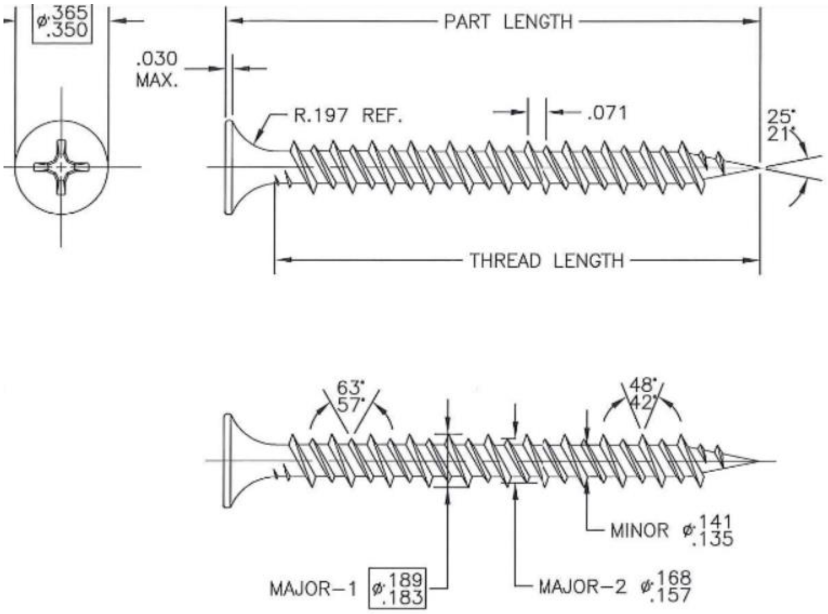


Figure 5. #10 wood screw to be used with TubeSeal^{TM} in wood stud connections.

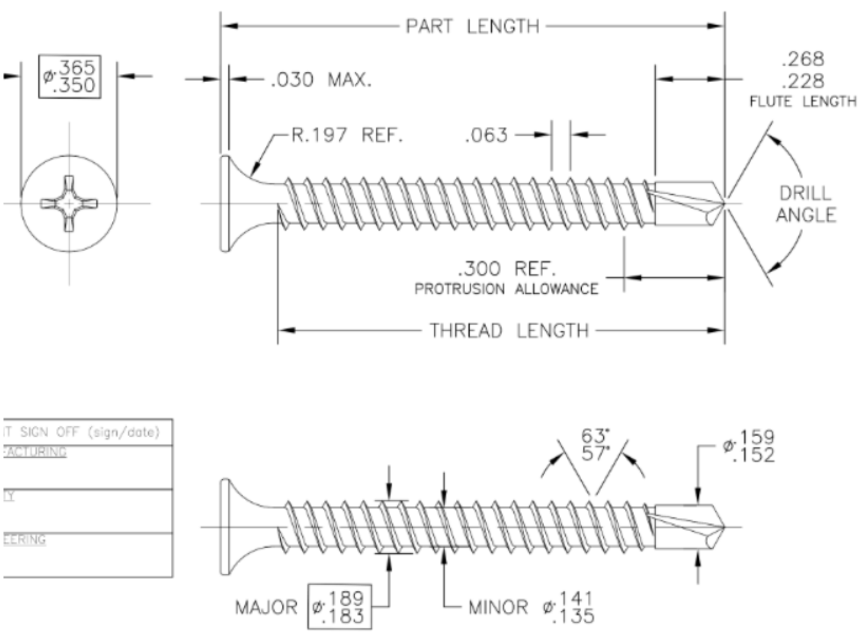


Figure 6. Bugle headed #10 drilling screw to be used with TubeSeal^{TM} in steel stud connections.

As shown in the figures above, the dimensions of the fasteners vary slightly due to the substrates to which they are intended to enter; however, the diameter is consistent, and this combined with length are the main geometric factors that determine the system's vertical deflection response to applied cladding loads.

1.4.3 Insulation Types

Our analysis uses the compressive resistance of Rockwool Comfortboard 80 mineral wool insulation, which has an elastic compressive modulus of 29 psi. Different insulation products and types have a widely varying, nonlinear elastic modulus, which is generally not publicly disclosed. The compressive elastic modulus is a property of the material that represents how much force it takes to move the material under compression. It relates force to deflection, and in our case, it determines the vertical displacement of screws by resisting the rotation of the screw head that would cause inward movement.

Insulation with a higher compressive elastic modulus provides increased resistance to vertical deflection of screws, and insulation with a lower elastic modulus allows more vertical deflection. Higher density insulation tends to have a higher elastic modulus. In configurations where dead loads are high, insulation thickness is high, or wind loads are low, the design will tend to be governed by vertical deflection of screws, and switching to a denser type may allow a greater spacing of screws.

Our research into additional insulation types gave inconclusive results for the elastic compressive modulus of insulation. It was discovered that layers of insulation are more flexible than a solid piece of the same thickness. Depending on the density of the insulation, the compressive elastic modulus can differ by one or two orders of magnitude. Most dense insulations should have a compressive elastic modulus of at least 29 psi. Conservatively, any insulation that exceeds this elastic modulus requirement can be used with the structural span tables presented in this report.

1.4.4 Sheathing Types

This wall system is intended to be used with sheathed stud wall systems. For combustible construction, it is normal to use plywood or oriented strand board and wood studs, while for non-combustible construction, it is normal to use glass mat reinforced gypsum boards with steel studs. The structural span tables were produced using 5/8” plywood with Douglas fir studs and 5/8” sheathing board with steel studs to match typical construction. Properties for these materials are shown in Table 2 below.

Table 2. Properties for sheathing boards.

Property	D. Fir Plywood	Glass Mat Gypsum Sheathing Panels
Proof Load*	None	100 lbf.
Elastic Modulus	1570 ksi	493 ksi
Compressive Strength	1200 psi	36 psi

** For glass mat gypsum sheathing panels, ASTM C1177-17 requires that specimens of these products be tested to ASTM C473-19 with a proof load that varies with the thickness of the specimen. We used 5/8” as the thickness for the proof load. This is used to evaluate the bending strength of sheathing.*

In general, it is not necessary for the screw spacing of the sheathing to match that of the cladding, and the spacing of the sheathing screws can be adjusted (within the limits of the stud layout) to meet wind load requirements. Therefore, in analyzing the wind load resistance of the cladding attachment system, the sheathing typically does not play a significant role. Instead, the wind load resistance is usually governed by the fasteners.

1.5 Assumptions & Limitations

Our analysis is subject to the following assumptions and limitations:

- Thermal expansion and contraction effects have been omitted. We expect that the designer will consider this when designing the wall system and include breaks at every floor according to normal practice.

- Dead load is assumed to be distributed evenly to each screw. While installation practices may vary the straightness of screws, the hat channel and panel system will tie them all together and force them to work as a system.

- The analysis precludes the capacity of the base wall structure.

2. STRUCTURAL ANALYSIS

We performed a structural analysis using IBC 2021 and ASCE 7-22 based on the variables in our scope. The analysis was conducted using an idealized mathematical model of the system. By changing the parameters, we were able to loop through 1176 combinations of parameters and produce a comprehensive table.

2.1 Design Methodology

A structural analysis for the whole attachment system has been conducted and a structural load span chart has been generated to compile our structural analysis result and various product structural requirements in Appendix A. The following outlines the approach:

- The structural analysis was performed based on detailed drawings provided by ClarkDietrich.

- The analysis was undertaken via static calculations in MathCAD and Excel to determine the maximum specified wind load. The static calculations were based on approaches outlined in the relevant codes and standards as well as standard engineering practice. Testing for the fasteners or components was not undertaken.

- Wind loads indicated in result tables were generated as nominal wind load (0.6x ultimate wind loads) to be compared to nominal loads calculated for the project according to local regulations. Allowable Stress Design (ASD) load combinations (1.0D + 0.6W) were used within the analysis.

- The structural analysis assumes that the horizontal and vertical distances between fasteners are equal to the area of cladding contributing to the loading of one screw for the vertically aligned hat channel system and two screws for horizontally aligned hat channel system.

- The structural analysis assumes that the exterior insulation is self-supported. The use of exterior insulation that is not self-supported may result in alternate results from those provided herein.

- The long screws were analyzed as a cantilevered beam with flexible rotation restraint from substrates and zero rotation restraint from the hat channel. The cantilevered length was measured from the outside surface of the hat channel to the outside surface of the substrate.

- The contribution of vertical load resistance from the insulation onto the screw has been neglected along with any frictional resistance of the hat channel to the face of the insulation.

2.2 Codes and References

The structural analysis was performed using allowable stress design (ASD) with appropriate safety factors per:

- International Building Code (IBC 2021)
- Minimum Design Loads and Associated Criteria for Buildings and Other Structures (ASCE 7-22)
- North American Specification for the Design of Cold-Formed Steel Structural Members (CSA S136-16 / AISI S100-16 w/ S2-20 supplement)
- National Design Specification for Wood Construction (NDS 2015)

In addition to the above, the following technical publications were referenced in the analysis.

- Fastening Systems for Continuous Insulation – NYSERDA
- American Wood Council Technical Report 12 (awc-tr12-1510)
- Short Term Deflection Testing Report provided by RDH (with Appendix 2019.08.22 JS RPT)

2.3 Structural Design Parameters

The following design parameters applied:

Parameter	Value
#10-16 Screw: Diameter	0.190 in. (4.826 mm)
#10-16 Screw: Threads per inch	16
#10-16 Screw: Area in shear	0.014 in^2 (9.23 mm^2)
#10-16 Screw: Root area	0.014 in^2 (9.23 mm^2)
#10-16 Screw: Stripping area of internal threads	0.365 in^2 (236 mm^2)
#10-16 Screw: Fastener grade per ASTM F593-17	SS 2 CW2
#10-16 Screw: Ultimate strength, F_u	F_u = 85 ksi (586 MPa)
#10-16 Screw: Yield strength, F_y	F_y = 45 ksi (310 MPa)
#10-16 Screw depth of penetration into wood stud	1.5 in
Young's modulus of steel, for all steel, E	29,000 ksi (200 GPa)
#10-16 Screw: Moment of Inertia	$6.40x10^{-5}$ in^4 (26.6 mm^4)
Young's modulus for insulation	0.029 ksi (0.200 MPa)
Young's modulus for douglas fir sheathing	1566 ksi (10.8 GPa)
Young's modulus for 0.625-inch glass mat gypsum sheathing panels	493 ksi (3.4 GPa)

Steel Studs	12, 14, 16 ga., F_y = 50 ksi 18, 20 ga., F_y = 33 ksi
Wood Studs	2" x 4" Douglas Fir.
Sheathing Board	5/8" thick
Hat channel	18 ga., 50 ksi; 16 ga, 50 ksi
Hat channel deflection criteria	L/240, L/360, and L/600
Range of insulation thicknesses (in)	2, 4
Number of fasteners in vertical system at each point	1
Number of fasteners in horizontal system at each point	2
Contact width of insulation and hat in vertical system	1.5 in
Contact width of insulation and hat in horizontal system	3 in

2.4 Structural Model Description

The model is described below:

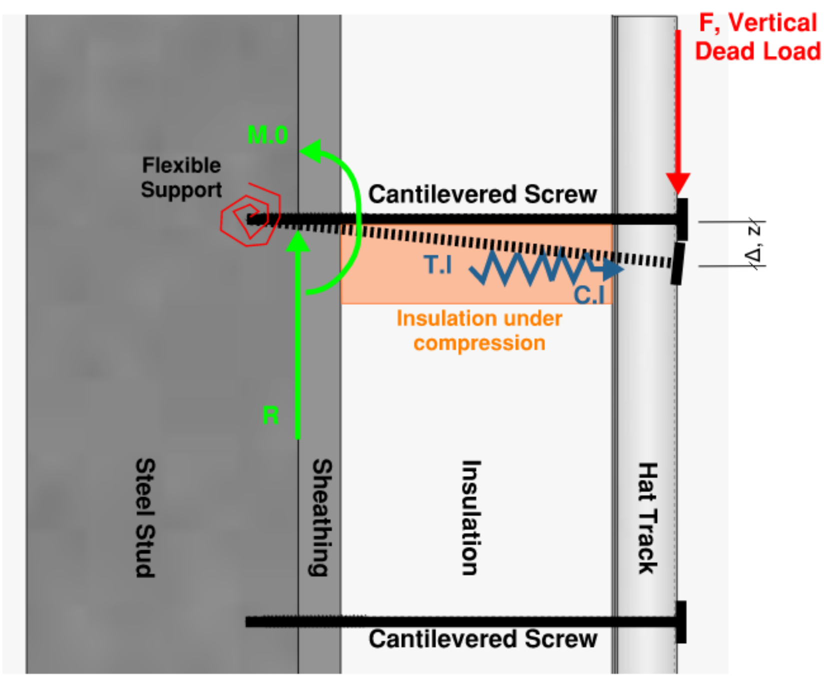


Figure 7. Free-body diagram of mathematical model.

In the model shown above, we treated the screw as a cantilever in a flexible support. Because most of the action takes place near the screw and the steel section is much more rigid than the insulation and screw, we assumed that the hat channel is an ideal rigid body. As the screw deflects due to dead load, it rotates along an assumed circular arc inward, bringing the hat channel with it and causing compression in the insulation. Compression resists the rotation, which results in a balance of forces between the bending of stud material at the screw tip, bending of the screw, tension in the screw, and the compression of the insulation. The result of this equilibrium of forces is an amount of vertical deflection that we can estimate with our model.

Friction and insulation are assumed to contribute zero resistance to the vertical movement of the screw head in this model.

We also estimated several other useful parameters from this model, including:

- The tension in the screw, which we add to the tension caused by wind forces when calculating the wind load resistance of a screw pattern.
- The amount of rotation at the screw tip due to the material and sheathing.
- The shear in each screw and the shear resistance of the connection.

The results of this analysis are tabulated in Appendix A. This estimate was based on an analysis which used several simplifying assumptions, and we expect that testing will produce more accurate results.

3. DISCUSSION

This section discusses the tables shown in Appendix A. The appendix includes three tables:

- Table A1 shows the vertical deflection amounts and wind load resistances for vertically aligned hat channel system configurations.
- Table A2 shows the same, but for horizontally aligned hat channel system configurations.
- Table A3 shows the shear utilization of fasteners for the configurations.

3.1 Vertical Deflection

In Tables A1 and A2, orange-highlighted deflection amounts represent deflections greater than 0.125 inches, which is an industry-standard guideline target for wall deflection. Cells highlighted red indicate deflection greater than 0.250 inches. Ultimately, acceptability of deflection is up to the engineer of record.

Excessive deflection may cause gaps to open, which can allow ingress of water, intrusion of pests, compromised aesthetics, and possible durability issues.

We found that the stud type had a negligible effect on the vertical deflection. This is because most of the deflection comes from the bending of the screw itself due to its narrow diameter and length. Because of this, the deflection increases significantly when the insulation thickness increases from 2 inches to 4 inches. A wider diameter of fastener would solve vertical deflection issues at greater insulation thicknesses.

If the cladding weight is on the heavier end, we recommend using a closer screw spacing. Increasing the fastener diameter will significantly reduce the deflection, but further analysis of this solution is outside the scope of this report.

3.2 Wind Load Resistance

The system wind load resistance is represented in pounds per square foot and is the least of the fastener resistance due to pull-out from substrate, tension in fastener, and pull-over of the fastener head. Cells are highlighted red when the wind load resistance is estimated to be 20 psf or less, which is a typical minimum wind load for low buildings. Cells are highlighted yellow when the wind load is 50 psf or less to indicate that wind load may govern. Wind loads of 20 to 50 psf are the most commonly seen on buildings. These wind loads are presented using 15 psf dead loads.

3.3 Shear Utilization of Fasteners

Shear utilization of fasteners in the wall system is governed by the seismic load case. Seismic forces in nonstructural components depend on where the building is located, the soil conditions of the building, the framing type, the height of the component in the building and the building, and various other building-specific factors that widely vary across project types and site locations. While it would be impossible to accommodate all combinations of these factors in our analysis, we have assumed the worst case. In parts of North America with high seismic risk, we estimate that the horizontal seismic force applied to any fasteners in the system will be approximately 1.4 to 1.6 times the dead load of the cladding. In regions with low seismicity, it could be as low as 0.3 times the dead load of cladding. Because the shear capacity is very good, we only produced a table for the worst-case scenario. A sample calculation for seismic force can be found in Appendix B.

We found that the shear capacity of the fasteners was generally very good. Shear did not govern the spacing of fasteners, except when wall studs are 20 gauge. In most configurations, the shear utilization was below 50%. However, in configurations where the horizontal and vertical spacings are large and the dead load is high (15 psf), utilization is as high as 82% in 18-gauge wall studs (or better) and 137% in 20-gauge steel stud.

3.4 Unlikely Failure Mode

We excluded from our analysi

- Failure of the hat char fasteners precludes thi

- We did not analyze seismic effects on this wall system. While the shear capacity of the fasteners is much higher than required, seismic forces vary considerably across the continent. We expect that this system will perform well under typical seismic conditions, based on its high shear capacity.
- Thermal expansion and contraction effects have designer will consider this when designing the wall s floor according to normal practice.
- Dead load is assumed to be distributed evenly practices may vary the straightness of screws, the

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- Failure of the hat channel due to bending or deflection in bending is an unlikely failure mode due to the short spacing of fasteners. We have excluded this failure mode from our design.
- Failure of the insulation or sheathing due to compression by wind effects. Because the compression strength is so high, wind forces are short duration, and some of the force in this direction will be carried by the fasteners, failure of the insulation is not a likely failure mode.

3.5 Possible Solutions to Increase Capacity

For configurations where the insulation is thick, we recommend first considering increasing the fastener diameter. This will both increase the stiffness of the screw to relieve dead load deflection and increase the wind load resistance of the screwed connection.

For configurations where the screw spacing is sparse, dead load deflection and wind load resistance issues can be solved by decreasing the screw spacing.

Changing the stud material, sheathing material, or insulation type can solve some issues, but generally include side-effects.

By using a stiffer insulation, more of the load will transfer to the wall through compression in the insulation. This will relieve dead load deflection but increase tension in the screw at the same time, ultimately reducing wind load resistance and dead load deflection. Using a stiffer insulation material can be considered when the wind load resistance is high and the dead load deflection is excessive. Conversely, using a more flexible insulation material can be considered when the wind load resistance is low and the dead load deflection is within acceptable parameters.

Using a thicker or stronger stud material can be beneficial when the wind load resistance is low. However, this will not solve dead load deflection issues.

Using a stronger sheathing material can solve the issue of low wind load resistance, but it does not help with dead load deflection. This is because the wind load resistance is limited by the resistance of the stud material. Table 3 below shows the wind load resistance of the sheathing products used in our analysis.

Table 3. Wind load resistance (ASD) of glass mat reinforced gypsum panel products per ASTM C1177-17, psf.

Wind load resistance of glass mat reinforced gypsum panel products to ASTM C1177-17, psf				
Span between supports	Sheathing thickness, in.			
	0.25	0.438	0.5	0.625
12 in	40 psf	70	80	100
16	30	52	60	75
24	20	35	40	50
36	13	23	27	33
48	10	17	20	25

Table 3 shows the wind load resistance of sheathing that limits the strength of the system. In our calculations, we used 0.625 inch thick sheathing with stud spacings of 16, 24, 36, or 48 inches. Where the screw spacing of the hat channel system results in a wind load resistance lower than the design load, additional fasteners will be required from the sheathing into the stud.

<u>Minimum bending stress of capacity of fiberglass sheathing, ASTM C1177</u>

ASTM C1177 requires that the flexural strength of a glass mat reinforced gypsum panel product be sufficient when tested to ASTM C473 with loading of P with respect to sheets t in thickness. The testing apparatus uses a point load at the midspan of a 14 in long sheet and applies the load over 12 in, where:

$$P := \begin{bmatrix} 40 \\ 70 \\ 80 \\ 100 \end{bmatrix} lbf \,,\; t := \begin{bmatrix} 0.25 \\ 0.438 \\ 0.5 \\ 0.625 \end{bmatrix} in$$

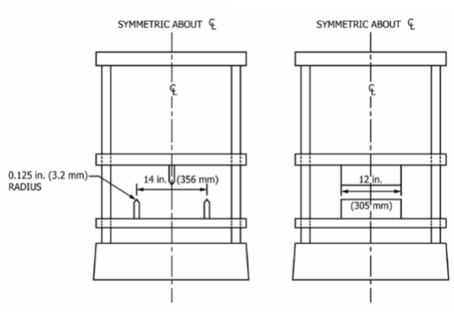

FIG. 4 Testing Machine

From this test method, an equivalent wind load can be derived for any sheathing relating basic loading formulas for different loadings, given:

Point load $P := 80\ lbf = 355.858\ N$

Dimensions of sample: $b := 12\ in$, $l := 14\ in$

Maximum bending stress is $M_{max} = \frac{P \cdot l}{4} = \frac{q \cdot b \cdot l^2}{8}$ --> $q := 2\ \frac{P}{b \cdot l} = 137.143\ psf$

If the sample actually fails in shear, then $V_{max} = \frac{P}{2} = \frac{q \cdot b \cdot l}{2}$ --> $q := \frac{P}{b \cdot l} = 68.571\ psf$

Depending on the failure mode, q ranges from 1 to 2 times $\frac{P}{b \cdot l}$. We assume the lowest load, which builds in a safety factor of 1 to 2. $M_{max} := \frac{P \cdot l}{4} = 280\ lbf \cdot in$

Expanding this for different thicknesses:

$$t := \begin{bmatrix} 0.25 \\ 0.438 \\ 0.5 \\ 0.625 \end{bmatrix} in;\; P := \begin{bmatrix} 40 \\ 70 \\ 80 \\ 100 \end{bmatrix} lbf \text{ --> } M_{max} := \frac{\overrightarrow{P \cdot l}}{4} = \begin{bmatrix} 140 \\ 245 \\ 280 \\ 350 \end{bmatrix} lbf \cdot in$$

Minimum tensile yield strength for $t = \begin{bmatrix} 0.25 \\ 0.438 \\ 0.5 \\ 0.625 \end{bmatrix} in$: $\sigma := \overrightarrow{\frac{\frac{P \cdot l}{4} \cdot (0.5\ t)}{\left(\frac{b \cdot t^3}{12}\right)}} = \begin{bmatrix} 1120 \\ 638.54 \\ 560 \\ 448 \end{bmatrix} psi$

For different spans with $b = 12\ in$, $l := \begin{bmatrix} 12 \\ 16 \\ 24 \\ 36 \\ 48 \end{bmatrix} in$, $q := \frac{1}{b \cdot l} \cdot P^{T} = \begin{bmatrix} 40 & 70 & 80 & 100 \\ 30 & 52.5 & 60 & 75 \\ 20 & 35 & 40 & 50 \\ 13.333 & 23.333 & 26.667 & 33.333 \\ 10 & 17.5 & 20 & 25 \end{bmatrix} psf$

4. CONCLUSION

We analyzed over 1000 combinations of input parameters and produced tables showing deflection, wind load resistance, and shear utilization. For this system, the vertical deflection is heavily dependent upon the screw diameter and length, and rotation of the screw tip in the substrate appears to be negligible.

Most horizontal and vertical systems are capable of holding up to 9 psf of cladding dead load with horizontal stud spacings up to 24 inches while maintaining less than 1/8" of vertical deflection and wind load resistances greater than 70 psf (ASD). Within certain limitations, the screw spacings can go as far apart as 48 inches horizontally and vertically, and dead load can be up to 15 psf.

We recommend that a representative sample of these systems be tested in vertical deflection as outlined in our report dated March 17, 2023 to confirm and fine tune our model so that we may extrapolate the fine-tuning to the entire design table.

4.1 Next Steps

The next steps in this project are:

1. Morison Hershfield and ClarkDietrich/TruFast Walls to meet and discuss this report.

2. ClarkDietrich/TruFast Walls to perform recommended structural testing, including short-term load test, long-term load test, and a seismic test.

3. Morrison Hershfield to update charts according to structural test results.

This report was prepared by Kevin Preston, P.Eng. and reviewed by Brett Pattrick, P.Eng. for ClarkDietrich and Altenloh Brinck and Co. U.S. (TruFast Walls).

Sincerely,

Kevin Preston, P.Eng.
Façade Structural Specialist

Brett Pattrick, P.Eng.
Principal, Façade Specialist & Secondary Structures Team Lead

APPENDIX A:
Result Tables

Tables A1 and A2 below show the vertical deflection amounts for different combinations of insulation thickness, cladding dead load, and spacing of fasteners. Identical vertical deflection results were produced for each stud type and have been combined. Identical results were also produced for both the 18-ga and 16-ga hat channels. On the right side of the table, wind loads are presented in units of pounds per square foot for each stud type. These are based on a load combination with a 15 psf dead load.

Table A1. Vertical deflection (in.) and wind load resistance for vertically-aligned hat track system

Spacing		2 inch insulation									4 inch insulation									Wind load resistance for various stud types (psf, ASD)					
		Dead load of cladding exterior of the hat track system																							
Horizontal	Vertical	3 psf	4	5	6	7	8	9	10	15	3 psf	4	5	6	7	8	9	10	15	Wood	12 ga.	14 ga.	16 ga.	18 ga.	20 ga.
16 in.	6 in.	0 in	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.03	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.13	607	506	355	282	155	107
	12	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.04	0.05	0.07	0.09	0.10	0.12	0.14	0.16	0.17	0.26	303	252	177	140	77	53
	18	0.01	0.01	0.02	0.02	0.03	0.03	0.03	0.04	0.05	0.08	0.10	0.13	0.16	0.18	0.21	0.23	0.26	0.38	201	167	117	93	50	34
	24	0.01	0.02	0.02	0.03	0.03	0.04	0.04	0.05	0.07	0.10	0.14	0.17	0.21	0.24	0.27	0.31	0.34	0.50	150	125	87	68	37	25
24	6	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.03	0.04	0.05	0.07	0.08	0.09	0.10	0.12	0.13	0.20	404	337	236	187	102	70
	12	0.01	0.01	0.02	0.02	0.03	0.03	0.03	0.04	0.05	0.08	0.10	0.13	0.16	0.18	0.21	0.23	0.26	0.39	200	167	116	92	49	33
	18	0.02	0.02	0.03	0.03	0.04	0.04	0.05	0.05	0.08	0.12	0.16	0.19	0.23	0.27	0.31	0.35	0.38	0.56	132	109	75	59	31	20
	24	0.02	0.03	0.04	0.04	0.05	0.06	0.07	0.07	0.11	0.16	0.21	0.26	0.31	0.36	0.40	0.45	0.50	0.71	97	80	55	43	21	13
32	6	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.04	0.05	0.07	0.09	0.10	0.12	0.14	0.16	0.17	0.26	302	251	176	139	76	52
	12	0.01	0.02	0.02	0.03	0.03	0.04	0.04	0.05	0.07	0.10	0.14	0.17	0.21	0.24	0.28	0.31	0.34	0.51	148	123	85	66	35	23
	18	0.02	0.03	0.04	0.04	0.05	0.06	0.07	0.07	0.11	0.16	0.21	0.26	0.31	0.36	0.41	0.45	0.50	0.72	96	79	53	41	20	12
	24	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.15	0.21	0.27	0.34	0.40	0.47	0.53	0.58	0.64	0.89	69	56	37	28	12	6
48	6	0.01	0.01	0.02	0.02	0.03	0.03	0.03	0.04	0.05	0.08	0.10	0.13	0.16	0.18	0.21	0.23	0.26	0.39	198	164	114	89	47	31
	12	0.02	0.03	0.04	0.04	0.05	0.06	0.07	0.07	0.11	0.16	0.21	0.26	0.31	0.36	0.41	0.46	0.51	0.74	93	76	51	39	18	10
	18	0.03	0.04	0.05	0.07	0.08	0.09	0.10	0.11	0.16	0.23	0.31	0.38	0.45	0.53	0.59	0.66	0.72	1.01	57	46	29	21	7	2
	24	0.04	0.06	0.07	0.09	0.10	0.12	0.13	0.15	0.22	0.31	0.40	0.50	0.58	0.67	0.75	0.82	0.89	1.19	39	30	18	12	1	**0**

Notes.
1. Industry standards normally limit deflection to 0.125 inches. Configurations with deflection amounts that exceed this limit are highlighted.
2. Where deflection exceeds 0.25 inches, deflection is highlighted red to indicate increasing severity.
3. Excessive deflection can lead to unwanted performance degradation, including ingress of rain water, increased air leakage, intrusion of pests, poor aesthetics, and in some cases structural failure.
4. Wind load resistances less than 50 psf are highlighted to show that wind load should be paid close attention to because they are commonly seen on buildings. Wind load resistances less than 20 psf are highlighted red to show very poor wind load resistance on most buildings.
5. To improve the performance of a system with zero wind load resistance, additional fasteners, thicker steel studs, or other solutions will be required.
6. Wind loads indicated in result tables were generated as nominal wind load (0.6x ultimate wind loads) to be compared to nominal loads calculated for the project according to local regulations. Allowable Stress Design (ASD) load combinations (1.0D + 0.6W) were used within the analysis.
7. The structural analysis assumes that the horizontal and vertical distances between fasteners are equal to the area of cladding contributing to the loading of one screw for the vertically aligned hat channel system and two screws for horizontally aligned hat channel system.
8. The structural analysis assumes that the exterior insulation is self-supported. The use of exterior insulation that is not self-supported may result in alternate results from those provided herein.
9. The long screws were analyzed as a cantilevered beam with flexible rotation restraint from substrates and zero rotation restraint from the hat channel. The cantilevered length was measured from the outside surface of the hat channel to the outside surface of the substrate.
10. The contribution of vertical load resistance from the insulation onto the screw has been neglected along with any frictional resistance of the hat channel to the face of the insulation.

Initial Angle due to Bending of Substrate at Fastener Tip

Length of embedment: $l_{emb} := t_{sh} + t_2 = 0.533\ in$

The initial angle of tilt for the screw is being derived as a best guess, because guessing that it's zero is not a best guess. In this case, I imagine that there is a stress block in the sheathing and a stress block in the stud, and each material receives equal and opposite forces. The bending moment being resisted at the screw tip is $M_0 = R \cdot \left(\frac{t_{sh}+t_2}{2}\right)$, where R is that equal and opposite force.

The stress block for the stud and sheathing are each imagined to be a rectangular prism as wide as the screw, as tall as the screw diameter, and as long as the thickness of material. By Hooke's law, each block will compress by a force $R = \Delta z \frac{E \cdot A}{l}$; in this case, $A = D \cdot t$ and $l = D$ because of my assumptions about the shape of the stress blocks. With a bit of trigonometry, a triangle can be formed with a base of length $\frac{t_{sh}+t_2}{2}$ and height $\Delta z_{sheathing} + \Delta z_{stud}$. The angle on this triangle is our initial angle θ that we're looking for, and $tan(\theta) = \frac{\Delta z_{sheathing} + \Delta z_{stud}}{\frac{t_{sh}+t_2}{2}}$;, but, since $R = \Delta z \frac{E \cdot (D \cdot t)}{D}$ and $M_0 = R \cdot \left(\frac{t_{sh}+t_2}{2}\right)$, substitution gets rid of R and Δz.

$$tan(\theta) = \frac{\left(R \leftarrow \frac{M_0}{\left(\frac{t_{sh}+t_2}{2}\right)}\right)(E \cdot t)_{sheathing} + \left(R \leftarrow \frac{M_0}{\left(\frac{t_{sh}+t_2}{2}\right)}\right)(E \cdot t)_{stud}}{\frac{t_{sh}+t_2}{2}}$$

Solving for $\theta = atan\left(4 \cdot M_0 \cdot \frac{\left(\frac{1}{E_{m2} \cdot t_{sh}} + \frac{1}{E_2 \cdot t_2}\right)}{(t_{sh}+t_2)^2}\right)$

$\theta_0(M_0) := atan\left(4 \cdot M_0 \cdot \frac{\left(\frac{1}{E_{m2} \cdot t_{sh}} + \frac{1}{E_2 \cdot t_2}\right)}{(t_{sh}+t_2)^2}\right)$, assuming that the stress block is a rectangular prism D high, D wide, and t_{sh} long at the sheathing and t_2 long at the stud.

Solving a System of Equations to Model Behavior

In this model, cladding is attached to sheathing and studs using a fastener through insulation.

The cladding dead load acts at the screw head, and the hat track itself is modeled as rigid. <u>The hat track is vertical.</u> (A horizontal model will be built based on this.) The hat track pushes on the insulation in an area $5\ in \cdot s_z = 80\ in^2$ in size and evenly distributes the force across that area.

The screw is axially rigid, not deforming at all due to tension or compression, but it is capable of bending due to vertically-applied loads. As load is transferred to the insulation, bending stress is relieved from the fastener.

The insulation takes compression forces only, and does not shear due to vertical fastener deflection.

Equation 1: Equilibrium

$M_0 = F_z \cdot l_c - C_I \cdot \delta_z$

The sum of bending moments in a static body equals zero at the screw point.

$F_z = u \cdot \frac{s_x \cdot s_z}{n_f}$

Where:

- M_0 is the bending moment of the screw at its tip
- F_z is the vertical force at the head of the screw
- l_c is the length of the screw outboard of the face of sheathing
- C_I is the compression in the insulation
- δ_z is the vertical deflection of the screw head
- s_x and s_z are the screw spacings in the x and z directions respectively
- n_f is the number of screws per connection point at those spacings

Equation 2: Triangle geometry

converts vertical deflection to horizontal deflection assuming rotation at screw point.

$\delta_x = \delta_z \cdot tan\left(asin\left(\frac{\delta_z}{l_c}\right)\right)$

Since the screw is axially rigid, when it bends down it's assumed to approximately rotate along a circular path. As the screw head moves vertically down, it also moves inwards. Using trigonometry, δ_z can be transformed into δ_x.

Equation 3: Deflection function for screw

$\delta_z = \frac{M_0 \cdot l_c^2}{3 \cdot E \cdot I_x} + \theta_0(M_0) \cdot l_c$

The screw deflects in bending (first term), and by rotation at the screw tip (second term), which is a function of the bending moment applied at that connection. E and I_x compose the stiffness of the screw.

Equation 4: Deflection function for insulation

$C_I = \frac{\delta_x \cdot E_I \cdot A_I}{t_{ins}}$

The insulation compresses by Hooke's Law.

Solve Block

These equations are put into a solve block and solutions are found.

Guess values

$$\begin{bmatrix}\delta_z \\ \delta_x \\ C_I \\ M_0\end{bmatrix} := \begin{bmatrix}2\ mm \\ 2\ mm \\ 1\ lbf \\ 10\ lbf \cdot in\end{bmatrix}$$

Equations

$$\delta_z = \frac{M_0 \cdot l_c^2}{3 \cdot E \cdot I_x} + \theta_0(M_0) \cdot l_c$$

$$\delta_x = \delta_z \cdot tan\left(asin\left(\frac{\delta_z}{l_c}\right)\right)$$

$$C_I = \frac{\delta_x \cdot E_I \cdot A_I}{t_{ins}}$$

$$M_0 = F_z \cdot l_c - C_I \cdot \delta_z$$

$$\begin{bmatrix}\delta_z \\ \delta_x \\ C_I \\ M_0\end{bmatrix} := find(\delta_z, \delta_x, C_I, M_0)$$

$\delta_z = 2.741\ mm$

$\delta_x = 0.073\ mm$

$C_I = 1\ lbf$

$M_0 = 33.267\ lbf \cdot in$

Bending of fastener itself:

$\frac{M_0 \cdot l_c^2}{3 \cdot E \cdot I_x} = 2.494\ mm$

Table A2. Vertical deflection (in.) and wind load resistance for horizontally-aligned hat track system

Spacing		2 inch insulation									4 inch insulation									Wind load resistance for various stud types (psf, ASD)					
		Dead load of cladding exterior of the hat track system																							
Horizontal	Vertical	3 psf	4	5	6	7	8	9	10	15	3 psf	4	5	6	7	8	9	10	15	Wood	12 ga.	14 ga.	16 ga.	18 ga.	20 ga.
16 in.	12 in.	0 in	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.03	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.13	606	505	353	280	153	105
	16	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.03	0.05	0.06	0.07	0.08	0.09	0.10	0.12	0.17	453	377	264	209	114	78
	24	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.04	0.05	0.07	0.09	0.10	0.12	0.14	0.16	0.17	0.26	300	249	173	137	74	50
	36	0.01	0.01	0.02	0.02	0.03	0.03	0.03	0.04	0.05	0.08	0.10	0.13	0.16	0.18	0.21	0.23	0.26	0.38	196	163	112	88	46	30
	48	0.01	0.02	0.02	0.03	0.03	0.04	0.04	0.05	0.07	0.10	0.14	0.17	0.21	0.24	0.27	0.31	0.34	0.49	144	119	81	63	31	19
24	12	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.03	0.04	0.05	0.07	0.08	0.09	0.10	0.12	0.13	0.19	400	333	232	183	99	67
	16	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.04	0.05	0.07	0.09	0.10	0.12	0.14	0.15	0.17	0.25	298	247	171	135	71	48
	24	0.01	0.01	0.02	0.02	0.03	0.03	0.03	0.04	0.05	0.08	0.10	0.13	0.15	0.18	0.21	0.23	0.25	0.37	194	160	110	85	43	27
	36	0.02	0.02	0.03	0.03	0.04	0.04	0.05	0.05	0.08	0.12	0.15	0.19	0.23	0.27	0.30	0.34	0.37	0.53	123	101	67	51	23	12
	48	0.02	0.03	0.04	0.04	0.05	0.06	0.07	0.07	0.11	0.15	0.21	0.25	0.30	0.35	0.39	0.44	0.48	0.66	87	70	45	33	12	4
32	12	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.04	0.05	0.07	0.09	0.10	0.12	0.14	0.15	0.17	0.25	296	245	169	133	70	46
	16	0.01	0.01	0.02	0.02	0.02	0.03	0.03	0.03	0.05	0.07	0.09	0.12	0.14	0.16	0.18	0.20	0.23	0.33	217	180	123	95	48	30
	24	0.01	0.02	0.02	0.03	0.03	0.04	0.04	0.05	0.07	0.10	0.14	0.17	0.20	0.24	0.27	0.30	0.33	0.47	138	113	75	57	25	13
	36	0.02	0.03	0.04	0.04	0.05	0.06	0.07	0.07	0.11	0.15	0.20	0.25	0.30	0.34	0.39	0.43	0.47	0.64	84	67	42	29	8	0
	48	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.14	0.20	0.27	0.33	0.39	0.44	0.49	0.54	0.58	0.78	56	43	25	15	0	0
48	12	0.01	0.01	0.02	0.02	0.03	0.03	0.03	0.04	0.05	0.08	0.10	0.13	0.15	0.18	0.20	0.23	0.25	0.35	186	153	102	78	36	20
	16	0.01	0.02	0.02	0.03	0.03	0.04	0.04	0.05	0.07	0.10	0.14	0.17	0.20	0.23	0.26	0.29	0.32	0.45	132	107	69	51	19	7
	24	0.02	0.03	0.04	0.04	0.05	0.06	0.07	0.07	0.11	0.15	0.20	0.25	0.29	0.33	0.37	0.41	0.45	0.60	78	61	36	24	2	0
	36	0.03	0.04	0.05	0.07	0.08	0.09	0.10	0.11	0.16	0.23	0.29	0.35	0.41	0.46	0.51	0.56	0.60	0.78	41	30	13	5	0	0
	48	0.04	0.06	0.07	0.09	0.10	0.12	0.13	0.14	0.21	0.29	0.37	0.45	0.51	0.57	0.63	0.68	0.72	0.91	23	15	2	0	0	0

Notes.
1. Industry standards normally limit deflection to 0.125 inches. Configurations with deflection amounts that exceed this limit are highlighted.
2. Where deflection exceeds 0.25 inches, deflection is highlighted red to indicate increasing severity.
3. Excessive deflection can lead to unwanted performance degradation, including ingress of rain water, increased air leakage, intrusion of pests, poor aesthetics, and in some cases structural failure.
4. Wind load resistances less than 50 psf are highlighted to show that wind load should be paid close attention to because they are commonly seen on buildings. Wind load resistances less than 20 psf are highlighted red to show very poor wind load resistance on most buildings.
5. To improve the performance of a system with zero wind load resistance, additional fasteners, thicker steel studs, or other solutions will be required.
6. Wind loads indicated in result tables were generated as nominal wind load (0.6x ultimate wind loads) to be compared to nominal loads calculated for the project according to local regulations. Allowable Stress Design (ASD) load combinations (1.0D + 0.6W) were used within the analysis.
7. The structural analysis assumes that the horizontal and vertical distances between fasteners are equal to the area of cladding contributing to the loading of one screw for the vertically aligned hat channel system and two screws for horizontally aligned hat channel system.
8. The structural analysis assumes that the exterior insulation is self-supported. The use of exterior insulation that is not self-supported may result in alternate results from those provided herein.
9. The long screws were analyzed as a cantilevered beam with flexible rotation restraint from substrates and zero rotation restraint from the hat channel. The cantilevered length was measured from the outside surface of the hat channel to the outside surface of the substrate.
10. The contribution of vertical load resistance from the insulation onto the screw has been neglected along with any frictional resistance of the hat channel to the face of the insulation.

Wind Load Resistance

Using the already-available tool "FAST", I can calculate the wind load resistance of a fastener with the given spacings, based on the parameters we have already in place.

$$R := \text{submatrix}\left(FAST\left(\left[\begin{matrix}\#10\text{–}24\\ \text{Grade: SS 2 CW2}\\ \text{Washer: none}\\ \text{Substrate1: Steel 33ksi}\\ \text{18 ga (43)}\\ \text{Substrate2: Steel 33ksi}\\ \text{18 ga (43)}\\ \text{ASD}\\ \text{special: No special conditions}\end{matrix}\right]\right), 3, 4, 1, 2\right) = \begin{bmatrix} 1081.606 & 1\ N \\ 461.205 & 1\ N \end{bmatrix}$$

$$\begin{bmatrix} V_r \\ T_r \end{bmatrix} := \overrightarrow{R^{\langle 0 \rangle} \cdot R^{\langle 1 \rangle}} = \begin{bmatrix} 243.155 \\ 103.683 \end{bmatrix} lbf$$

$$\begin{bmatrix} \delta_z \\ \delta_x \\ C_I \\ M_0 \end{bmatrix} := f\_hrz\left(\left[\begin{matrix}\#10\text{–}16\\ \text{Grade: SS 2 CW2}\\ n_f \leftarrow 2\\ \begin{bmatrix} E \leftarrow 200\ GPa \\ s_x \leftarrow 16\ in \\ s_z \leftarrow 24\ in \\ u \leftarrow 15\ psf \end{bmatrix}\\ \text{Substrate1: Steel 33ksi}\\ t_1 \leftarrow \text{18 ga (43)}\\ \begin{bmatrix} t_{ins} \leftarrow 4\ in \\ E_I \leftarrow \text{Rockwool Comfortboard 80} \\ A_I \leftarrow 3\ in \cdot s_z \\ t_{sh} \leftarrow 0.625\ in \end{bmatrix}\\ \text{Material: Fiberglass Sheathing 0.625''}\\ \text{Substrate2: Steel 33ksi}\\ t_2 \leftarrow \text{18 ga (43)}\\ \begin{bmatrix} l \leftarrow t_1 + t_{ins} + t_{sh} + t_2 + D \\ l_c \leftarrow t_1 + t_{ins} \end{bmatrix}\end{matrix}\right]\right) = \begin{bmatrix} 0.007\ m \\ 0\ m \\ 25.191\ N \\ 8.972\ J \end{bmatrix} ;\ C_I = 5.663\ lbf$$

Wind load resistance due to tension in screws: $\frac{T_r - C_I}{(24\ in \cdot 16\ in)} \cdot 2 = 73.515\ psf$

Table A2. Vertical deflection (in.) and wind load resistance for horizontally-aligned hat track system

Spacing		2 inch insulation									4 inch insulation									Wind load resistance for various stud types (psf, ASD)					
		Dead load of cladding exterior of the hat track system																							
Horizontal	Vertical	3 psf	4	5	6	7	8	9	10	15	3psf	4	5	6	7	8	9	10	15	Wood	12 ga.	14 ga.	16 ga.	18 ga.	20 ga.
16 in.	12 in.	0 in	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.03	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.13	606	505	353	280	153	105
	16	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.03	0.05	0.06	0.07	0.08	0.09	0.10	0.12	0.17	453	377	264	209	114	78
	24	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.04	0.05	0.07	0.09	0.10	0.12	0.14	0.16	0.17	0.26	300	249	173	137	74	50
	36	0.01	0.01	0.02	0.02	0.03	0.03	0.03	0.04	0.05	0.08	0.10	0.13	0.16	0.18	0.21	0.23	0.26	0.38	196	163	112	88	46	30
	48	0.01	0.02	0.02	0.03	0.03	0.04	0.04	0.05	0.07	0.10	0.14	0.17	0.21	0.24	0.27	0.31	0.34	0.49	144	119	81	63	31	19

"Max wind load resistance due to fiberglass sheathing"

$proof\_load \leftarrow \left(sheathing_{i1}\right)_8$

$q_{max_1} \leftarrow \frac{proof\_load}{b \cdot 12\ in}$

"Max wind load due to bending and deflection in bending"

$q_{max_2} \leftarrow \frac{M_r \cdot 8}{b \cdot l^2}$

$q_{max_3} \leftarrow \frac{l}{600} \cdot \frac{384 \cdot E \cdot I_x}{5 \cdot b \cdot l^4}$

™ Hat (

For different spans with $b = 12\ in$, $l := \begin{bmatrix} 12 \\ 16 \\ 24 \\ 36 \\ 48 \end{bmatrix} in$, $q := \frac{1}{b \cdot l} \cdot P^{T} = \begin{bmatrix} 40 & 70 & 80 & 100 \\ 30 & 52.5 & 60 & 75 \\ 20 & 35 & 40 & 50 \\ 13.333 & 23.333 & 26.667 & 33.333 \\ 10 & 17.5 & 20 & 25 \end{bmatrix} psf$

Date: July 10, 2023

Table A3 below shows the shear utilization of the fasteners for the hat channel system. Utilization is the ratio of load to capacity, including safety factors, and anything below 100% is a pass. For 18-gauge steel studs, steel studs with thicker gauges, and wood studs, the results are the same and all below 100%, but for 20-gauge studs, there are a few failing configurations. Forces used in these configurations are 1.6 times the dead load of cladding; the 1.6 factor represents the highest seismic factor we would reasonably expect in North America for wall cladding systems. We have used this factor throughout Table A3 as a worst-case scenario. Therefore, in regions with low seismicity, the utilization will be lower than what's shown in the table.

Table A3. Shear utilization for hat track systems

Stud	Spacing		2 inch insulation									4 inch insulation								
			Dead load of cladding exterior of the hat track system																	
	Horizontal	Vertical	3 psf	4	5	6	7	8	9	10	15	3 psf	4	5	6	7	8	9	10	15
18 ga, 16 ga, 14, ga, or 12 ga Steel Stud, or Douglas Fir or S-P-F Wood Stud	16 in.	6 in.	1%	2%	2%	3%	3%	4%	4%	5%	7%	1%	2%	2%	3%	3%	4%	4%	5%	7%
		12	3%	4%	5%	5%	6%	7%	8%	9%	14%	3%	4%	5%	5%	6%	7%	8%	9%	14%
		18	4%	5%	7%	8%	10%	11%	12%	14%	21%	4%	5%	7%	8%	10%	11%	12%	14%	21%
		24	5%	7%	9%	11%	13%	15%	16%	18%	27%	5%	7%	9%	11%	13%	15%	16%	18%	27%
	16	12	1%	2%	2%	3%	3%	4%	4%	5%	7%	1%	2%	2%	3%	3%	4%	4%	5%	7%
		16	2%	2%	3%	4%	4%	5%	5%	6%	9%	2%	2%	3%	4%	4%	5%	5%	6%	9%
		24	3%	4%	5%	5%	6%	7%	8%	9%	14%	3%	4%	5%	5%	6%	7%	8%	9%	14%
		36	4%	5%	7%	8%	10%	11%	12%	14%	21%	4%	5%	7%	8%	10%	11%	12%	14%	21%
		48	5%	7%	9%	11%	13%	15%	16%	18%	27%	5%	7%	9%	11%	13%	15%	16%	18%	27%
	24	6	2%	3%	3%	4%	5%	5%	6%	7%	10%	2%	3%	3%	4%	5%	5%	6%	7%	10%
		12	4%	5%	7%	8%	10%	11%	12%	14%	21%	4%	5%	7%	8%	10%	11%	12%	14%	21%
		18	6%	8%	10%	12%	14%	16%	18%	21%	31%	6%	8%	10%	12%	14%	16%	18%	21%	31%
		24	8%	11%	14%	16%	19%	22%	25%	27%	41%	8%	11%	14%	16%	19%	22%	25%	27%	41%
	24	12	2%	3%	3%	4%	5%	5%	6%	7%	10%	2%	3%	3%	4%	5%	5%	6%	7%	10%
		16	3%	4%	5%	5%	6%	7%	8%	9%	14%	3%	4%	5%	5%	6%	7%	8%	9%	14%
		24	4%	5%	7%	8%	10%	11%	12%	14%	21%	4%	5%	7%	8%	10%	11%	12%	14%	21%
		36	6%	8%	10%	12%	14%	16%	18%	21%	31%	6%	8%	10%	12%	14%	16%	18%	21%	31%
		48	8%	11%	14%	16%	19%	22%	25%	27%	41%	8%	11%	14%	16%	19%	22%	25%	27%	41%
	32	6	3%	4%	5%	5%	6%	7%	8%	9%	14%	3%	4%	5%	5%	6%	7%	8%	9%	14%
		12	5%	7%	9%	11%	13%	15%	16%	18%	27%	5%	7%	9%	11%	13%	15%	16%	18%	27%
		18	8%	11%	14%	16%	19%	22%	25%	27%	41%	8%	11%	14%	16%	19%	22%	25%	27%	41%
		24	11%	15%	18%	22%	26%	29%	33%	36%	55%	11%	15%	18%	22%	26%	29%	33%	36%	55%
	32	12	3%	4%	5%	5%	6%	7%	8%	9%	14%	3%	4%	5%	5%	6%	7%	8%	9%	14%
		16	4%	5%	6%	7%	9%	10%	11%	12%	18%	4%	5%	6%	7%	9%	10%	11%	12%	18%
		24	5%	7%	9%	11%	13%	15%	16%	18%	27%	5%	7%	9%	11%	13%	15%	16%	18%	27%
		36	8%	11%	14%	16%	19%	22%	25%	27%	41%	8%	11%	14%	16%	19%	22%	25%	27%	41%
		48	11%	15%	18%	22%	26%	29%	33%	36%	55%	11%	15%	18%	22%	26%	29%	33%	36%	55%
	48	6	4%	5%	7%	8%	10%	11%	12%	14%	21%	4%	5%	7%	8%	10%	11%	12%	14%	21%
		12	8%	11%	14%	16%	19%	22%	25%	27%	41%	8%	11%	14%	16%	19%	22%	25%	27%	41%
		18	12%	16%	21%	25%	29%	33%	37%	41%	62%	12%	16%	21%	25%	29%	33%	37%	41%	62%
		24	16%	22%	27%	33%	38%	44%	49%	55%	82%	16%	22%	27%	33%	38%	44%	49%	55%	82%
	48	12	4%	5%	7%	8%	10%	11%	12%	14%	21%	4%	5%	7%	8%	10%	11%	12%	14%	21%
		16	5%	7%	9%	11%	13%	15%	16%	18%	27%	5%	7%	9%	11%	13%	15%	16%	18%	27%
		24	8%	11%	14%	16%	19%	22%	25%	27%	41%	8%	11%	14%	16%	19%	22%	25%	27%	41%
		36	12%	16%	21%	25%	29%	33%	37%	41%	62%	12%	16%	21%	25%	29%	33%	37%	41%	62%
		48	16%	22%	27%	33%	38%	44%	49%	55%	82%	16%	22%	27%	33%	38%	44%	49%	55%	82%

"Fastener utilization due to shear"

$$VU_{row,col} \leftarrow C_E \frac{u_{i5} \cdot s_{x_{i2}} \cdot s_{z_{i3}}}{n_f \cdot V_r}$$

Where,

C.E is the seismic factor as a multiple of the dead load; in this case, 1.6
u is the dead load per square foot
s.x and *s.z* are the horizontal and vertical spacings respectively.
n.f is the number of fasteners, which is 1 or 2 depending on system.
V.r is the shear resistance of a screw, calculated using AISI S100.
The subscripts *i5, i2, and i3* are the positive, incremental integers referring to rows in a vector that we use in our loops.
Ultimately, the seismic force is *C.E*u*s.x*s.z* and the resistance is *n.f*V.r*

Table A3. Shear utilization for hat track systems (continued.)

Stud	Spacing		2 inch insulation									4 inch insulation								
			Dead load of cladding exterior of the hat track system																	
	Horizontal	Vertical	3 psf	4	5	6	7	8	9	10	15	3 psf	4	5	6	7	8	9	10	15
20 ga. Stud	16 in.	6 in.	2%	3%	4%	5%	5%	6%	7%	8%	11%	2%	3%	4%	5%	5%	6%	7%	8%	11%
		12	5%	6%	8%	9%	11%	12%	14%	15%	23%	5%	6%	8%	9%	11%	12%	14%	15%	23%
		18	7%	9%	11%	14%	16%	18%	21%	23%	34%	7%	9%	11%	14%	16%	18%	21%	23%	34%
		24	9%	12%	15%	18%	21%	24%	27%	31%	46%	9%	12%	15%	18%	21%	24%	27%	31%	46%
	16	12	2%	3%	4%	5%	5%	6%	7%	8%	11%	2%	3%	4%	5%	5%	6%	7%	8%	11%
		16	3%	4%	5%	6%	7%	8%	9%	10%	15%	3%	4%	5%	6%	7%	8%	9%	10%	15%
		24	5%	6%	8%	9%	11%	12%	14%	15%	23%	5%	6%	8%	9%	11%	12%	14%	15%	23%
		36	7%	9%	11%	14%	16%	18%	21%	23%	34%	7%	9%	11%	14%	16%	18%	21%	23%	34%
		48	9%	12%	15%	18%	21%	24%	27%	31%	46%	9%	12%	15%	18%	21%	24%	27%	31%	46%
	24	6	3%	5%	6%	7%	8%	9%	10%	11%	17%	3%	5%	6%	7%	8%	9%	10%	11%	17%
		12	7%	9%	11%	14%	16%	18%	21%	23%	34%	7%	9%	11%	14%	16%	18%	21%	23%	34%
		18	10%	14%	17%	21%	24%	27%	31%	34%	51%	10%	14%	17%	21%	24%	27%	31%	34%	51%
		24	14%	18%	23%	27%	32%	37%	41%	46%	69%	14%	18%	23%	27%	32%	37%	41%	46%	69%
	24	12	3%	5%	6%	7%	8%	9%	10%	11%	17%	3%	5%	6%	7%	8%	9%	10%	11%	17%
		16	5%	6%	8%	9%	11%	12%	14%	15%	23%	5%	6%	8%	9%	11%	12%	14%	15%	23%
		24	7%	9%	11%	14%	16%	18%	21%	23%	34%	7%	9%	11%	14%	16%	18%	21%	23%	34%
		36	10%	14%	17%	21%	24%	27%	31%	34%	51%	10%	14%	17%	21%	24%	27%	31%	34%	51%
		48	14%	18%	23%	27%	32%	37%	41%	46%	69%	14%	18%	23%	27%	32%	37%	41%	46%	69%
	32	6	5%	6%	8%	9%	11%	12%	14%	15%	23%	5%	6%	8%	9%	11%	12%	14%	15%	23%
		12	9%	12%	15%	18%	21%	24%	27%	31%	46%	9%	12%	15%	18%	21%	24%	27%	31%	46%
		18	14%	18%	23%	27%	32%	37%	41%	46%	69%	14%	18%	23%	27%	32%	37%	41%	46%	69%
		24	18%	24%	31%	37%	43%	49%	55%	61%	92%	18%	24%	31%	37%	43%	49%	55%	61%	92%
	32	12	5%	6%	8%	9%	11%	12%	14%	15%	23%	5%	6%	8%	9%	11%	12%	14%	15%	23%
		16	6%	8%	10%	12%	14%	16%	18%	20%	31%	6%	8%	10%	12%	14%	16%	18%	20%	31%
		24	9%	12%	15%	18%	21%	24%	27%	31%	46%	9%	12%	15%	18%	21%	24%	27%	31%	46%
		36	14%	18%	23%	27%	32%	37%	41%	46%	69%	14%	18%	23%	27%	32%	37%	41%	46%	69%
		48	18%	24%	31%	37%	43%	49%	55%	61%	92%	18%	24%	31%	37%	43%	49%	55%	61%	92%
	48	6	7%	9%	11%	14%	16%	18%	21%	23%	34%	7%	9%	11%	14%	16%	18%	21%	23%	34%
		12	14%	18%	23%	27%	32%	37%	41%	46%	69%	14%	18%	23%	27%	32%	37%	41%	46%	69%
		18	21%	27%	34%	41%	48%	55%	62%	69%	103%	21%	27%	34%	41%	48%	55%	62%	69%	103%
		24	27%	37%	46%	55%	64%	73%	82%	92%	137%	27%	37%	46%	55%	64%	73%	82%	92%	137%
	48	12	7%	9%	11%	14%	16%	18%	21%	23%	34%	7%	9%	11%	14%	16%	18%	21%	23%	34%
		16	9%	12%	15%	18%	21%	24%	27%	31%	46%	9%	12%	15%	18%	21%	24%	27%	31%	46%
		24	14%	18%	23%	27%	32%	37%	41%	46%	69%	14%	18%	23%	27%	32%	37%	41%	46%	69%
		36	21%	27%	34%	41%	48%	55%	62%	69%	103%	21%	27%	34%	41%	48%	55%	62%	69%	103%
		48	27%	37%	46%	55%	64%	73%	82%	92%	137%	27%	37%	46%	55%	64%	73%	82%	92%	137%

Notes.

1. Shear utilization is the ratio of vertical dead load to shear capacity of the screwed connection. Less than 100% is OK.

2. This table was produced using a seismic force factor of 1.6 on the dead load. This represents a very high seismic force, which could be generated by an earthquake in a region with high seismicity under the worst-case conditions.

Table A3. Shear utilization for hat track systems

Stud	Spacing		2 inch insulation									4 inch insulation								
			Dead load of cladding exterior of the hat track system																	
	Horizontal	Vertical	3 psf	4	5	6	7	8	9	10	15	3 psf	4	5	6	7	8	9	10	15
...uglas Fir or S-P-F Wood Stud	16 in.	6 in.	1%	2%	2%	3%	3%	4%	4%	5%	7%	1%	2%	2%	3%	3%	4%	4%	5%	7%
		12	3%	4%	5%	5%	6%	7%	8%	9%	14%	3%	4%	5%	5%	6%	7%	8%	9%	14%
		18	4%	5%	7%	8%	10%	11%	12%	14%	21%	4%	5%	7%	8%	10%	11%	12%	14%	21%
		24	5%	7%	9%	11%	13%	15%	16%	18%	27%	5%	7%	9%	11%	13%	15%	16%	18%	27%
	16	12	1%	2%	2%	3%	3%	4%	4%	5%	7%	1%	2%	2%	3%	3%	4%	4%	5%	7%
		16	2%	2%	3%	4%	4%	5%	5%	6%	9%	2%	2%	3%	4%	4%	5%	5%	6%	9%
		24	3%	4%	5%	5%	6%	7%	8%	9%	14%	3%	4%	5%	5%	6%	7%	8%	9%	14%
		36	4%	5%	7%	8%	10%	11%	12%	14%	21%	4%	5%	7%	8%	10%	11%	12%	14%	21%
		48	5%	7%	9%	11%	13%	15%	16%	18%	27%	5%	7%	9%	11%	13%	15%	16%	18%	27%
	24	6	2%	3%	3%	4%	5%	5%	6%	7%	10%	2%	3%	3%	4%	5%	5%	6%	7%	10%
		12	4%	5%	7%	8%	10%	11%	12%	14%	21%	4%	5%	7%	8%	10%	11%	12%	14%	21%
		18	6%	8%	10%	12%	14%	16%	18%	21%	31%	6%	8%	10%	12%	14%	16%	18%	21%	31%
		24	8%	11%	14%	16%	19%	22%	25%	27%	41%	8%	11%	14%	16%	19%	22%	25%	27%	41%
		12	2%	3%	3%	4%	5%	5%	6%	7%	10%	2%	3%	3%	4%	5%	5%	6%	7%	10%

Example Seismic Utilization Calculation

Resistances of fastener:

$$R := \text{submatrix}\left(FAST\left(\begin{bmatrix} \#10\text{–}16 \\ \text{Grade: SS 2 CW2} \\ \text{Washer: none} \\ \text{Substrate1: Steel 33ksi} \\ \text{18 ga (43)} \\ \text{Substrate2: Steel 33ksi} \\ \text{18 ga (43)} \\ \text{ASD} \\ \text{special: No special conditions} \end{bmatrix} \right), 3, 4, 1, 2 \right) = \begin{bmatrix} 1040.541 & 1\ N \\ 461.205 & 1\ N \end{bmatrix}$$

Tension and shear resistance $\begin{bmatrix} V_r \\ T_r \end{bmatrix} := \overrightarrow{R^{\langle 0 \rangle} \cdot R^{\langle 1 \rangle}} = \begin{bmatrix} 233.923 \\ 103.683 \end{bmatrix}$ **lbf** per AISI S100

Given:

$C_E := 1.6$ Seismic factor

$u := 15$ **psf** Dead load

$s_x := 24$ **in** and $s_z := 24$ **in** (spacings)

$n_f := 1$ fasteners for vertical system

$V_r = 233.923$ **lbf** calculated above

$$VU := \frac{C_E \cdot u \cdot s_x \cdot s_z}{n_f \cdot V_r} = 0.41$$

APPENDIX B:
Sample Calculations