K2 Engineering, Inc.

An Alabama Corporation

Robert P. Kiser, PE
President
5549 Hunter's Hill Road
Irondale, AL 35210-3036

Licensed in AL, GA, MS, SC, LA, TN, & FL
Voice & Fax: (205) 951-3825
e-mail: rkiser@k2engineeringinc.com
http://www.k2engineeringinc.com

AISI S211-07 Design of Wall Stud

References:

1. AISI S211-07 North American Standard for Cold-Formed Steel Framing - Wall Stud Design
2. AISI S100-07 North American Specification for the Design of Cold-Formed Steel Structural Members
3. AISI S200-07 North AmericanStandard for Cold-Formed Steel Framing - General Provisions
4. Various MathCAD spreadsheets based upon equations and specifications in References 1, 2, and 3.

Assumptions:

1. Studs are not adjacent to a wall opening where the track terminates.
2. Both stud flanges are connected to track flanges.
3. Track thickness is equal to or greater than stud thickness.
4. Bracing is considered as an "all steel" design.

Name of current project — Project := "Example project Gardendale, AL"

Description of Curtainwall Stud — Description := "42-6 1200S200-97 curtainwall stud on North wall"

Wall Height — $H_{wall} := 510.0 \cdot in$ $H_{wall} = 42.500\ ft$

Wall Thickness — $T_{wall} := 12.000 \cdot in$

Wall Stud Designation — WallStud := "1200S200-97"

Wall Track Designation — WallTrack := "1200T125-97"

Stud Spacing — $StudSpacing := 16.0 \cdot in$

Wind Pressure — $Pressure_{Wind} := 16.67 \cdot psf$

Worst Case Downward Axial Load — $P := 0.0 \cdot lbf$

Dimensions Cross-Reference:

	Gauge	Thk.	Inside Radius
33 Mil	20 ga	0.0346 in.	0.0764 in.
43 Mil	18 ga	0.0451 in.	0.0712 in.
54 Mil	16 ga	0.0566 in.	0.0849 in.
68 Mil	14 ga	0.0713 in.	0.1069 in.
97 Mil	12 ga	0.1017 in.	0.1525 in.

Modulus of Elasticity (E) — $E := 29500000 \cdot psi$

Material Yield Stress (Sy) — $S_y := 50000 \cdot psi$

Deflection Criteria (L/???) — DeflectionCriteria := 360

<u>Typical Deflection Criteria</u>

L / 720 for Stone
L / 600 for Brick
L / 360 for other finishes
L / 240 for EIFS or Stucco
L / 120 for Metal Cladding

Base Deflection Limits on 70% of Component and cladding wind Loads as per A3.1 (a)? — Use70Percent := "Y"

Wall Stud Properties

Effective Strong Axis Inertia (Iex) $I_{ex} := 28.3968 \cdot in^4$ Un-reduced Strong Axis Inertia (Ix) $I_x := 29.676 \cdot in^4$

Effective Weak Axis Inertia (Iey) $I_{ey} := 0.5137 \cdot in^4$ Un-reduced Weak Axis Inertia (Iy) $I_y := 0.572 \cdot in^4$

Effective Weak Axis Modulus (Sey) $S_{ey} := 0.3362 \cdot in^3$

Allowable Shear in Wall Stud $V_{Allowable} := 7361 \cdot lbf$ (calculated as per AISI S100-07 EQ. C3.2)

Allowable Moment in Wall Stud about Strong Axis $M_{ax} := 135639 \cdot lbf \cdot in$ (calculated as per AISI S100-07 EQ. C3.1.1)

Nominal Moment in Wall Stud about Strong Axis $M_{nx} := 226517 \cdot lbf \cdot in$

Distance from Shear Center to member centroid $m := 0.6173 \cdot in$

Wall Stud Thickness $WallStud_t := 0.1017 \cdot in$

Wall Stud Inside Bend Radius $WallStud_R := 0.1525 \cdot in$

Effective Length - X Axis $KL_x := H_{wall}$ $KL_x = 42.50\,ft$

Effective Length - Y Axis $KL_y := 48.0 \cdot in$

Effective Length - Twisting $KL_t := 48.0 \cdot in$

Allowable Compression, w/ given effective lengths $P_a := 1.91 \cdot kip$ (calculated as per AISI S100-07 Section C4.2)

Nominal Compression, w/ given effective lengths $P_n := 19.840 \cdot kip$

Weight per foot - Stud $Stud_{Weight} := 5.618 \cdot \frac{lbf}{ft}$

Wall Track Properties

Weight per foot - Track $Track_{Weight} := 5.01 \cdot \frac{lbf}{ft}$

Brace Properties (Flat Strap)

Brace Designation: $Designation_{Brace} :=$ "2 in. 43 Mil flat strap"

Brace, maximum allowable tension, Tmax $BraceTension_{max} := 1.653 \cdot kip$

Brace, number of #10 screws attaching to Stud $N_{screws} := 2$

Shear Capacity of each #10 screw in Brace material $\tau_{screw} := 263 \cdot lbf$

Brace Properties (CRC bridging through punchout)

Bridging Designation: $Designation_{Bridging} :=$ "075U50-54 CRC Channel"

Bridging Allowable Moment: $Bridging_{AllowableMoment} := 38.0 lbf \cdot ft$

Moment Arm - Horiz. Face of Clip $MomArm_{HorizontalFace} := 1.0 \cdot in$

Moment Arm - Vertical Face of Clip $MomArm_{VerticalFace} := 4.75 \cdot in$

Screw Designation $Screw :=$ "#10 x 3/4 in."

Screw Allowable Shear $Screw_{AllowableShear} := 263 \cdot lbf$

Screw Allowable Pullout $Screw_{AllowablePullout} := 109 \cdot lbf$

As per B2.2 - Calculate Web Crippling Strength for C section stud-to-track connections

$t_S := WallStud_t$ $R_S := WallStud_R$

$r := R_S + \frac{t_S}{2}$

$h := T_{wall} - (2 \cdot r + t_S)$

Web Crippling Coefficient $C := 3.7$

Inside Bend Radius Coefficient $C_R := 0.19$

Bearing Length Coefficient $C_N := 0.74$

Web Slenderness Coefficient $C_h := 0.019$

Inside Bend Radius $R = 6.6667\,ft^{-1.0000} \cdot K \cdot in$

Stud Bearing Length $N := 1.25 \cdot in$ **(Assume a 1.25 inch leg on track section)**

Depth of Flat Portion of Web $h = 11.4916 \cdot in$

Nominal Web Crippling Strength, EQ. B2.2-1 $P_{nst} := C \cdot t_S^2 S_y \cdot \left(1 - C_R \cdot \sqrt{\frac{R_S}{t_S}}\right) \cdot \left(1 + C_N \cdot \sqrt{\frac{N}{t_S}}\right) \cdot \left(1 - C_h \cdot \sqrt{\frac{h}{t_S}}\right)$

$P_{nst} = 4212 \cdot lbf$

ASD Safety Factor, as per B2.2-1 $\Omega_{wc} := 1.7$

Allowable Web Crippling Strength, EQ. B2.2-1 $P_{WebCrippling} := \frac{P_{nst}}{\Omega_{wc}}$

$P_{WebCrippling} = 2477 \cdot lbf$

Derived Stud Properties

$\Omega_b := 1.67$

$M_{ny} := S_{ey} \cdot \frac{S_y}{\Omega_b}$ $M_{ny} = 10066 \cdot lbf \cdot in$

B1.2 - Axial Load   Check against allowable axial load as per AISI Section C4

Note: we will compare the imposed axial load against the calculated allowable axial load (input above).

An "all steel" design approach is used, which ignores contribution of sheathing.

$CheckAxialLoad := if(P \le P_a, "OK", "Failed")$

$CheckAxialLoad = "OK"$

B1.3 - Bending   Check against Bending Criteria

Note: since we are using an "all steel" design approach, we simply need to compare the resultant moment against the stud's allowable moment, calculated as per AISI C3.1.

Determine the Maximum Moment

$w := Pressure_{Wind} \cdot StudSpacing$

$L := H_{wall}$

$M_{Max} := \frac{w \cdot L^2}{8}$

$M_x := M_{Max}$

$CheckBending := if(M_{Max} \le M_{nx}, "OK", "Failed")$

$w = 1.852 \cdot \frac{lbf}{in}$

$M_{Max} = 60220 \cdot lbf \cdot in$

$M_{ax} = 135639 \cdot lbf \cdot in$

$CheckBending = "OK"$

B1.4 - Shear   Check against Shear Criteria

Note: since we are using an "all steel" design approach, we simply need to compare the resultant shear against the stud's allowable shear, calculated as per AISI C3.2.

Determine Loads at Stud Ends, depending upon end fixity conditions

$R_{Top} := 0.5 \cdot Pressure_{Wind} \cdot H_{wall} \cdot StudSpacing$

$R_{Bottom} := 0.5 \cdot Pressure_{Wind} \cdot H_{wall} \cdot StudSpacing$

$V_{Max} := max(R_{Top}, R_{Bottom})$ $V_{Max} = 472 \cdot lbf$

$CheckShear := if(V_{Max} \le V_{Allowable}, "OK", "Failed")$

$CheckShear = "OK"$

B1.5 - Axial Load and Bending   Check against Axial/Bending Interaction Criteria

Note: as per AISI S100 section C5.2, we will calculate the interaction between axial loading and bending and compare it to the allowable value.

$$P_{Ex} := \frac{\pi^2 \cdot E \cdot I_x}{{KL_x}^2} \qquad P_{Ex} = 33219 \cdot lbf \qquad \text{(Eq. C5.2.1-6)}$$

$$P_{Ey} := \frac{\pi^2 \cdot E \cdot I_y}{{KL_y}^2} \qquad P_{Ey} = 72283 \cdot lbf \qquad \text{(Eq. C5.2.1-7)}$$

$\Omega_c := 1.80$ $\qquad$ $\Omega_b := 1.67$

$$\alpha_x := \max\left(0.0, 1 - \frac{\Omega_c \cdot P}{P_{Ex}}\right) \qquad \alpha_x = 1.000 \qquad \text{(Eq. C5.2.1-4)}$$

$$\alpha_y := \max\left(0.0, 1 - \frac{\Omega_c \cdot P}{P_{Ey}}\right) \qquad \alpha_y = 1.000 \qquad \text{(Eq. C5.2.1-5)}$$

$C_{mx} := 1.0$ **(as per C5.2.1, note (c))**

$C_{my} := 1.0$ **(as per C5.2.1, note (c))**

Evaluate each component of Eq. C5.2.1-1

$M_y := 0.0 \cdot lbf \cdot in$ **Note: there is no load to cause bending about the Y Axis.**

$$Ratio1 := \frac{\Omega_c \cdot P}{P_n} \qquad Ratio1 = 0.000$$

$P = 0 \cdot lbf$

$P_n = 19840 \cdot lbf$

$$Ratio2 := \frac{\Omega_b \cdot C_{mx} \cdot M_x}{M_{nx} \cdot \alpha_x} \qquad Ratio2 = 0.444$$

$$Ratio3 := \frac{\Omega_b \cdot C_{my} \cdot M_y}{M_{ny} \cdot \alpha_y} \qquad Ratio3 = 0.000$$

Now evaluate Eq. C5.2.1-1

$$Interaction1 := Ratio1 + Ratio2 + Ratio3 \qquad Interaction1 = 0.444$$

<u>**Evaluate each component of Eq. C5.2.1-2**</u>

$$\mathbf{Ratio4} := \frac{\Omega_c \cdot P}{P_n} \qquad \mathbf{Ratio4} = 0.000$$

$$\mathbf{Ratio5} := \frac{\Omega_b \cdot M_x}{M_{nx}} \qquad \mathbf{Ratio5} = 0.444$$

$$\mathbf{Ratio6} := \frac{\Omega_b \cdot M_y}{M_{ny}} \qquad \mathbf{Ratio6} = 0.000$$

<u>**Now evaluate Eq. C5.2.1-2**</u>

$$\mathbf{Interaction2} := \mathbf{Ratio4} + \mathbf{Ratio5} + \mathbf{Ratio6} \qquad \mathbf{Interaction2} = 0.444$$

$$\mathbf{Test1} := \mathbf{if}(\mathbf{Ratio1} < 1, 1, 0)$$

$$\mathbf{Test2} := \mathbf{if}(\mathbf{Ratio2} < 1, 1, 0)$$

$$\mathbf{Test3} := \mathbf{if}(\mathbf{Ratio3} < 1, 1, 0)$$

$$\mathbf{Test4} := \mathbf{if}(\mathbf{Interaction1} < 1, 1, 0)$$

$$\mathbf{Test5} := \mathbf{if}(\mathbf{Ratio4} < 1, 1, 0)$$

$$\mathbf{Test6} := \mathbf{if}(\mathbf{Ratio5} < 1, 1, 0)$$

$$\mathbf{Test7} := \mathbf{if}(\mathbf{Ratio6} < 1, 1, 0)$$

$$\mathbf{Test8} := \mathbf{if}(\mathbf{Interaction2} < 1, 1, 0)$$

$$\mathbf{TestSum} := \mathbf{Test1} + \mathbf{Test2} + \mathbf{Test3} + \mathbf{Test4} + \mathbf{Test5} + \mathbf{Test6} + \mathbf{Test7} + \mathbf{Test8}$$

$$\mathbf{CheckAxialBendingInteraction} := \mathbf{if}(\mathbf{TestSum} = 8, \text{"OK"}, \text{"Failed"})$$

$$\mathbf{CheckAxialBendingInteraction} = \text{"OK"}$$

<u>B1.6 - Web Crippling   Check against Web Crippling Criteria</u>

Note: we will compare the resultant shear reactions (due to the wind pressure) against the calculated allowable web crippling (input above).

An "all steel" design approach is used, which ignores contribution of sheathing.

$$\mathbf{CheckWebCrippling} := \mathbf{if}\left(V_{Max} \le P_{WebCrippling}, \text{"OK"}, \text{"Failed"}\right)$$

$$V_{Max} = 472 \cdot lbf$$

$$P_{WebCrippling} = 2477 \cdot lbf$$

$$\mathbf{CheckWebCrippling} = \text{"OK"}$$

<u>**Determine how much this steel framing weighs per lineal foot of wall**</u>

$$\mathbf{WPF} := Stud_{Weight} \cdot H_{wall} \cdot \frac{StudSpacing}{12.0 \cdot in} + 2.0 \cdot Track_{Weight} \cdot 12.0 \cdot in \qquad \mathbf{WPF} = 328.4 \cdot lbf$$

Additionially, check Deflection against Deflection Criteria

Check for Deflection within Limits Note: Deflection may optionially use factored wind loads, as per User Input

$\text{Adjustment} := \text{if}(\text{Use70Percent} = \text{"Y"}, 0.70, 1.0)$ $\quad$ $\text{Adjustment} = 0.70$

$w := \text{Adjustment} \cdot \text{Pressure}_{Wind} \cdot \text{StudSpacing}$ $\quad$ $w = 1.297 \cdot \frac{lbf}{in}$

$I := I_{ex}$ $\quad$ $I = 28.397 \cdot in^4$

$d_{Max} := \frac{5 \cdot w \cdot L^4}{384 \cdot E \cdot I}$ $\quad$ $d_{Max} = 1.363 \cdot in$

$d_{Allowable} := \frac{L}{\text{DeflectionCriteria}}$ $\quad$ $d_{Allowable} = 1.417 \cdot in$

$\text{CheckDeflection} := \text{if}\left(\left|d_{Max}\right| < d_{Allowable}, \text{"OK"}, \text{"Failed"}\right)$ $\quad$ $\text{CheckDeflection} = \text{"OK"}$

B3.1 - Intermediate Brace Design (assuming flat strap method)

Note: An "all steel" design approach is used, which ignores contribution of sheathing. Therefore, all bracing forces will be handled by a flat strap/ shear blocking assembly, spaced vertically as per KLy (input above).

Design brace force will be the greater of that calculated in AISI S100 Eq. D3.2.1-3 or 2% of axial force in stud.

A C shape section is assumed.

d is depth of C shape section $d := T_{wall}$ $d = 12.000 \cdot in$

m is distance from Shear Center to member centroid $m = 0.6173 \cdot in$

W is total lateral load between brace points $W := Pressure_{Wind} \cdot StudSpacing \cdot KL_y$ $W = 89 \cdot lbf$

$P_{L1} := 1.5 \cdot \left(\frac{m}{d}\right) \cdot W$ **(Eq. D3.2.1-3, for C Sections)** $P_{L1} = 6.86 \cdot lbf$

$P_{2Percent} := 0.02 \cdot P$ $P_{2Percent} = 0.00 \cdot lbf$

$P_{Brace} := \max\left(P_{L1}, P_{2Percent}\right)$ $P_{Brace} = 6.86 \cdot lbf$

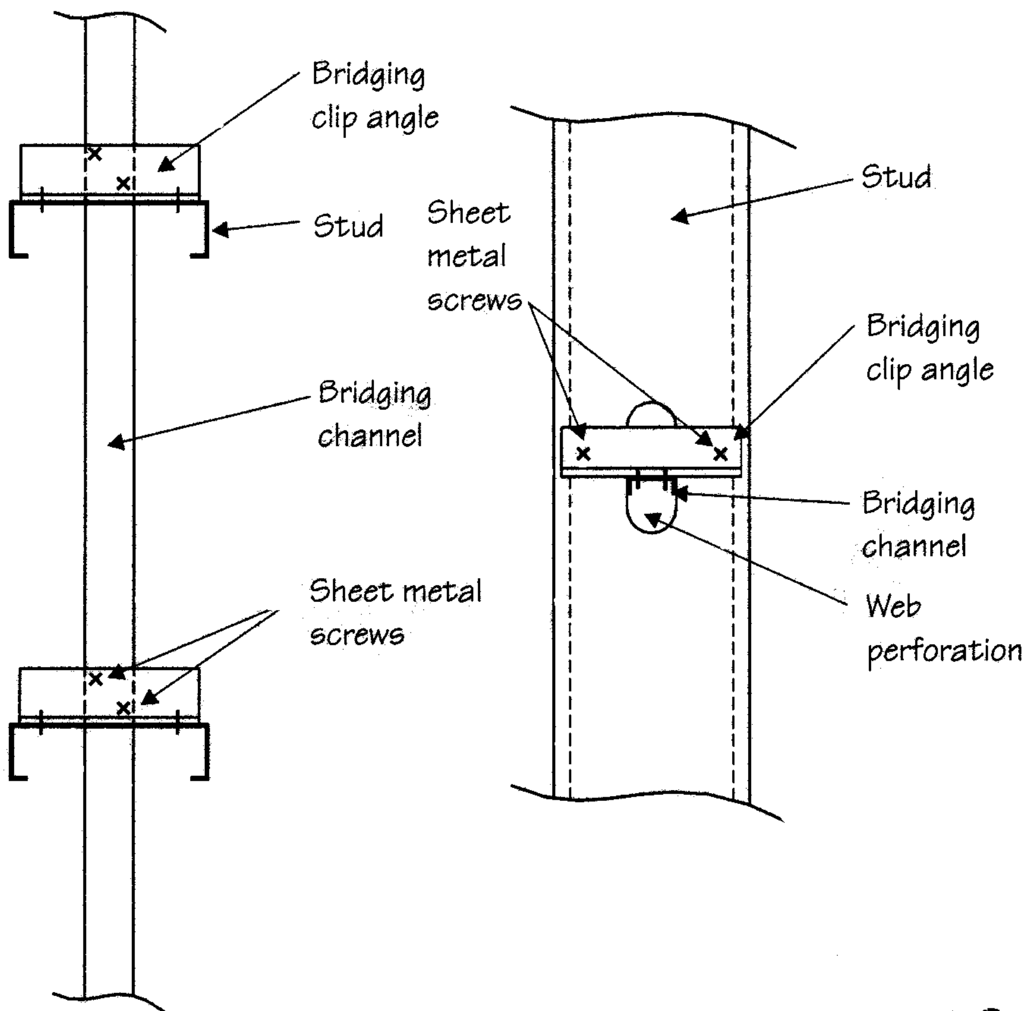
See if brace forces are within capacity

$CheckBraceForces := if\left[P_{Brace} \le \left(BraceTension_{max}\right), \text{"OK"}, \text{"Failed"}\right]$ $CheckBraceForces = \text{"OK"}$

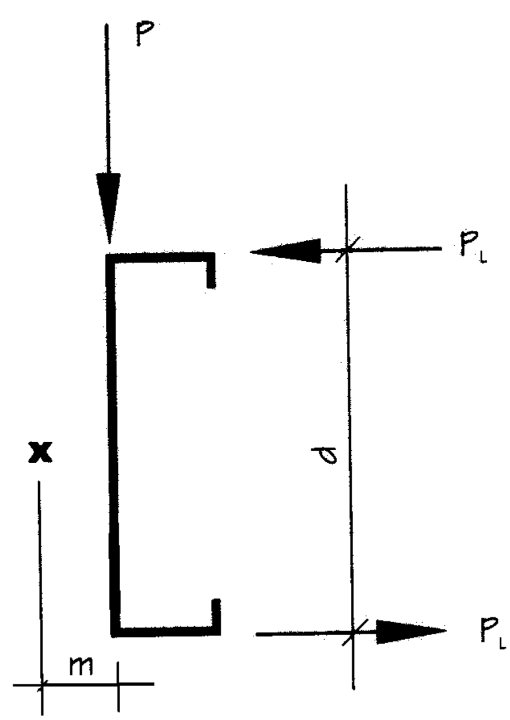
See if brace screws are adequate

$CheckBraceScrews := if\left(P_{Brace} \le N_{screws} \cdot \tau_{screw}, \text{"OK"}, \text{"Failed"}\right)$ $CheckBraceScrews = \text{"OK"}$

B3.1 - Intermediate Brace Design (assuming CRC through punchouts)



THROUGH THE KNOCKOUT BRIDGING



Check brace requirement moment against bridging Allowable Moment

$\mathbf{Mom_{BridgingRequirement} := P_{L1} \cdot d}$

$\mathbf{Mom_{BridgingRequirement} = 82.32 \cdot lbf \cdot in}$

$\mathbf{Bridging_{AllowableMoment} = 456.00 \cdot lbf \cdot in}$

$\mathbf{BridgingMomentCheck := if\left(Mom_{BridgingRequirement} < Bridging_{AllowableMoment}, \text{"OK"}, \text{"Failed"}\right)}$

$\mathbf{BridgingMomentCheck = \text{"OK"}}$

Check Screw connections - Clip to Stud, and Clip to Bridging

$$\mathbf{ActualShear_{HorizontalFace} := \frac{Mom_{BridgingRequirement}}{MomArm_{HorizontalFace}}}$$

$\mathbf{ActualShear_{HorizontalFace} = 82.32 \cdot lbf}$

$\mathbf{ScrewShearHorizontalFaceCheck := if\left(ActualShear_{HorizontalFace} < Screw_{AllowableShear}, \text{"OK"}, \text{"Failed"}\right)}$

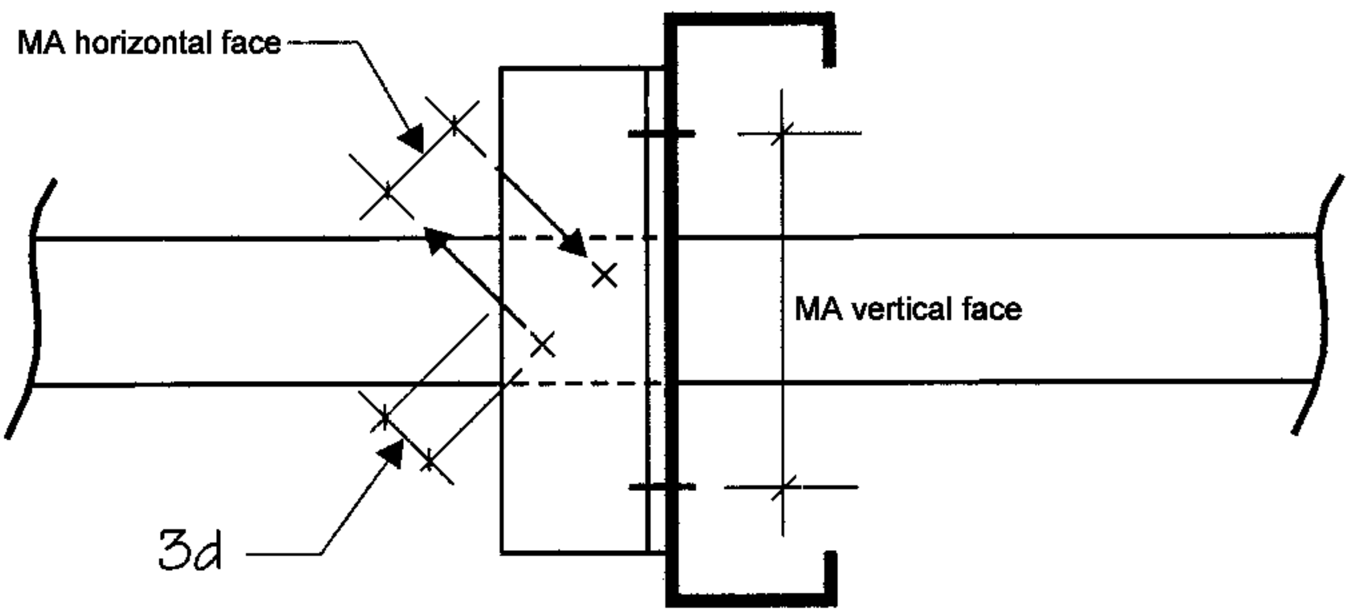
$\mathbf{ScrewShearHorizontalFaceCheck = \text{"OK"}}$

$$\mathbf{ActualPullout_{VerticalFace} := \frac{Mom_{BridgingRequirement}}{MomArm_{VerticalFace}}}$$

$\mathbf{ActualPullout_{VerticalFace} = 17.33 \cdot lbf}$

$\mathbf{ScrewPulloutVerticalFaceCheck := if\left(ActualPullout_{VerticalFace} < Screw_{AllowablePullout}, \text{"OK"}, \text{"Failed"}\right)}$

$\mathbf{ScrewPulloutVerticalFaceCheck = \text{"OK"}}$



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Results: AISI S211-07 Design of Wall Stud

Current Project Name — Project = "Example project Gardendale, AL"

Description of Curtain wall Stud — Description = "42-6 1200S200-97 curtainwall stud on North wall"

Summary of Results

Maximum Compression	$P = 0.000 \cdot kip$	**Allowable Compression**	$P_a = 1.910 \cdot kip$
Maximum Moment	$M_{Max} = 60.220 \cdot kip \cdot in$	**Allowable Moment**	$M_{ax} = 135.639 \cdot kip \cdot in$
Maximum Shear	$V_{Max} = 0.472 \cdot kip$	**Allowable Shear**	$V_{Allowable} = 7.361 \cdot kip$
		Allowable Web Crippling	$P_{WebCrippling} = 2.477 \cdot kip$
Maximum Deflection	$d_{Max} = 1.363 \cdot in$	**Allowable Deflection**	$d_{Allowable} = 1.417 \cdot in$
Reaction at Top	$R_{Top} = 0.472 \cdot kip$	**Reaction at Bottom**	$R_{Bottom} = 0.472 \cdot kip$

AISI S100 Interaction Equation C5.1.1-1 Interaction1 = 0.444

AISI S100 Interaction Equation C5.1.1-2 Interaction2 = 0.444

CheckAxialLoad = "OK"

CheckBending = "OK"

CheckAxialBendingInteraction = "OK"

CheckWebCrippling = "OK"

CheckDeflection = "OK"

CheckBraceForces = "OK"

Results - CRC Bridging through punchouts

BridgingMomentCheck = "OK"

ScrewShearHorizontalFaceCheck = "OK"

ScrewPulloutVerticalFaceCheck = "OK"

Results - Flat Strapping

CheckBraceForces = "OK"

CheckBraceScrews = "OK"

Brace Force $P_{Brace} = 0.007 \cdot kip$

Assembly weight per foot of wall $WPF = 328.4 \cdot lbf$