

Overview: This Mathcad worksheet is intended to analyze gusset plates using Load Factor Design. Gusset plates are analyzed for shear and axial force effects by the conventional "Method-of-Section" procedures. It should be noted that this Mathcad worksheet only investigates three common sections of interest, two vertical and one horizontal section. Additional sections should be investigated at joints that have a break in the alignment of the chord and/or unusual joint configurations. Member connections are analyzed for bolt/rivet capacity, block shear capacity and Whitmore section stresses.

The calculations assume each truss member is connected to each gusset plate if more than one gusset plate is entered (N). The bottom chord is assumed continuous (either spliced or non-jointed) across the panel point. The calculations do not check the base material capacity of the truss members.

Disclaimer: This worksheet and sample calculations outline an acceptable method for analyzing the capacity of existing truss gusset plates. There may be other acceptable procedures for this analysis. While this Mathcad sheet has been checked, it should be used by an engineer familiar with truss and gusset plate analysis. Sound engineering judgement is required to apply this method to individual situations and to bridges that may vary from this example.

Revisions: The February 2009 Baker Revision included the following additional calculations and modifications to the MathCAD file provided by VDOT:

- Added Exterior/End Fastener Capacity
- Added Truss Member base material check
- Modified the file such that Tension and Compression checks are completed for each member
- Added Rating Factor Summaries for each member
- Added Controlling Member Designation in the Rating Summary
- Added input for Member Force Reduction due to Chord Splice Plates
- Added controlling failure check (Block Shear vs. Net Section Fracture)

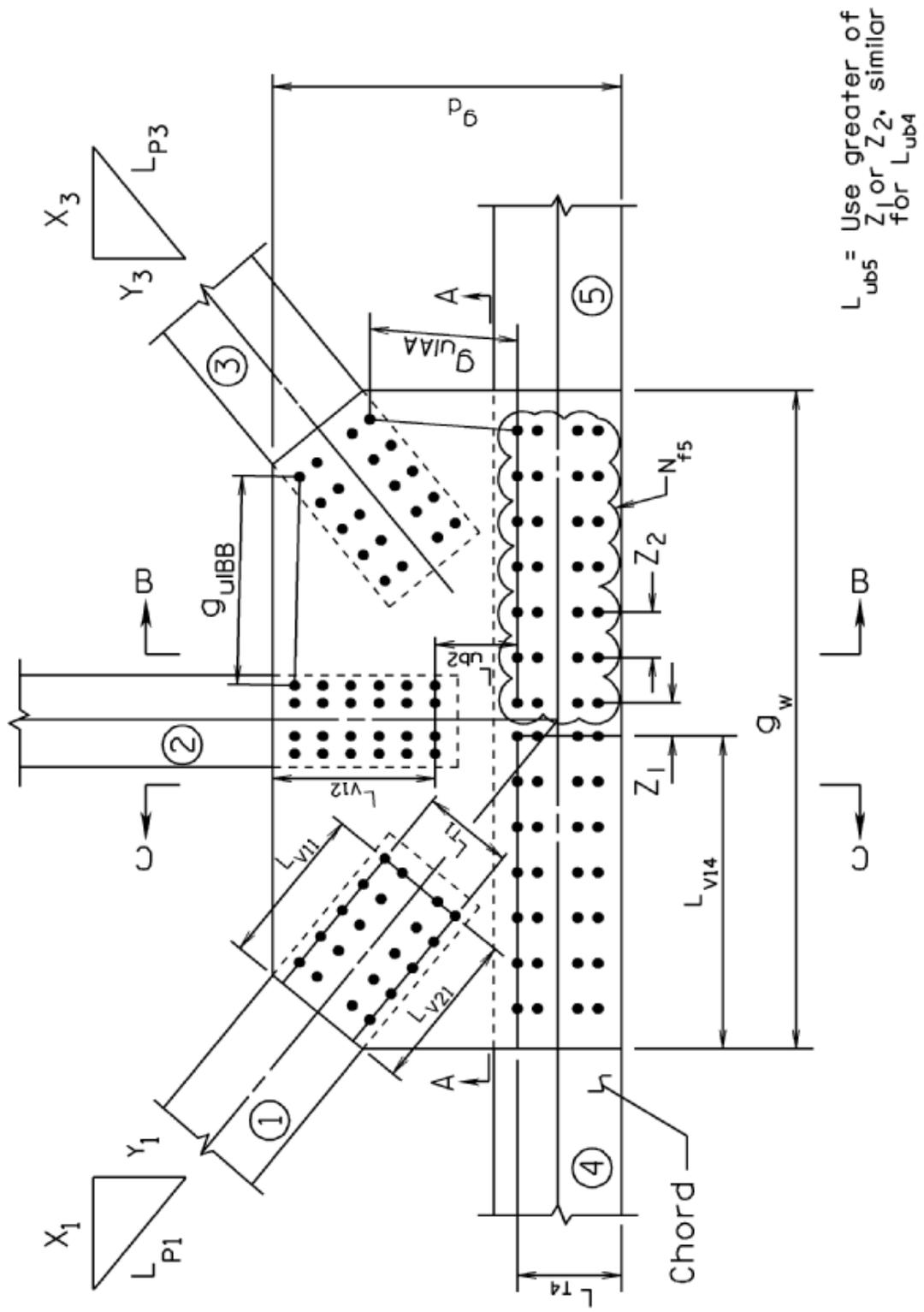


Figure-2

Member Loads: Sign convention: **(+)** Compression, **(-)** Tension

Chord splices (when applicable): To determine the forces transferred to the gusset plate(s) from members 4 and 5, reduce the total chord force by the capacity of the splice plates. For example, if the capacity of the splice plates is 43% of the total chord force, then 57% of the total chord force is carried by the gusset plate.

	Member (1)	Member (2)	Member (3)	Member (4)	Member (5)
<u>Dead Loads:</u>	$P1_{DL} := -51.28 \cdot \text{kip}$	$P2_{DL} := -26.73 \cdot \text{kip}$	$P3_{DL} := 101.53 \cdot \text{kip}$	$P4_{DL} := 125.17 \cdot \text{kip}$	$P5_{DL} := 0 \cdot \text{kip}$
<u>Live Loads:</u>	$P1_{LL} := -59.71 \cdot \text{kip}$	$P2_{LL} := -35.6 \cdot \text{kip}$	$P3_{LL} := 84.82 \cdot \text{kip}$	$P4_{LL} := 99.96 \cdot \text{kip}$	$P5_{LL} := 0 \cdot \text{kip}$
<u>Chord Splice Data:</u>	Percentage of Force carried by the Gusset Plate:			$GP_4 := 100.0\%$	$GP_5 := 0.0\%$
	Percentage of Force transferred by the Fasteners:			$BP_4 := 100.0\%$	$BP_5 := 0.0\%$
<u>Member Thickness:</u>	$m_{t1} := \frac{5}{16} \cdot \text{in}$	$m_{t2} := \frac{3}{8} \cdot \text{in}$	$m_{t3} := \frac{0.24}{1} \cdot \text{in}$	$m_{t4} := \frac{0.24}{1} \cdot \text{in}$	$m_{t5} := \frac{0}{0} \cdot \text{in}$

Note: The input format for live load forces are intended to be for a single truck or lane without impact. If live load forces already include distribution factors, set DF and m in previous page to 1. Live loads should not correspond to a specific live load case (i.e., maximum values for each member should be entered).

Vertical and Diagonal Member Components:

$X_1 := -15 \cdot \text{ft}$	$Y_1 := 10.5 \cdot \text{ft}$	$L_{p1} := \sqrt{(X_1^2 + Y_1^2)}$	$L_{p1} = 18.31 \text{ ft}$
$X_2 := 0 \cdot \text{ft}$	$Y_2 := 10.5 \cdot \text{ft}$	$L_{p2} := \sqrt{(X_2^2 + Y_2^2)}$	$L_{p2} = 10.5 \text{ ft}$
$X_3 := 15 \cdot \text{ft}$	$Y_3 := 10.5 \cdot \text{ft}$	$L_{p3} := \sqrt{(X_3^2 + Y_3^2)}$	$L_{p3} = 18.31 \text{ ft}$

Gusset Plate Properties:

Number of gusset plates:	$N := 2$	Thickness of gusset plate:	$g_t := \frac{1}{2} \cdot \text{in}$
Depth of gusset plate:	$g_d := 2.167 \cdot \text{ft}$	Width of gusset plate:	$g_w := 4.167 \cdot \text{ft}$
Depth of the chord member:	$C_{\text{depth}} := 10 \cdot \text{in}$	Width of vertical member:	$w_{\text{vertical}} := 6.25 \cdot \text{in}$
Unsupported length for Section A-A, B-B & C-C (Distance between bolts as shown in Figure 2):	$g_{ulAA} := 15.5 \cdot \text{in}$	$g_{ulBB} := 9.5625 \cdot \text{in}$	$g_{ulCC} := 23.0625 \cdot \text{in}$
Effective length factor:	$k := 1.2$ (ALFD 10.54.12)		
Corrosion of Gusset along the section (Average thickness):	$C_{AA} := 0.0 \cdot \text{in}$	$C_{BB} := 0.0 \cdot \text{in}$	$C_{CC} := 0.0 \cdot \text{in}$

Fastener details: Corrosion in the bolts should be accounted in the diameter of the bolt

Diameter of fasteners: $\phi_b := 0.75 \cdot \text{in}$ $A_{\text{bolt}} := \frac{\pi}{4} \phi_b^2$ $A_{\text{bolt}} = 0.442 \cdot \text{in}^2$

Alternate diameter of fasteners
 if more than one diameter is used: $\phi_{b2} := 0 \cdot \text{in}$ $A_{\text{bolt}2} := \frac{\pi}{4} \phi_{b2}^2$ $A_{\text{bolt}2} = 0 \cdot \text{in}^2$

In calculating the effective gross section yield resistance, if the area of the net section is less than 85% of the gross area, gross area is reduced by that % difference. $\beta := 0.15$

	Member (1)	Member (2)	Member (3)	Member (4)	Member (5)
Area of fasteners:	$A_{f1} := A_{\text{bolt}}$	$A_{f2} := A_{\text{bolt}}$	$A_{f3} := A_{\text{bolt}}$	$A_{f4} := A_{\text{bolt}}$	$A_{f5} := A_{\text{bolt}}$

Member connection details:

Fastener shear:

Number of fasteners:	$N_{f1} := 12$	$N_{f2} := 9$	$N_{f3} := 19$	$N_{f4} := 18$	$N_{f5} := 0$
Number of end fasteners :	$N_{\text{endf}1} := 2$	$N_{\text{endf}2} := 2$	$N_{\text{endf}3} := 3$	$N_{\text{endf}4} := 3$	$N_{\text{endf}5} := 0$
Number of shear planes per fastener:	$N_{\text{shear}1} := 1$	$N_{\text{shear}2} := 1$	$N_{\text{shear}3} := 1$	$N_{\text{shear}4} := 1$	$N_{\text{shear}5} := 0$

Bearing of fasteners:

Avg. clear distance between holes (spa. - $(\phi_b + 1/16)$):
 $L_{c1} := 1.675 \cdot \text{in}$ $L_{c2} := 1.563 \cdot \text{in}$ $L_{c3} := 1.780 \cdot \text{in}$ $L_{c4} := 1.767 \cdot \text{in}$ $L_{c5} := 0 \cdot \text{in}$

Avg. end distance from holes to edge of plate (Edge Distance - $1/2(\phi_b + 1/16)$):
 $L_{ce1} := 0.969 \cdot \text{in}$ $L_{ce2} := 1.16 \cdot \text{in}$ $L_{ce3} := 0.594 \cdot \text{in}$ $L_{ce4} := 1.594 \cdot \text{in}$ $L_{ce5} := 0 \cdot \text{in}$

Avg. end distance from holes to edge of truss member (Edge Distance - $1/2(\phi_b + 1/16)$):
 $L_{cem1} := 0.969 \cdot \text{in}$ $L_{cem2} := 1.16 \cdot \text{in}$ $L_{cem3} := 0.594 \cdot \text{in}$ $L_{cem4} := 1.594 \cdot \text{in}$ $L_{cem5} := 0 \cdot \text{in}$

Block Shear:

Length in tension, Lt: (Gusset Plate)
 $L_{t1} := 5.3125 \cdot \text{in}$ $L_{t2} := 4.62 \cdot \text{in}$ $L_{t3} := 6.74 \cdot \text{in}$ $L_{t4} := 6.70 \cdot \text{in}$ $L_{t5} := 0 \cdot \text{in}$

Length in tension, Ltm: (Truss Member)
 $L_{tm1} := 2.890 \cdot \text{in}$ $L_{tm2} := 2.663 \cdot \text{in}$ $L_{tm3} := 6.74 \cdot \text{in}$ $L_{tm4} := 6.70 \cdot \text{in}$ $L_{tm5} := 0 \cdot \text{in}$

Block Shear (continued):

Number of holes along Lt:	$N_{\text{holesT1}} := 2$	$N_{\text{holesT2}} := 2$	$N_{\text{holesT3}} := 3$	$N_{\text{holesT4}} := 3$	$N_{\text{holesT5}} := 0$
Length in shear, Lv1: (Gusset Plate)	$L_{v11} := 13.75 \cdot \text{in}$	$L_{v12} := 11.5 \cdot \text{in}$	$L_{v13} := 11.95 \cdot \text{in}$	$L_{v14} := 14.875 \cdot \text{in}$	$L_{v15} := 0 \cdot \text{in}$
Length in shear, Lvm1: (Truss Member)	$L_{vm11} := 13.75 \cdot \text{in}$	$L_{vm12} := 11.5 \cdot \text{in}$	$L_{vm13} := 11.95 \cdot \text{in}$	$L_{vm14} := 14.875 \cdot \text{in}$	$L_{vm15} := 0 \cdot \text{in}$
Number of holes along Lv1:	$N_{\text{holesV11}} := 6$	$N_{\text{holesV12}} := 5$	$N_{\text{holesV13}} := 5$	$N_{\text{holesV14}} := 6$	$N_{\text{holesV15}} := 0$
Length in shear, Lv2:	$L_{v21} := 13.75 \cdot \text{in}$	$L_{v22} := 8.4375 \cdot \text{in}$	$L_{v23} := 19.0625 \cdot \text{in}$		
Length in shear, Lvm2:	$L_{vm21} := 13.75 \cdot \text{in}$	$L_{vm22} := 8.4375 \cdot \text{in}$	$L_{vm23} := 19.0625$	$L_{vm24} := 0 \cdot \text{in}$	$L_{vm25} := 0 \cdot \text{in}$
Number of holes along Lv2:	$N_{\text{holesV21}} := 6$	$N_{\text{holesV22}} := 4$	$N_{\text{holesV23}} := 8$	$N_{\text{holesV24}} := 0$	$N_{\text{holesV25}} := 0$

Gross Section Yielding:

Whitmore section length:	$L_{ws1} := 17.875 \cdot \text{in}$	$L_{ws2} := 13.75 \cdot \text{in}$	$L_{ws3} := 15 \cdot \text{in}$	$L_{ws4} := 16.625 \cdot \text{in}$	$L_{ws5} := 0 \cdot \text{in}$
Unbraced length:	$L_{ub1} := 11.5625 \cdot \text{in}$	$L_{ub2} := 3.0 \cdot \text{in}$	$L_{ub3} := 4.81 \cdot \text{in}$	$L_{ub4} := 3.13 \cdot \text{in}$	$L_{ub5} := 0 \cdot \text{in}$

Member Fracture:

$A_{\text{net1}} := 6.17 \cdot \text{in}^2$	$A_{\text{net2}} := 6.93 \cdot \text{in}^2$	$A_{\text{net3}} := 7.15 \cdot \text{in}^2$	$A_{\text{net4}} := 6.96 \cdot \text{in}^2$	$A_{\text{net5}} := 0 \cdot \text{in}^2$
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Average thickness of corrosion (inches) to the gusset plate at the bolt locations in each member.

$C_1 := 0.0 \cdot \text{in}$	$C_2 := 0.0 \cdot \text{in}$	$C_3 := 0.0 \cdot \text{in}$	$C_4 := 0.0 \cdot \text{in}$	$C_5 := 0.0 \cdot \text{in}$
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Average thickness of corrosion (inches) to the truss member at the bolt locations in each member.

$C_{m1} := 0.0 \cdot \text{in}$	$C_{m2} := 0.0 \cdot \text{in}$	$C_{m3} := 0.12 \cdot \text{in}$	$C_{m4} := 0 \cdot \text{in}$	$C_{m5} := 0 \cdot \text{in}$
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ALLOWABLE STRESSES:

Truss Member Properties:

Fy - Member:	$F_{ym1} := 30000\text{-psi}$	$F_{ym2} := 30000\text{-psi}$	$F_{ym3} := 30000\text{-psi}$	$F_{ym4} := 30000\text{-psi}$	$F_{ym5} := 30000\text{-psi}$
Fu - Member:	$F_{um1} := 60000\text{-psi}$	$F_{um2} := 60000\text{-psi}$	$F_{um3} := 60000\text{-psi}$	$F_{um4} := 60000\text{-psi}$	$F_{um5} := 60000\text{-psi}$

Gusset Plate Properties:

- $F_y := 30000\text{-psi}$ For members with unknown properties, see Table 6.6.2.1-2 in AASHTO Manual for Condition Evaluation of Bridges.
- $F_U := 60000\text{psi}$ Specified minimum tensile strength of the connected material

Following are the four levels of rating in LFD method. Dead load and live load factors vary for these ratings:

<u>Case</u>		<u>Dead Load Factors</u>	<u>Live Load Factors</u>
1 -Inventory	$\sigma_1 := F_y$	$DL_1 := 1.3$	$LL_1 := 2.17$
2 -Operating	$\sigma_2 := F_y$	$DL_2 := 1.3$	$LL_2 := 1.3$

In Axial Tension: $f_{ten} := F_y$

In Shear: $f_v := \frac{F_y}{1.35\sqrt{3}}$

Modulus of elasticity: $E_s := 29000000\text{-psi}$

Design Strength of Fasteners: $\sigma_{Design} := 18000\text{-psi}$

Shown for Power Driven Rivets ASTM A502, Shear - Grade 2, (ALFD Table 10.56A)

Connection Analysis:

FORCE CONVENTION: TENSION (-)
 COMPRESSION (+).

$$P_{1DL} := P1_{DL} \quad P_{1LL} := m \cdot DF \cdot (1 + IM) \cdot P1_{LL}$$

$$P_{1DL} = -51.28 \cdot \text{kip} \quad P_{1LL} = -79.12 \cdot \text{kip}$$



$M1_T =$ "MEMBER IS IN TENSION, TENSION CHECK IS REQUIRED"

Analysis of Gusset Plate @ Diagonal (Member 1): (TENSION CHECK)

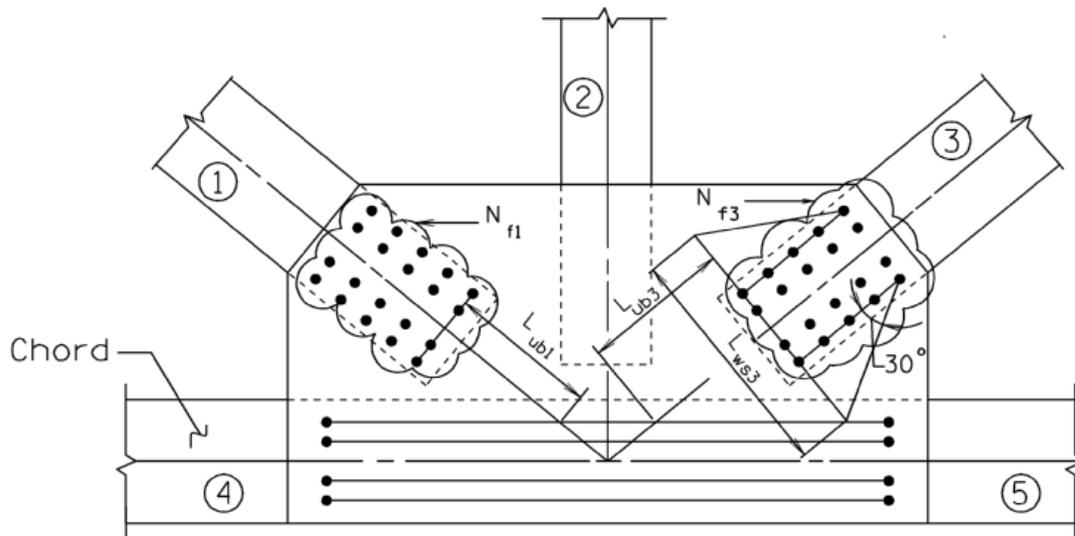


Figure-3

Fastener Capacity: (Tension or Compression)

Shear in fasteners:

$$\text{Shear Area: } A_{\text{shear}} := N_{f1} \cdot A_{\text{bolt}} \quad A_{\text{shear}} = 5.3 \cdot \text{in}^2$$

$$\text{Shear Capacity: } C_{\text{shear}} := \sigma_{\text{Design}} \cdot A_{\text{shear}} \cdot N \cdot N_{\text{shear1}} \quad C_{\text{shear}} = 191 \cdot \text{kip}$$

Bearing of fasteners (INTERIOR) (ALFD 10.56.1.3):

$j := 1..2$

$$\phi R := \min[0.9 \cdot L_{c1} \cdot (g_t - C_1) \cdot F_U, 1.8 \cdot \phi_b \cdot (g_t - C_1) \cdot F_U] \quad \phi R = 40.5 \cdot \text{kip} \quad (\text{ALFD 10-166b})$$

Fastener Capacity:

$$C_{\text{bearing}} := (N_{f1} - N_{\text{endf1}}) \cdot \phi R \quad C_{\text{bearing}} = 405 \cdot \text{kip}$$

Bearing of fasteners (END) (AASHTO 10.56.1.3):

$$\phi R_{\text{end}} := \min[0.9 \cdot L_{ce1} \cdot (g_t - C_1) \cdot F_U, 1.8 \cdot \phi_b \cdot (g_t - C_1) \cdot F_U] \quad \phi R_{\text{end}} = 26.16 \cdot \text{kip} \quad (\text{ALFD 10-166b})$$

Fastener Capacity:

$$C_{\text{endbearing}} := N_{\text{endf1}} \cdot \phi R_{\text{end}} \quad C_{\text{endbearing}} = 52 \cdot \text{kip}$$

Bearing of fasteners - Controlling

$$C_{\text{controlling}} := \min[C_{\text{shear}} \cdot 2 \cdot (C_{\text{bearing}} + C_{\text{endbearing}})]$$

$$C_{\text{controlling}} = 190.85 \cdot \text{kip}$$

Ratings (Tons)

$$R_{\text{Fastener}1_j} := \frac{0.9 C_{\text{controlling}} - DL_j \cdot |P_{1DL}|}{LL_j \cdot |P_{1LL}|} \cdot HS$$

	1	
1	22.0	· Ton
2	36.8	

Rating Factors

$$RF_{\text{Fastener}1_j} := \frac{0.9 C_{\text{controlling}} - DL_j \cdot |P_{1DL}|}{LL_j \cdot |P_{1LL}|}$$

	1
1	0.6
2	1.0

Block Shear Capacity:

$$A_{\text{Shear}} := \left[L_{v11} - \left(N_{\text{holes}V11} - \frac{1}{2} \right) \cdot \left(\phi_b + \frac{1}{8} \cdot \text{in} \right) \right] + \left[L_{v21} - \left(N_{\text{holes}V21} - \frac{1}{2} \right) \cdot \left(\phi_b + \frac{1}{8} \cdot \text{in} \right) \right] \cdot [(g_t - C_1) \cdot N]$$

$$A_{\text{Shear}} = 17.88 \cdot \text{in}^2$$

$$A_{\text{Tension}} := \left[L_{t1} - \left(N_{\text{holes}T1} - 1 \right) \cdot \left(\phi_b + \frac{1}{8} \cdot \text{in} \right) \right] \cdot [(g_t - C_1) \cdot N] \quad A_{\text{Tension}} = 4.44 \cdot \text{in}^2$$

Block Shear Capacity:

$$C := \begin{cases} 0.85 [0.58 \cdot F_y \cdot [(L_{v11} + L_{v21}) \cdot (g_t - C_1) \cdot N] + F_U \cdot A_{\text{Tension}}] & \text{if } (A_{\text{Tension}}) \geq 0.58 \cdot A_{\text{Shear}} \\ 0.85 [0.58 \cdot F_U \cdot A_{\text{Shear}} + F_y \cdot [L_{t1} \cdot (g_t - C_1) \cdot N]] & \text{otherwise} \end{cases} \quad C = 664 \cdot \text{kip}$$

Ratings (Tons)

$$R_{Tens.block1_j} := \text{if} \left[P_{1DL} > 0, "NA", \frac{0.9C - DL_j \cdot |P_{1DL}|}{LL_j \cdot |P_{1LL}|} \cdot (HS) \right]$$

$$R_{Tens.block1} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 111.4 \\ \hline 2 & 185.9 \\ \hline \end{array} \cdot \text{Ton}$$

Rating Factors

$$RF_{Tens.block1_j} := \text{if} \left(P_{1DL} > 0, "NA", \frac{0.9C - DL_j \cdot |P_{1DL}|}{LL_j \cdot |P_{1LL}|} \right)$$

$$RF_{Tens.block1} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 3.1 \\ \hline 2 & 5.2 \\ \hline \end{array}$$

Tension Capacity of the Gusset plate (Whitmore Section):

$$A_e := \min \left[L_{ws1} \cdot (g_t - C_1), \left[L_{ws1} - (N_{holesT1}) \cdot \left(\phi_b + \frac{1}{8} \cdot \text{in} \right) \right] \cdot (g_t - C_1) + \beta \cdot [L_{ws1} \cdot (g_t - C_1)] \right]$$

$$A_e = 8.94 \cdot \text{in}^2$$

Stress due to Dead Load: $\sigma_{DL} := \frac{P_{1DL}}{N \cdot A_e} \quad \sigma_{DL} = -2869 \cdot \text{psi}$

Stress due to Live Load: $\sigma_{LL} := \frac{P_{1LL}}{N \cdot A_e} \quad \sigma_{LL} = -4426 \cdot \text{psi}$

Ratings (Tons)

$$R_{Yielding1_j} := \text{if} \left[P_{1DL} > 0, "NA", \frac{0.9F_y - DL_j \cdot |\sigma_{DL}|}{LL_j \cdot |\sigma_{LL}|} \cdot (HS) \right]$$

$$R_{Yielding1} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 87.2 \\ \hline 2 & 145.6 \\ \hline \end{array} \cdot \text{Ton}$$

Rating Factors

$$RF_{Yielding1_j} := \text{if} \left(P_{1DL} > 0, "NA", \frac{0.9F_y - DL_j \cdot |\sigma_{DL}|}{LL_j \cdot |\sigma_{LL}|} \right)$$

$$RF_{Yielding1} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 2.4 \\ \hline 2 & 4.0 \\ \hline \end{array}$$



$M1_C = \text{"MEMBER IS IN TENSION, COMPRESSION CHECK IS NOT REQUIRED"}$

Analysis of Gusset Plate @ Diagonal (Member 1): (COMPRESSION CHECK)

Note: See Tension Check for Fastener Capacity

Compression Capacity of the Gusset plate (Whitmore Section):

Stress due to Dead Load: $\sigma_{DL} := \frac{P_{1DL}}{N \cdot L_{ws1} \cdot (g_t - C_1)} \quad \sigma_{DL} = -2869 \cdot \text{psi}$

Stress due to Live Load: $\sigma_{LL} := \frac{P_{1LL}}{N \cdot L_{ws1} \cdot (g_t - C_1)} \quad \sigma_{LL} = -4426 \cdot \text{psi}$

Allowable compressive stresses (ALFD 10.54.1.1): FHWA Guidelines calculate the unbraced length as the average of three distances. Using the unbraced length along the line of action, as done here, should provide conservative ratings.

$L := L_{ub1}$ $k = 1.20$ $r := \sqrt{\frac{(g_t - C_1)^2}{12}} \quad r = 0.14 \cdot \text{in}$

$c_c := \sqrt{\frac{2 \cdot (\pi)^2 \cdot E_s}{F_y}} \quad c_c = 138.1 \quad \frac{k \cdot L}{r} = 96.1$

$$F_{aLd} := \begin{cases} 0.85 F_y \cdot \left[1 - \frac{\left(\frac{k \cdot L}{r}\right)^2 \cdot F_y}{4 \cdot (\pi)^2 \cdot E_s} \right] & \text{if } \frac{k \cdot L}{r} \leq c_c \\ 0.85 \cdot \frac{(\pi)^2 \cdot E_s}{\left(\frac{k \cdot L}{r}\right)^2} & \text{otherwise} \end{cases}$$

$F_{aLd} = 19325 \cdot \text{psi}$

Ratings (Tons)

$$R_{\text{Buckling}1_j} := \text{if} \left[P_{1DL} < 0, \text{"NA"}, \frac{0.9 F_{aLd} - DL_j \cdot |\sigma_{DL}|}{LL_j \cdot |\sigma_{LL}|} \cdot (\text{HS}) \right]$$

$R_{\text{Buckling}1} =$

	1
1	"NA"
2	"NA"

 $\cdot \text{Ton}$

Rating Factors

$$RF_{\text{Buckling}1_j} := \text{if} \left(P_{1DL} < 0, \text{"NA"}, \frac{0.9 F_{aLd} - DL_j \cdot |\sigma_{DL}|}{LL_j \cdot |\sigma_{LL}|} \right)$$

$RF_{\text{Buckling}1} =$

	1
1	"NA"
2	"NA"

M1_T = "MEMBER IS IN TENSION, TENSION CHECK IS REQUIRED"

Analysis of Diagonal Truss Member (Member 1):

Fastener Capacity:

Note: Shear in Fasteners is the same as in the Gusset Plate (See Gusset Plate Calcs)

Bearing of fasteners (INTERIOR) (ALFD 10.56.1.3): j := 1..2

$$\phi R_{\text{member}} := \min[0.9 \cdot L_{c1} \cdot (m_{t1} - C_{m1}) \cdot F_{um1}, 1.8 \cdot \phi_b \cdot (m_{t1} - C_{m1}) \cdot F_{um1}] \quad (\text{ALFD 10-166b})$$

$$\phi R_{\text{member}} = 25.31 \cdot \text{kip}$$

Fastener Capacity:

$$C_{\text{mbearing}} := (N_{f1} - N_{\text{endf1}}) \cdot \phi R_{\text{member}} \quad C_{\text{mbearing}} = 253 \cdot \text{kip}$$

Bearing of fasteners (END) (ALFD 10.56.1.3):

$$\phi R_{\text{memberend}} := \min[0.9 \cdot L_{\text{cem1}} \cdot (m_{t1} - C_{m1}) \cdot F_{um1}, 1.8 \cdot \phi_b \cdot (m_{t1} - C_{m1}) \cdot F_{um1}] \quad (\text{ALFD 10-166b})$$

$$\phi R_{\text{memberend}} = 16.35 \cdot \text{kip}$$

Fastener Capacity:

$$C_{\text{mendbearing}} := N_{\text{endf1}} \cdot \phi R_{\text{memberend}} \quad C_{\text{mendbearing}} = 33 \cdot \text{kip}$$

Fasteners - Controlling

$$C_{\text{mcontrolling}} := \min[C_{\text{shear}}, 2 \cdot (C_{\text{mbearing}} + C_{\text{mendbearing}})]$$

$$C_{\text{mcontrolling}} = 190.85 \cdot \text{kip}$$

Ratings (Tons)

$$R_{\text{mFastener}1_j} := \frac{0.9 C_{\text{mcontrolling}} - DL_j \cdot |P_{1DL}|}{LL_j \cdot |P_{1LL}|} \cdot \text{HS}$$

$$R_{\text{mFastener}1} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 22.0 \\ \hline 2 & 36.8 \\ \hline \end{array} \cdot \text{Ton}$$

Rating Factors

$$RF_{\text{mFastener}1_j} := \frac{0.9 C_{\text{mcontrolling}} - DL_j \cdot |P_{1DL}|}{LL_j \cdot |P_{1LL}|}$$

$$RF_{\text{mFastener}1} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 0.6 \\ \hline 2 & 1.0 \\ \hline \end{array}$$

Block Shear Capacity:

$$A_{mShear} := \left[\left[L_{vm11} - \left(N_{holesV11} - \frac{1}{2} \right) \cdot \left(\phi_b + \frac{1}{8} \cdot \text{in} \right) \right] + \left[L_{vm21} - \left(N_{holesV21} - \frac{1}{2} \right) \cdot \left(\phi_b + \frac{1}{8} \cdot \text{in} \right) \right] \right] \cdot \left[(m_{t1} - C_{m1}) \cdot N \right]$$

$$A_{mShear} = 11.17 \cdot \text{in}^2$$

$$A_{mTension} := \left[L_{tm1} - (N_{holesT1} - 1) \cdot \left(\phi_b + \frac{1}{8} \cdot \text{in} \right) \right] \cdot \left[(m_{t1} - C_{m1}) \cdot N \right] \quad A_{mTension} = 1.26 \cdot \text{in}^2$$

Block Shear Capacity:

$$C_{BlockShear} := \begin{cases} 0.85 \left[0.58 \cdot F_{ym1} \cdot \left[(L_{vm11} + L_{vm21}) \cdot (m_{t1} - C_{m1}) \cdot N \right] + F_{um1} \cdot A_{mTension} \right] & \text{if } (A_{mTension}) \geq 0.58 \cdot A_{mShear} \\ 0.85 \cdot \left[0.58 \cdot F_{um1} \cdot A_{mShear} + F_{ym1} \cdot \left[L_{tm1} \cdot (m_{t1} - C_{m1}) \cdot N \right] \right] & \text{otherwise} \end{cases}$$

$$C_{BlockShear} = 377 \cdot \text{kip}$$

$$C_{Fracture} := F_{um1} \cdot A_{net1} \quad C_{Fracture} = 370.2 \cdot \text{kip}$$

$$C_m := \min(C_{BlockShear}, C_{Fracture}) \quad C_m = 370.2 \cdot \text{kip}$$

Ratings (Tons)

$$R_{mTen.block1j} := \text{if} \left[P_{1DL} > 0, "NA", \frac{0.9C_m - DL_j \cdot |P_{1DL}|}{LL_j \cdot |P_{1LL}|} \cdot (HS) \right] \quad R_{mTen.block1} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 55.9 \\ \hline 2 & 93.3 \\ \hline \end{array} \cdot \text{Ton}$$

Rating Factors

$$RF_{mTen.block1j} := \text{if} \left(P_{1DL} > 0, "NA", \frac{0.9C_m - DL_j \cdot |P_{1DL}|}{LL_j \cdot |P_{1LL}|} \right) \quad RF_{mTen.block1} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 1.6 \\ \hline 2 & 2.6 \\ \hline \end{array}$$

$$P_{2DL} := P_{2DL} \quad P_{2LL} := m \cdot DF \cdot (1 + IM) \cdot P_{2LL}$$

$$P_{2DL} = -26.73 \cdot \text{kip} \quad P_{2LL} = -47.17 \cdot \text{kip}$$



M2_T = "MEMBER IS IN TENSION, TENSION CHECK IS REQUIRED"

Analysis of Gusset Plate @ Vertical (Member 2): (TENSION CHECK)

Fastener Capacity:

Shear in fasteners:

$$\text{Shear Area: } A_{\text{shear}} := N_{f2} \cdot A_{\text{bolt}} \quad A_{\text{shear}} = 3.98 \cdot \text{in}^2$$

$$\text{Shear Capacity: } C_{\text{shear}} := \sigma_{\text{Design}} \cdot A_{\text{shear}} \cdot N \cdot N_{\text{shear2}} \quad C_{\text{shear}} = 143 \cdot \text{kip}$$

Bearing of fasteners (INTERIOR) (ALFD 10.56.1.3):

$$j := 1..2$$

$$\phi R := \min[0.9 \cdot L_{c2} \cdot (g_t - C_2) \cdot F_U, 1.8 \cdot \phi_b \cdot (g_t - C_2) \cdot F_U] \quad \phi R = 40.5 \cdot \text{kip} \quad (\text{ALFD 10-166b})$$

$$\text{Fastener Capacity: } C_{\text{bearing}} := (N_{f2} - N_{\text{endf2}}) \cdot \phi R \quad C_{\text{bearing}} = 283 \cdot \text{kip}$$

Bearing of fasteners (END) (ALFD 10.56.1.3):

$$\phi R_{\text{end}} := \min[0.9 \cdot L_{ce2} \cdot (g_t - C_2) \cdot F_U, 1.8 \cdot \phi_b \cdot (g_t - C_2) \cdot F_U] \quad \phi R_{\text{end}} = 31.32 \cdot \text{kip} \quad (\text{ALFD 10-166b})$$

$$\text{Fastener Capacity: } C_{\text{endbearing}} := N_{\text{endf2}} \cdot \phi R_{\text{end}} \quad C_{\text{endbearing}} = 63 \cdot \text{kip}$$

$$\text{Bearing of fasteners - Controlling } C_{\text{controlling}} := \min[C_{\text{shear}} \cdot 2 \cdot (C_{\text{bearing}} + C_{\text{endbearing}})]$$

$$C_{\text{controlling}} = 143.14 \cdot \text{kip}$$

Ratings (Tons)

$$R_{\text{Fastener2}_j} := \frac{0.9 C_{\text{controlling}} - DL_j \cdot |P_{2DL}|}{LL_j \cdot |P_{2LL}|} \cdot HS$$

$$R_{\text{Fastener2}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 33.1 \\ \hline 2 & 55.2 \\ \hline \end{array} \cdot \text{Ton}$$

Rating Factors

$$RF_{\text{Fastener2}_j} := \frac{0.9 C_{\text{controlling}} - DL_j \cdot |P_{2DL}|}{LL_j \cdot |P_{2LL}|}$$

$$RF_{\text{Fastener2}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 0.9 \\ \hline 2 & 1.5 \\ \hline \end{array}$$

Block Shear Capacity:

$$A_{\text{Shear}} := \left[L_{v12} - \left(N_{\text{holes}V12} - \frac{1}{2} \right) \cdot \left(\phi_b + \frac{1}{8} \cdot \text{in} \right) \right] + \left[L_{v22} - \left(N_{\text{holes}V22} - \frac{1}{2} \right) \cdot \left(\phi_b + \frac{1}{8} \cdot \text{in} \right) \right] \cdot \left[(g_t - C_2) \cdot N \right]$$

$$A_{\text{Shear}} = 12.94 \cdot \text{in}^2$$

$$A_{\text{Tension}} := \left[L_{t2} - (N_{\text{holes}T2} - 1) \cdot \left(\phi_b + \frac{1}{8} \cdot \text{in} \right) \right] \cdot \left[(g_t - C_2) \cdot N \right] \quad A_{\text{Tension}} = 3.75 \cdot \text{in}^2$$

Block Shear Capacity:

$$C := \begin{cases} 0.85 \left[0.58 \cdot F_y \cdot \left[(L_{v12} + L_{v22}) \cdot (g_t - C_2) \cdot N \right] + F_U \cdot A_{\text{Tension}} \right] & \text{if } (A_{\text{Tension}}) \geq 0.58 \cdot A_{\text{Shear}} \\ 0.85 \cdot \left[0.58 \cdot F_U \cdot A_{\text{Shear}} + F_y \cdot \left[L_{t2} \cdot (g_t - C_2) \cdot N \right] \right] & \text{otherwise} \end{cases} \quad C = 501 \cdot \text{kip}$$

Ratings (Tons)

$$R_{\text{Ten.block2}_j} := \text{if} \left[P_{2\text{DL}} > 0, \text{"NA"}, \frac{0.9C - DL_j \cdot |P_{2\text{DL}}|}{LL_j \cdot |P_{2\text{LL}}|} \cdot (\text{HS}) \right] \quad R_{\text{Ten.block2}} = \begin{matrix} & & 1 \\ 1 & 146.2 & \\ 2 & 244.0 & \end{matrix} \cdot \text{Ton}$$

Rating Factors

$$RF_{\text{Ten.block2}_j} := \text{if} \left(P_{2\text{DL}} > 0, \text{"NA"}, \frac{0.9C - DL_j \cdot |P_{2\text{DL}}|}{LL_j \cdot |P_{2\text{LL}}|} \right) \quad RF_{\text{Ten.block2}} = \begin{matrix} & & 1 \\ 1 & 4.1 & \\ 2 & 6.8 & \end{matrix}$$

Tension Capacity of the Gusset plate (Whitmore Section):

$$A_e := \min \left[L_{ws2} \cdot (g_t - C_2), \left[L_{ws2} - (N_{\text{holes}T2}) \cdot \left(\phi_b + \frac{1}{8} \cdot \text{in} \right) \right] \cdot (g_t - C_2) + \beta \cdot \left[L_{ws2} \cdot (g_t - C_2) \right] \right]$$

$$A_e = 6.87 \cdot \text{in}^2$$

Stress due to Dead Load: $\sigma_{\text{DL}} := \frac{P_{2\text{DL}}}{N \cdot A_e} \quad \sigma_{\text{DL}} = -1944 \cdot \text{psi}$

Stress due to Live Load: $\sigma_{\text{LL}} := \frac{P_{2\text{LL}}}{N \cdot A_e} \quad \sigma_{\text{LL}} = -3431 \cdot \text{psi}$



Ratings (Tons)

$$R_{Yielding2_j} := \text{if} \left[P_{2DL} > 0, "NA", \frac{0.9F_y - DL_j \cdot |\sigma_{DL}|}{LL_j \cdot |\sigma_{LL}|} \cdot (HS) \right]$$

	1	
$R_{Yielding2} =$	1	118.3 · Ton
	2	197.6

Rating Factors

$$RF_{Yielding2_j} := \text{if} \left(P_{2DL} > 0, "NA", \frac{0.9F_y - DL_j \cdot |\sigma_{DL}|}{LL_j \cdot |\sigma_{LL}|} \right)$$

	1
$RF_{Yielding2} =$	1
	3.3
	2
	5.5



M2_C = "MEMBER IS IN TENSION, COMPRESSION CHECK IS NOT REQUIRED"

Analysis of Gusset Plate @ Vertical (Member 2): (COMPRESSION CHECK)

Note: See Tension Check for Fastener Capacity

Compression Capacity of the Gusset plate (Whitmore Section):

Stress due to Dead Load: $\sigma_{DL} := \frac{P_{2DL}}{N \cdot L_{ws2} \cdot (g_t - C_2)}$ $\sigma_{DL} = -1944 \cdot \text{psi}$

Stress due to Live Load: $\sigma_{LL} := \frac{P_{2LL}}{N \cdot L_{ws2} \cdot (g_t - C_2)}$ $\sigma_{LL} = -3431 \cdot \text{psi}$

Allowable compressive stresses (ALFD 10.54.1.1): FHWA Guidelines calculate the unbraced length as the average of three distances. Using the unbraced length along the line of action, as done here, should provide conservative ratings.

$L := L_{ub2}$ $k = 1.20$ $r := \sqrt{\frac{(g_t - C_2)^2}{12}}$ $r = 0.14 \cdot \text{in}$
 $c_c := \sqrt{\frac{2 \cdot (\pi)^2 \cdot E_s}{F_y}}$ $c_c = 138.1$ $\frac{k \cdot L}{r} = 24.9$

$$F_{aLd} := \begin{cases} 0.85 F_y \cdot \left[1 - \frac{\left(\frac{k \cdot L}{r} \right)^2 \cdot F_y}{4 \cdot (\pi)^2 \cdot E_s} \right] & \text{if } \frac{k \cdot L}{r} \leq c_c \\ 0.85 \cdot \frac{(\pi)^2 \cdot E_s}{\left(\frac{k \cdot L}{r} \right)^2} & \text{otherwise} \end{cases}$$

$F_{aLd} = 25084 \cdot \text{psi}$

Ratings (Tons)

$$R_{\text{Buckling}2_j} := \text{if} \left[P_{2DL} < 0, "NA", \frac{0.9 F_{aLd} - DL_j \cdot |\sigma_{DL}|}{LL_j \cdot |\sigma_{LL}|} \cdot (HS) \right]$$

	1
1	"NA"
2	"NA"

·Ton

Rating Factors

$$RF_{\text{Buckling}2_j} := \text{if} \left(P_{2DL} < 0, "NA", \frac{0.9 F_{aLd} - DL_j \cdot |\sigma_{DL}|}{LL_j \cdot |\sigma_{LL}|} \right)$$

	1
1	"NA"
2	"NA"

M2_T = "MEMBER IS IN TENSION, TENSION CHECK IS REQUIRED"

Analysis of Vertical Truss Member (Member 2):

Fastener Capacity:

Note: Shear in Fasteners is the same as in the Gusset Plate (See Gusset Plate Calcs)

Bearing of fasteners (INTERIOR) (ALFD 10.56.1.3): j := 1..2

$$\phi R_{\text{member}} := \min[0.9 \cdot L_{c2} \cdot (m_{t2} - C_{m2}) \cdot F_{um2}, 1.8 \cdot \phi_b \cdot (m_{t2} - C_{m2}) \cdot F_{um2}] \quad (\text{ALFDO 10-166b})$$

$$\phi R_{\text{member}} = 30.37 \cdot \text{kip}$$

Fastener Capacity: $C_{\text{mbearing}} := (N_{f2} - N_{\text{end}f2}) \cdot \phi R_{\text{member}}$ C_{mbearing} = 212.625 · kip

Bearing of fasteners (END) (ALFD 10.56.1.3):

$$\phi R_{\text{memberend}} := \min[0.9 \cdot L_{\text{cem}2} \cdot (m_{t2} - C_{m2}) \cdot F_{um2}, 1.8 \cdot \phi_b \cdot (m_{t2} - C_{m2}) \cdot F_{um2}] \quad (\text{ALFD 10-166b})$$

$$\phi R_{\text{memberend}} = 23.49 \cdot \text{kip}$$

Fastener Capacity: $C_{\text{mendbearing}} := N_{\text{end}f2} \cdot \phi R_{\text{memberend}}$ C_{mendbearing} = 46.98 · kip

Bearing of fasteners - Controlling $C_{\text{mcontrolling}} := \min[C_{\text{shear}}, 2 \cdot (C_{\text{mbearing}} + C_{\text{mendbearing}})]$

C_{mcontrolling} = 143.14 · kip

Ratings (Tons)

$$R_{\text{mFastener}2_j} := \frac{0.9 C_{\text{mcontrolling}} - DL_j \cdot |P_{2DL}|}{LL_j \cdot |P_{2LL}|} \cdot \text{HS}$$

$$R_{\text{mFastener}2} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 33.1 \\ \hline 2 & 55.2 \\ \hline \end{array} \cdot \text{Ton}$$

Rating Factors

$$RF_{\text{mFastener}2_j} := \frac{0.9 C_{\text{mcontrolling}} - DL_j \cdot |P_{2DL}|}{LL_j \cdot |P_{2LL}|}$$

$$RF_{\text{mFastener}2} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 0.9 \\ \hline 2 & 1.5 \\ \hline \end{array}$$

Block Shear Capacity:

$$A_{mShear} := \left[\left[L_{vm12} - \left(N_{holesV12} - \frac{1}{2} \right) \cdot \left(\phi_b + \frac{1}{8} \cdot \text{in} \right) \right] + \left[L_{vm22} - \left(N_{holesV22} - \frac{1}{2} \right) \cdot \left(\phi_b + \frac{1}{8} \cdot \text{in} \right) \right] \right] \cdot \left[(m_{t2} - C_{m2}) \cdot N \right]$$

$$A_{mShear} = 9.7 \cdot \text{in}^2$$

$$A_{mTension} := \left[L_{tm2} - (N_{holesT2} - 1) \cdot \left(\phi_b + \frac{1}{8} \cdot \text{in} \right) \right] \cdot \left[(m_{t2} - C_{m2}) \cdot N \right] \quad A_{mTension} = 1.34 \cdot \text{in}^2$$

Block Shear Capacity:

$$C_{BlockShear} := \begin{cases} 0.85 \left[0.58 \cdot F_{ym2} \cdot \left[(L_{vm12} + L_{vm22}) \cdot (m_{t2} - C_{m2}) \cdot N \right] + F_{um2} \cdot A_{mTension} \right] & \text{if } (A_{mTension}) \geq 0.58 \cdot A_{mShear} \\ 0.85 \cdot \left[0.58 \cdot F_{um2} \cdot A_{mShear} + F_{ym2} \cdot \left[L_{tm2} \cdot (m_{t2} - C_{m2}) \cdot N \right] \right] & \text{otherwise} \end{cases}$$

$$C_{BlockShear} = 338 \cdot \text{kip}$$

$$C_{Fracture} := F_{um2} \cdot A_{net2} \quad C_{Fracture} = 415.8 \cdot \text{kip}$$

$$C_m := \min(C_{BlockShear}, C_{Fracture}) \quad C_m = 337.95 \cdot \text{kip}$$

Ratings (Tons)

$$R_{mTen.block2_j} := \text{if} \left[P_{2DL} > 0, \text{"NA"}, \frac{0.9C_m - DL_j \cdot |P_{2DL}|}{LL_j \cdot |P_{2LL}|} \cdot (HS) \right] \quad R_{mTen.block2} = \begin{matrix} & & 1 \\ 1 & 94.8 & \\ 2 & 158.2 & \end{matrix} \cdot \text{Ton}$$

Rating Factors

$$RF_{mTen.block2_j} := \text{if} \left(P_{2DL} > 0, \text{"NA"}, \frac{0.9C_m - DL_j \cdot |P_{2DL}|}{LL_j \cdot |P_{2LL}|} \right) \quad RF_{mTen.block2} = \begin{matrix} & & 1 \\ 1 & 2.6 & \\ 2 & 4.4 & \end{matrix}$$

$$P_{3DL} := P_{3DL} \quad P_{3LL} := m \cdot DF \cdot (1 + IM) \cdot P_{3LL}$$

$$P_{3DL} = 101.53 \cdot \text{kip} \quad P_{3LL} = 112.39 \cdot \text{kip}$$



M3_T = "MEMBER IS IN COMPRESSION, TENSION CHECK IS NOT REQUIRED"

Analysis of Gusset Plate @ Diagonal (Member 3): (TENSION CHECK)

Fastener Capacity:

Shear in fasteners:

$$\text{Shear Area: } A_{\text{shear}} := N_{f3} \cdot A_{\text{bolt}} \quad A_{\text{shear}} = 8.39 \cdot \text{in}^2$$

$$\text{Shear Capacity: } C_{\text{shear}} := \sigma_{\text{Design}} \cdot A_{\text{shear}} \cdot N_{\text{shear}3} \quad C_{\text{shear}} = 302 \cdot \text{kip}$$

Bearing of fasteners (INTERIOR) (AASHTO 10.56.1.3): $j := 1..2$

$$\phi R := \min[0.9 \cdot L_{ce3} \cdot (g_t - C_3) \cdot F_U, 1.8 \cdot \phi_b \cdot (g_t - C_3) \cdot F_U] \quad \phi R = 40.5 \cdot \text{kip} \quad (\text{ALFD 10-166b})$$

$$\text{Fastener Capacity: } C_{\text{bearing}} := (N_{f3} - N_{\text{end}f3}) \cdot \phi R \quad C_{\text{bearing}} = 648 \cdot \text{kip}$$

Bearing of fasteners (END) (ALFD 10.56.1.3):

$$\phi R_{\text{end}} := \min[0.9 \cdot L_{ce3} \cdot (g_t - C_3) \cdot F_U, 1.8 \cdot \phi_b \cdot (g_t - C_3) \cdot F_U] \quad \phi R_{\text{end}} = 16.04 \cdot \text{kip} \quad (\text{ALFD 10-166b})$$

$$\text{Fastener Capacity: } C_{\text{endbearing}} := N_{\text{end}f3} \cdot \phi R_{\text{end}} \quad C_{\text{endbearing}} = 48.114 \cdot \text{kip}$$

$$\text{Bearing of fasteners - Controlling } C_{\text{controlling}} := \min[C_{\text{shear}} \cdot 2 \cdot (C_{\text{bearing}} + C_{\text{endbearing}})]$$

$$C_{\text{controlling}} = 302.18 \cdot \text{kip}$$

Ratings (Tons)

$$R_{\text{Fastener}3_j} := \frac{0.9 C_{\text{controlling}} - DL_j \cdot |P_{3DL}|}{LL_j \cdot |P_{3LL}|} \cdot HS$$

$$R_{\text{Fastener}3} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 20.7 \\ \hline 2 & 34.5 \\ \hline \end{array} \cdot \text{Ton}$$

Rating Factors

$$RF_{\text{Fastener}3_j} := \frac{0.9 C_{\text{controlling}} - DL_j \cdot |P_{3DL}|}{LL_j \cdot |P_{3LL}|}$$

$$RF_{\text{Fastener}3} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 0.6 \\ \hline 2 & 1.0 \\ \hline \end{array}$$

Block Shear Capacity:

$$A_{\text{Shear}} := \left[L_{v13} - \left(N_{\text{holes}V13} - \frac{1}{2} \right) \cdot \left(\phi_b + \frac{1}{8} \cdot \text{in} \right) \right] + \left[L_{v23} - \left(N_{\text{holes}V23} - \frac{1}{2} \right) \cdot \left(\phi_b + \frac{1}{8} \cdot \text{in} \right) \right] \cdot \left[(g_t - C_3) \cdot N \right]$$

$$A_{\text{Shear}} = 20.51 \cdot \text{in}^2$$

$$A_{\text{Tension}} := \left[L_{t3} - (N_{\text{holes}T3} - 1) \cdot \left(\phi_b + \frac{1}{8} \cdot \text{in} \right) \right] \cdot \left[(g_t - C_3) \cdot N \right] \quad A_{\text{Tension}} = 4.99 \cdot \text{in}^2$$

Block Shear Capacity:

$$C := \begin{cases} 0.85 \left[0.58 \cdot F_y \cdot \left[(L_{v13} + L_{v23}) \cdot (g_t - C_3) \cdot N \right] + F_U \cdot A_{\text{Tension}} \right] & \text{if } (A_{\text{Tension}}) \geq 0.58 \cdot A_{\text{Shear}} \\ 0.85 \cdot \left[0.58 \cdot F_U \cdot A_{\text{Shear}} + F_y \cdot \left[L_{t3} \cdot (g_t - C_3) \cdot N \right] \right] & \text{otherwise} \end{cases} \quad C = 779 \cdot \text{kip}$$

Ratings (Tons)

$$R_{\text{Ten.block3}_j} := \text{if} \left[P_{3\text{DL}} > 0, \text{"NA"}, \frac{0.9C - DL_j \cdot |P_{3\text{DL}}|}{LL_j \cdot |P_{3\text{LL}}|} \cdot (\text{HS}) \right] \quad R_{\text{Ten.block3}} = \begin{matrix} & 1 \\ 1 & \text{"NA"} \\ 2 & \text{"NA"} \end{matrix} \cdot \text{Ton}$$

Rating Factors

$$RF_{\text{Ten.block3}_j} := \text{if} \left(P_{3\text{DL}} > 0, \text{"NA"}, \frac{0.9C - DL_j \cdot |P_{3\text{DL}}|}{LL_j \cdot |P_{3\text{LL}}|} \right) \quad RF_{\text{Ten.block3}} = \begin{matrix} & 1 \\ 1 & \text{"NA"} \\ 2 & \text{"NA"} \end{matrix}$$

Tension Capacity of the Gusset plate (Whitmore Section):

$$A_e := \min \left[L_{ws3} \cdot (g_t - C_3), \left[L_{ws3} - (N_{\text{holes}T3}) \cdot \left(\phi_b + \frac{1}{8} \cdot \text{in} \right) \right] \cdot (g_t - C_3) + \beta \cdot \left[L_{ws3} \cdot (g_t - C_3) \right] \right]$$

$$A_e = 7.31 \cdot \text{in}^2$$

Stress due to Dead Load: $\sigma_{\text{DL}} := \frac{P_{3\text{DL}}}{N \cdot A_e} \quad \sigma_{\text{DL}} = 6942 \cdot \text{psi}$

Stress due to Live Load: $\sigma_{\text{LL}} := \frac{P_{3\text{LL}}}{N \cdot A_e} \quad \sigma_{\text{LL}} = 7685 \cdot \text{psi}$



Ratings (Tons)

$$R_{Yielding3_j} := \text{if} \left[P_{3DL} > 0, "NA", \frac{0.9F_y - DL_j \cdot |\sigma_{DL}|}{LL_j \cdot |\sigma_{LL}|} \cdot (HS) \right]$$

$$R_{Yielding3} =$$

	1
1	"NA"
2	"NA"

·Ton

Rating Factors

$$RF_{Yielding3_j} := \text{if} \left(P_{3DL} > 0, "NA", \frac{0.9F_y - DL_j \cdot |\sigma_{DL}|}{LL_j \cdot |\sigma_{LL}|} \right)$$

$$RF_{Yielding3} =$$

	1
1	"NA"
2	"NA"

M3_C = "MEMBER IS IN COMPRESSION, COMPRESSION CHECK IS REQUIRED"

Analysis of Gusset Plate @ Diagonal (Member 3): (COMPRESSION CHECK)

Note: See Tension Check for Fastener Capacity

Compression Capacity of the Gusset plate (Whitmore Section):

Stress due to Dead Load: $\sigma_{DL} := \frac{P_{3DL}}{N \cdot L_{ws3} \cdot (g_t - C_3)}$ $\sigma_{DL} = 6769 \cdot \text{psi}$

Stress due to Live Load: $\sigma_{LL} := \frac{P_{3LL}}{N \cdot L_{ws3} \cdot (g_t - C_3)}$ $\sigma_{LL} = 7492 \cdot \text{psi}$

Allowable compressive stresses (ALFD 10.54.1.1): FHWA Guidelines calculate the unbraced length as the average of three distances. Using the unbraced length along the line of action, as done here, should provide conservative ratings.

$L := L_{ub3}$ $k = 1.20$ $r := \sqrt{\frac{(g_t - C_3)^2}{12}}$ $r = 0.14 \cdot \text{in}$
 $c_c := \sqrt{\frac{2 \cdot (\pi)^2 \cdot E_s}{F_y}}$ $c_c = 138.1$ $\frac{k \cdot L}{r} = 40$

$F_{aLd} := \begin{cases} 0.85 F_y \cdot \left[1 - \frac{\left(\frac{k \cdot L}{r}\right)^2 \cdot F_y}{4 \cdot (\pi)^2 \cdot E_s} \right] & \text{if } \frac{k \cdot L}{r} \leq c_c \\ 0.85 \cdot \left[\frac{(\pi)^2 \cdot E_s}{\left(\frac{k \cdot L}{r}\right)^2} \right] & \text{otherwise} \end{cases}$ $F_{aLd} = 24431 \cdot \text{psi}$

Ratings (Tons)

$R_{Buckling3j} := \text{if} \left[P_{3DL} < 0, "NA", \frac{0.9 F_{aLd} - DL_j \cdot |\sigma_{DL}|}{LL_j \cdot |\sigma_{LL}|} \cdot (HS) \right]$

	1
1	29.2
2	48.7

$R_{Buckling3} =$ ·Ton

Rating Factors

$RF_{Buckling3j} := \text{if} \left(P_{3DL} < 0, "NA", \frac{0.9 F_{aLd} - DL_j \cdot |\sigma_{DL}|}{LL_j \cdot |\sigma_{LL}|} \right)$

	1
1	0.8
2	1.4

$RF_{Buckling3} =$

M3_T = "MEMBER IS IN COMPRESSION, TENSION CHECK IS NOT REQUIRED"

Analysis of Diagonal Truss Member (Member 3):

Fastener Capacity:

Note: Shear in Fasteners is the same as in the Gusset Plate (See Gusset Plate Calcs)

Bearing of fasteners (INTERIOR) (ALFD 10.56.1.3): j := 1..2

$$\phi R_{\text{member}} := \min[0.9 \cdot L_{c3} \cdot (m_{t3} - C_{m3}) \cdot F_{um3}, 1.8 \cdot \phi_b \cdot (m_{t3} - C_{m3}) \cdot F_{um3}] \quad (\text{ALFD 10-166b})$$

$$\phi R_{\text{member}} = 9.72 \cdot \text{kip}$$

Fastener Capacity: $C_{\text{mbearing}} := (N_{f3} - N_{\text{endf}3}) \cdot \phi R_{\text{member}} \quad C_{\text{mbearing}} = 155.52 \cdot \text{kip}$

Bearing of fasteners (END) (ALFD 10.56.1.3):

$$\phi R_{\text{memberend}} := \min[0.9 \cdot L_{\text{cem}3} \cdot (m_{t3} - C_{m3}) \cdot F_{um3}, 1.8 \cdot \phi_b \cdot (m_{t3} - C_{m3}) \cdot F_{um3}] \quad (\text{ALFD 10-166b})$$

$$\phi R_{\text{memberend}} = 3.85 \cdot \text{kip}$$

Fastener Capacity: $C_{\text{mendbearing}} := N_{\text{endf}3} \cdot \phi R_{\text{memberend}} \quad C_{\text{mendbearing}} = 11.547 \cdot \text{kip}$

Bearing of fasteners - Controlling $C_{\text{mcontrolling}} := \min[C_{\text{shear}}, 2 \cdot (C_{\text{mbearing}} + C_{\text{mendbearing}})]$

$$C_{\text{mcontrolling}} = 302.18 \cdot \text{kip}$$

Ratings (Tons)

$$R_{\text{mFastener}3_j} := \frac{0.9 C_{\text{mcontrolling}} - DL_j \cdot |P_{3DL}|}{LL_j \cdot |P_{3LL}|} \cdot HS$$

$$R_{\text{mFastener}3} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 20.7 \\ \hline 2 & 34.5 \\ \hline \end{array} \cdot \text{Ton}$$

Rating Factors

$$RF_{\text{mFastener}3_j} := \frac{0.9 C_{\text{mcontrolling}} - DL_j \cdot |P_{3DL}|}{LL_j \cdot |P_{3LL}|}$$

$$RF_{\text{mFastener}3} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 0.6 \\ \hline 2 & 1.0 \\ \hline \end{array}$$

Block Shear Capacity:

$$A_{mShear} := \left[L_{vm13} - \left(N_{holesV13} - \frac{1}{2} \right) \cdot \left(\phi_b + \frac{1}{8} \cdot \text{in} \right) \right] + \left[L_{vm23} - \left(N_{holesV23} - \frac{1}{2} \right) \cdot \left(\phi_b + \frac{1}{8} \cdot \text{in} \right) \right] \cdot [(m_{t3} - C_{m3}) \cdot N]$$

$$A_{mShear} = 4.92 \cdot \text{in}^2$$

$$A_{mTension} := \left[L_{tm3} - (N_{holesT3} - 1) \cdot \left(\phi_b + \frac{1}{8} \cdot \text{in} \right) \right] \cdot [(m_{t3} - C_{m3}) \cdot N] \quad A_{mTension} = 1.2 \cdot \text{in}^2$$

Block Shear Capacity:

$$C_{BlockShear} := \begin{cases} 0.85 \left[0.58 \cdot F_{ym3} \cdot \left[(L_{vm13} + L_{vm23}) \cdot (m_{t3} - C_{m3}) \cdot N \right] + F_{um3} \cdot A_{mTension} \right] & \text{if } (A_{mTension}) \geq 0.58 \cdot A_{mShear} \\ 0.85 \cdot \left[0.58 \cdot F_{um3} \cdot A_{mShear} + F_{ym3} \cdot \left[L_{tm3} \cdot (m_{t3} - C_{m3}) \cdot N \right] \right] & \text{otherwise} \end{cases}$$

$$C_{BlockShear} = 187 \cdot \text{kip}$$

$$C_{Fracture} := F_{um3} \cdot A_{net3} \quad C_{Fracture} = 429 \cdot \text{kip}$$

$$C_m := \min(C_{BlockShear}, C_{Fracture}) \quad C_m = 186.87 \cdot \text{kip}$$

Ratings (Tons)

$$R_{mTen.block3j} := \text{if} \left[P_{3DL} > 0, "NA", \frac{0.9C_m - DL_j \cdot |P_{3DL}|}{LL_j \cdot |P_{3LL}|} \cdot (HS) \right] \quad R_{mTen.block3} = \begin{matrix} & 1 \\ 1 & "NA" \\ 2 & "NA" \end{matrix} \cdot \text{Ton}$$

Rating Factors

$$RF_{mTen.block3j} := \text{if} \left(P_{3DL} > 0, "NA", \frac{0.9C_m - DL_j \cdot |P_{3DL}|}{LL_j \cdot |P_{3LL}|} \right) \quad RF_{mTen.block3} = \begin{matrix} & 1 \\ 1 & "NA" \\ 2 & "NA" \end{matrix}$$

$$P_{4DL} := P_{4DL} \quad P_{4LL} := m \cdot DF \cdot (1 + IM) \cdot P_{4LL}$$

$$P_{4DL} = 125.17 \cdot \text{kip} \quad P_{4LL} = 132.45 \cdot \text{kip}$$



M4_T = "MEMBER IS IN COMPRESSION, TENSION CHECK IS NOT REQUIRED"

Analysis of Gusset Plate @ Left Chord (Member 4): (TENSION CHECK)

Fastener Capacity:

Shear in fasteners:

$$\text{Shear Area: } A_{\text{shear}} := N_{f4} \cdot A_{\text{bolt}} \quad A_{\text{shear}} = 7.95 \cdot \text{in}^2$$

$$\text{Shear Capacity: } C_{\text{shear}} := \sigma_{\text{Design}} \cdot A_{\text{shear}} \cdot N \cdot N_{\text{shear4}} \quad C_{\text{shear}} = 286 \cdot \text{kip}$$

Bearing of fasteners (INTERIOR) (ALFD 10.56.1.3): j := 1..2

$$\phi R := \min[0.9 \cdot L_{c4} \cdot (g_t - C_4) \cdot F_U, 1.8 \cdot \phi_b \cdot (g_t - C_4) \cdot F_U] \quad \phi R = 40.5 \cdot \text{kip} \quad (\text{ALFD 10-166b})$$

$$\text{Fastener Capacity: } C_{\text{bearing}} := (N_{f4} - N_{\text{endf4}}) \cdot \phi R \quad C_{\text{bearing}} = 607.5 \cdot \text{kip}$$

Bearing of fasteners (END) (ALFD 10.56.1.3):

$$\phi R_{\text{end}} := \min[0.9 \cdot L_{ce4} \cdot (g_t - C_4) \cdot F_U, 1.8 \cdot \phi_b \cdot (g_t - C_4) \cdot F_U] \quad \phi R_{\text{end}} = 40.5 \cdot \text{kip} \quad (\text{ALFD 10-166b})$$

$$\text{Fastener Capacity: } C_{\text{endbearing}} := N_{\text{endf4}} \cdot \phi R_{\text{end}} \quad C_{\text{endbearing}} = 121.5 \cdot \text{kip}$$

Bearing of fasteners - Controlling $C_{\text{controlling}} := \min[C_{\text{shear}}, 2 \cdot (C_{\text{bearing}} + C_{\text{endbearing}})]$

$$C_{\text{controlling}} = 286.28 \cdot \text{kip}$$

Ratings (Tons)

$$R_{\text{Fastener4}_j} := \frac{0.9 C_{\text{controlling}} - DL_j \cdot |P_{4DL}| \cdot BP_4}{LL_j \cdot |P_{4LL}| \cdot BP_4} \cdot HS$$

		1	
R _{Fastener4} =	1	11.9	· Ton
	2	19.8	

Rating Factors

$$RF_{\text{Fastener4}_j} := \frac{0.9 C_{\text{controlling}} - DL_j \cdot |P_{4DL}| \cdot BP_4}{LL_j \cdot |P_{4LL}| \cdot BP_4}$$

		1
RF _{Fastener4} =	1	0.3
	2	0.6

Block Shear Capacity:

$$A_{\text{Shear}} := \left[\left[L_{v14} - \left(N_{\text{holes}V14} - \frac{1}{2} \right) \cdot \left(\phi_b + \frac{1}{8} \cdot \text{in} \right) \right] \right] \cdot \left[(g_t - C_4) \cdot N \right]$$

$$A_{\text{Shear}} = 10.06 \cdot \text{in}^2$$

$$A_{\text{Tension}} := \left[L_{t4} - \left(N_{\text{holes}T4} - \frac{1}{2} \right) \cdot \left(\phi_b + \frac{1}{8} \cdot \text{in} \right) \right] \cdot \left[(g_t - C_4) \cdot N \right]$$

$$A_{\text{Tension}} = 4.51 \cdot \text{in}^2$$

Block Shear Capacity:

$$C := \begin{cases} 0.85 \left[0.58 \cdot F_y \cdot \left[(L_{v14}) \cdot (g_t - C_4) \cdot N \right] + F_U \cdot A_{\text{Tension}} \right] & \text{if } (A_{\text{Tension}}) \geq 0.58 \cdot A_{\text{Shear}} \\ 0.85 \cdot \left[0.58 \cdot F_U \cdot A_{\text{Shear}} + F_y \cdot \left[L_{t4} \cdot (g_t - C_4) \cdot N \right] \right] & \text{otherwise} \end{cases}$$

$$C = 468 \cdot \text{kip}$$

Ratings (Tons)

$$R_{\text{Ten.block4}_j} := \text{if} \left[P_{4\text{DL}} > 0, \text{"NA"}, \frac{0.9C - DL_j \cdot |P_{4\text{DL}}| \cdot (GP_4)}{LL_j \cdot |P_{4\text{LL}}| \cdot (GP_4)} \cdot (HS) \right]$$

	1	
1	"NA"	·Ton
2	"NA"	

Rating Factors

$$RF_{\text{Ten.block4}_j} := \text{if} \left[P_{4\text{DL}} > 0, \text{"NA"}, \frac{0.9C - DL_j \cdot |P_{4\text{DL}}| \cdot (GP_4)}{LL_j \cdot |P_{4\text{LL}}| \cdot (GP_4)} \right]$$

	1
1	"NA"
2	"NA"

Tension Capacity of the Gusset plate (Whitmore Section):

$$A_e := \min \left[L_{ws4} \cdot (g_t - C_4), \left[L_{ws4} - \left(N_{\text{holes}T4} \right) \cdot \left(\phi_b + \frac{1}{8} \cdot \text{in} \right) \right] \cdot (g_t - C_4) + \beta \cdot \left[L_{ws4} \cdot (g_t - C_4) \right] \right]$$

$$A_e = 8.25 \cdot \text{in}^2$$

Stress due to Dead Load: $\sigma_{\text{DL}} := \frac{P_{4\text{DL}} \cdot (GP_4)}{N \cdot A_e}$ $\sigma_{\text{DL}} = 7589 \cdot \text{psi}$

Stress due to Live Load: $\sigma_{\text{LL}} := \frac{P_{4\text{LL}} \cdot (GP_4)}{N \cdot A_e}$ $\sigma_{\text{LL}} = 8030 \cdot \text{psi}$



Ratings (Tons)

$$R_{Yielding4_j} := \text{if} \left[P_{4DL} > 0, "NA", \frac{0.9F_y - DL_j \cdot |\sigma_{DL}|}{LL_j \cdot |\sigma_{LL}|} \cdot (HS) \right]$$

$$R_{Yielding4} =$$

	1
1	"NA"
2	"NA"

$$\cdot \text{Ton}$$

Rating Factors

$$RF_{Yielding4_j} := \text{if} \left(P_{4DL} > 0, "NA", \frac{0.9F_y - DL_j \cdot |\sigma_{DL}|}{LL_j \cdot |\sigma_{LL}|} \right)$$

$$RF_{Yielding4} =$$

	1
1	"NA"
2	"NA"



M4_C = "MEMBER IS IN COMPRESSION, COMPRESSION CHECK IS REQUIRED"

Analysis of Gusset Plate @ Left Chord (Member 4): (COMPRESSION CHECK)

Note: See Tension Check for Fastener Capacity

Compression Capacity of the Gusset plate (Whitmore Section):

Stress due to Dead Load: $\sigma_{DL} := \frac{P_{4DL} \cdot (GP_4)}{N \cdot L_{ws4} \cdot (g_t - C_4)}$ $\sigma_{DL} = 7529 \cdot \text{psi}$

Stress due to Live Load: $\sigma_{LL} := \frac{P_{4LL} \cdot (GP_4)}{N \cdot L_{ws4} \cdot (g_t - C_4)}$ $\sigma_{LL} = 7967 \cdot \text{psi}$

Allowable compressive stresses (ALFD 10.54.1.1): FHWA Guidelines calculate the unbraced length as the average of three distances. Using the unbraced length along the line of action, as done here, should provide conservative ratings.

$L := L_{ub4}$ $k = 1.20$ $r := \sqrt{\frac{(g_t - C_4)^2}{12}}$ $r = 0.14 \cdot \text{in}$
 $c_c := \sqrt{\frac{2 \cdot (\pi)^2 \cdot E_s}{F_y}}$ $c_c = 138.1$ $\frac{k \cdot L}{r} = 26$

$F_{aLd} := \begin{cases} 0.85F_y \cdot \left[1 - \frac{\left(\frac{k \cdot L}{r}\right)^2 \cdot F_y}{4 \cdot (\pi)^2 \cdot E_s} \right] & \text{if } \frac{k \cdot L}{r} \leq c_c \\ 0.85 \cdot \frac{(\pi)^2 \cdot E_s}{\left(\frac{k \cdot L}{r}\right)^2} & \text{otherwise} \end{cases}$ $F_{aLd} = 25048 \cdot \text{psi}$

Ratings (Tons)

$R_{Buckling4_j} := \text{if} \left[P_{4DL} < 0, "NA", \frac{0.9F_{aLd} - DL_j \cdot |\sigma_{DL}|}{LL_j \cdot |\sigma_{LL}|} \cdot (HS) \right]$ $R_{Buckling4} = \begin{bmatrix} & 1 \\ 1 & 26.6 \\ 2 & 44.3 \end{bmatrix} \cdot \text{Ton}$

Rating Factors

$RF_{Buckling4_j} := \text{if} \left(P_{4DL} < 0, "NA", \frac{0.9F_{aLd} - DL_j \cdot |\sigma_{DL}|}{LL_j \cdot |\sigma_{LL}|} \right)$ $RF_{Buckling4} = \begin{bmatrix} & 1 \\ 1 & 0.7 \\ 2 & 1.2 \end{bmatrix}$

M4_T = "MEMBER IS IN COMPRESSION, TENSION CHECK IS NOT REQUIRED"

Analysis of Left Chord Truss Member (Member 4):

Fastener Capacity:

Note: Shear in Fasteners is the same as in the Gusset Plate (See Gusset Plate Calcs)

Bearing of fasteners (INTERIOR) (ALFD 10.56.1.3): j := 1..2

$$\phi R_{\text{member}} := \min\left[0.9 \cdot L_{c4} \cdot (m_{t4} - C_{m4}) \cdot F_{um4}, 1.8 \cdot \phi_b \cdot (m_{t4} - C_{m4}) \cdot F_{um4}\right] \quad (\text{ALFD 10-166b})$$

$$\phi R_{\text{member}} = 19.44 \cdot \text{kip}$$

Fastener Capacity: $C_{\text{mbearing}} := (N_{f4} - N_{\text{endf4}}) \cdot \phi R_{\text{member}}$ C_{mbearing} = 291.6 · kip

Bearing of fasteners (END) (ALFD 10.56.1.3):

$$\phi R_{\text{memberend}} := \min\left[0.9 \cdot L_{cem4} \cdot (m_{t4} - C_{m4}) \cdot F_{um4}, 1.8 \cdot \phi_b \cdot (m_{t4} - C_{m4}) \cdot F_{um4}\right] \quad (\text{ALFD 10-166b})$$

$$\phi R_{\text{memberend}} = 19.44 \cdot \text{kip}$$

Fastener Capacity: $C_{\text{mendbearing}} := N_{\text{endf4}} \cdot \phi R_{\text{memberend}}$ C_{mendbearing} = 58.32 · kip

Bearing of fasteners - Controlling $C_{\text{mcontrolling}} := \min\left[C_{\text{shear}}, 2 \cdot (C_{\text{mbearing}} + C_{\text{mendbearing}})\right]$

C_{mcontrolling} = 286.28 · kip

Ratings (Tons)

$$R_{\text{mFastener}4_j} := \frac{0.9 C_{\text{mcontrolling}} - DL_j \cdot |P_{4DL}| \cdot BP_4}{LL_j \cdot |P_{4LL}| \cdot BP_4} \cdot HS$$

$$R_{\text{mFastener}4} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 11.9 \\ \hline 2 & 19.8 \\ \hline \end{array} \cdot \text{Ton}$$

Rating Factors

$$RF_{\text{mFastener}4_j} := \frac{0.9 C_{\text{mcontrolling}} - DL_j \cdot |P_{4DL}| \cdot BP_4}{LL_j \cdot |P_{4LL}| \cdot BP_4}$$

$$RF_{\text{mFastener}4} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 0.3 \\ \hline 2 & 0.6 \\ \hline \end{array}$$

Block Shear Capacity:

$$A_{mShear} := \left[L_{vm14} - \left(N_{holesV14} - \frac{1}{2} \right) \cdot \left(\phi_b + \frac{1}{8} \cdot \text{in} \right) \right] + \left[L_{vm24} - \left(N_{holesV24} - \frac{1}{2} \right) \cdot \left(\phi_b + \frac{1}{8} \cdot \text{in} \right) \right] \cdot \left[(m_{t4} - C_{m4}) \cdot N \right]$$

$$A_{mShear} = 5.04 \cdot \text{in}^2$$

$$A_{mTension} := \left[L_{tm4} - (N_{holesT4} - 1) \cdot \left(\phi_b + \frac{1}{8} \cdot \text{in} \right) \right] \cdot \left[(m_{t4} - C_{m4}) \cdot N \right] \quad A_{mTension} = 2.38 \cdot \text{in}^2$$

Block Shear Capacity:

$$C_{BlockShear} := \begin{cases} 0.85 \left[0.58 \cdot F_{ym4} \cdot \left[(L_{vm14}) \cdot (m_{t4} - C_{m4}) \cdot N \right] + F_{um4} \cdot A_{mTension} \right] & \text{if } (A_{mTension}) \geq 0.58 \cdot A_{mShear} \\ 0.85 \cdot \left[0.58 \cdot F_{um4} \cdot A_{mShear} + F_{ym4} \cdot \left[L_{tm4} \cdot (m_{t4} - C_{m4}) \cdot N \right] \right] & \text{otherwise} \end{cases}$$

$$C_{BlockShear} = 231 \cdot \text{kip}$$

$$C_{Fracture} := F_{um4} \cdot A_{net4} \quad C_{Fracture} = 417.6 \cdot \text{kip}$$

Ratings (Tons)

$$R_{mTen.block4_j} := \text{if} \left[P_{4DL} > 0, \text{"NA"}, \min \left[\frac{0.9C_{BlockShear} - DL_j \cdot |P_{4DL}| \cdot GP_4}{LL_j \cdot |P_{4LL}| \cdot GP_4} \cdot (HS), \frac{0.9C_{Fracture} - DL_j \cdot |P_{4DL}|}{LL_j \cdot |P_{4LL}|} \cdot (HS) \right] \right]$$

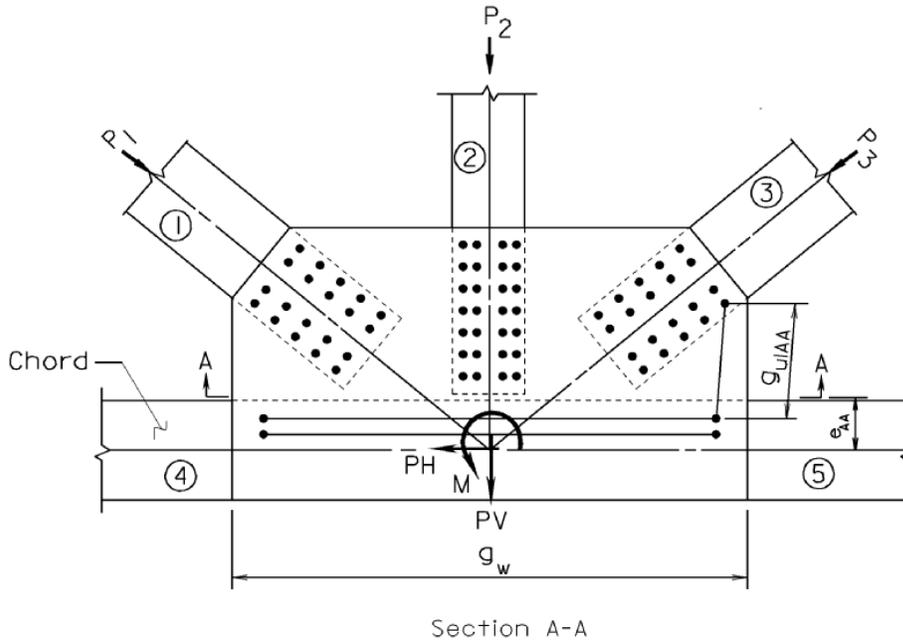
$$R_{mTen.block4} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & \text{"NA"} \\ \hline 2 & \text{"NA"} \\ \hline \end{array} \cdot \text{Ton}$$

Rating Factors

$$RF_{mTen.block4_j} := \text{if} \left(P_{4DL} > 0, \text{"NA"}, \min \left(\frac{0.9C_{BlockShear} - DL_j \cdot |P_{4DL}| \cdot GP_4}{LL_j \cdot |P_{4LL}| \cdot GP_4}, \frac{0.9C_{Fracture} - DL_j \cdot |P_{4DL}|}{LL_j \cdot |P_{4LL}|} \right) \right)$$

$$RF_{mTen.block4} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & \text{"NA"} \\ \hline 2 & \text{"NA"} \\ \hline \end{array}$$

Section A-A: (Parallel to Chord member): Gusset Plates Subject to Horizontal Shear



$$\text{Area}_{AA} := N \cdot [g_w \cdot (g_t - C_{AA})] \quad \text{Area}_{AA} = 50 \cdot \text{in}^2$$

Unsupported length to thickness ratio:

$$\text{Ratio} := \frac{g_{ulAA}}{(g_t - C_{AA})} \quad \text{Ratio} = 31$$

$$\text{Edge} := \begin{cases} \text{"PASS"} & \text{if } \frac{11000}{\sqrt{F_y \cdot \left(\frac{1}{1 \cdot \text{psi}}\right)}} \geq \text{Ratio} \\ \text{"FAIL"} & \text{otherwise} \end{cases} \quad \text{(AASHTO Guide Specifications for Strength Design Section 1.11)}$$

Edge = "PASS"

Summation of Horizontal Forces:

$$\text{For Dead Load:} \quad P_{H_{DL}} := -P_{1_{DL}} \cdot \left(\frac{X_1}{L_{P1}}\right) + P_{2_{DL}} \cdot \left(\frac{X_2}{L_{P2}}\right) + P_{3_{DL}} \cdot \left(\frac{X_3}{L_{P3}}\right) \quad P_{H_{DL}} = 41.2 \cdot \text{kip}$$

$$\text{For Live Load:} \quad P_{H_{LL}} := -P_{1_{LL}} \cdot \left(\frac{X_1}{L_{P1}}\right) + P_{2_{LL}} \cdot \left(\frac{X_2}{L_{P2}}\right) + P_{3_{LL}} \cdot \left(\frac{X_3}{L_{P3}}\right) \quad P_{H_{LL}} = 20.57 \cdot \text{kip}$$

Gross Section Shear Yielding Resistance:

$$V_{rgross} := \frac{Area_{AA} \cdot f_v}{N} \quad V_{rgross} = 320.78 \cdot \text{kip}$$

Net Section Shear Fracture Resistance:

$$V_{rnet} := \left[\frac{Area_{AA}}{N} - g_t \cdot [(N_{holesV14} + N_{holesV15}) \cdot (\phi_b + 0.125 \text{in})] \right] \cdot 0.85 \cdot 0.58 \cdot F_U \quad V_{rnet} = 661.91 \cdot \text{kip}$$

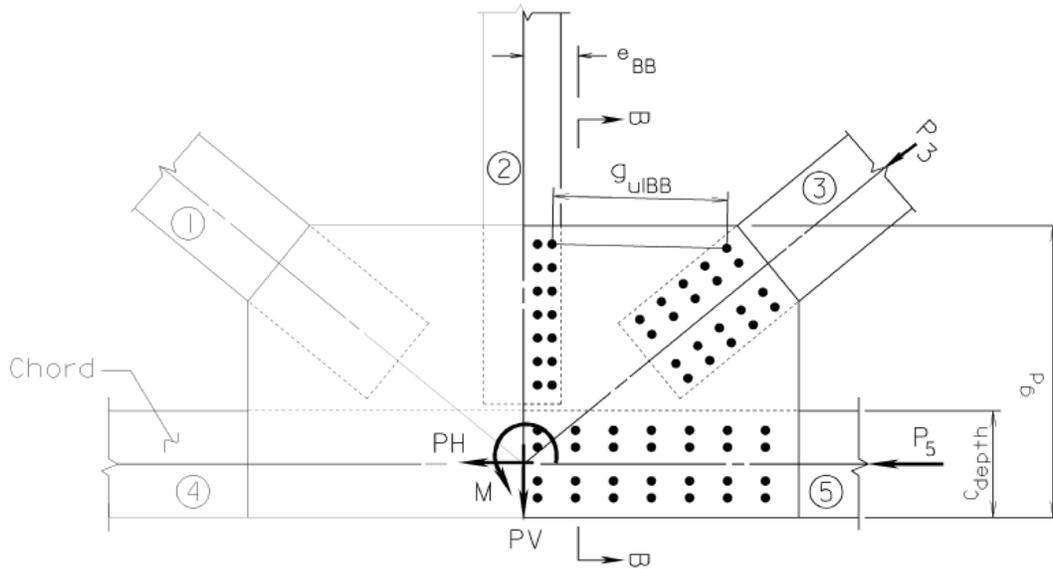
Controlling Shear Resistance:

$$V_r := \min(V_{rgross}, V_{rnet}) \quad V_r = 320.78 \cdot \text{kip}$$

$$R_{VrAA_j} := \frac{0.9V_r - DL_j \cdot \left| \frac{PH_{DL}}{N} \right|}{LL_j \cdot \left| \frac{PH_{LL}}{N} \right|} \cdot (HS) \quad R_{VrAA} = \begin{pmatrix} 422.49 \\ 705.24 \end{pmatrix} \cdot \text{Ton}$$

$$RF_{VrAA_j} := \frac{0.9V_r - DL_j \cdot \left| \frac{PH_{DL}}{N} \right|}{LL_j \cdot \left| \frac{PH_{LL}}{N} \right|} \quad RF_{VrAA} = \begin{pmatrix} 11.74 \\ 19.59 \end{pmatrix}$$

SECTION B-B: Load rating, along Section B-B



Section B-B

$$\text{Area}_{BB} := N \cdot [g_d \cdot (g_t - C_{BB})] \quad \text{Area}_{BB} = 26 \cdot \text{in}^2$$

Unsupported length to thickness ratio:

$$\text{Ratio} := \frac{g_{ulBB}}{(g_t - C_{BB})} \quad \text{Ratio} = 19.13$$

$$\text{Edge} := \begin{cases} \text{"PASS"} & \text{if } \frac{11000}{\sqrt{F_y \cdot \left(\frac{1}{1 \cdot \text{psi}}\right)}} \geq \text{Ratio} \\ \text{"FAIL"} & \text{otherwise} \end{cases}$$

(AASHTO Guide Specifications for Strength Design Section 1.11)

Edge = "PASS"

Summation of Vertical Forces:

$$\text{For Dead Load:} \quad P_{V_{DL}} := P_{3_{DL}} \cdot \left(\frac{Y_3}{L_{P3}}\right) \quad P_{V_{DL}} = 58.2 \cdot \text{kip}$$

$$\text{For Live Load:} \quad P_{V_{LL}} := P_{3_{LL}} \cdot \left(\frac{Y_3}{L_{P3}}\right) \quad P_{V_{LL}} = 48.641 \cdot \text{kip}$$

Gross Section Shear Yielding Resistance:

$$V_{rgross} := \frac{Area_{BB} \cdot f_v}{N} \quad V_{rgross} = 166.82 \cdot kip$$

Net Section Shear Fracture Resistance:

Use T = 1 when line through the bolts for Vertical member passes through the bolts for Chord member, otherwise, use T = 2.

T := 2

$$N_{holes} := \begin{cases} \max(N_{holesT5}, N_{holesV22}) & \text{if } T \neq 1 \\ ((N_{holesT5} + N_{holesV22})) & \text{otherwise} \end{cases}$$

$$V_{rnet} := \left[\frac{Area_{BB}}{N} - g_t \cdot [(N_{holes}) \cdot (\phi_b + 0.125in)] \right] \cdot 0.85 \cdot 0.58 \cdot F_U \quad V_{rnet} = 332.83 \cdot kip$$

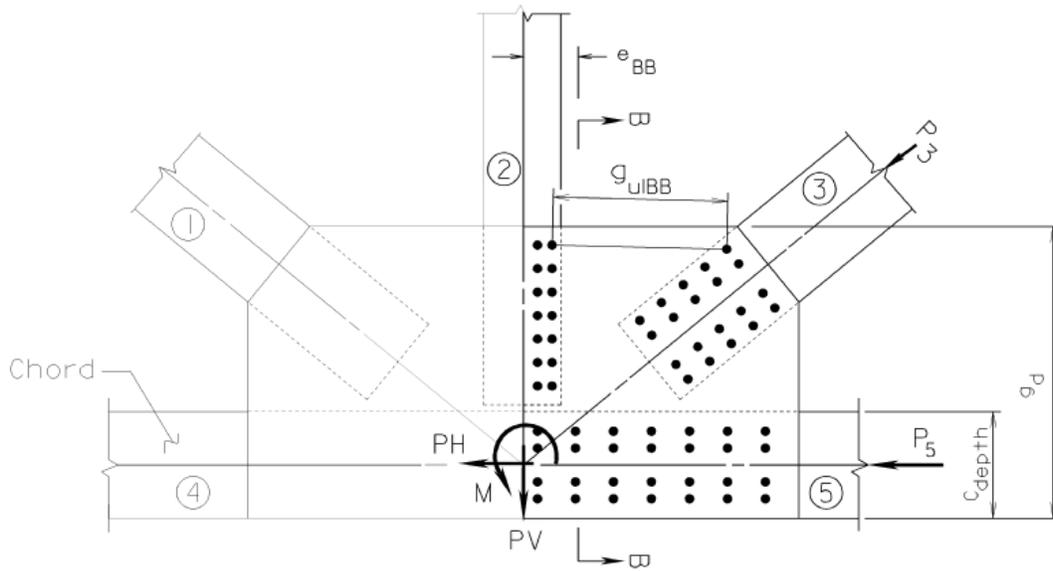
Controlling Shear Resistance:

$$V_r := \min(V_{rgross}, V_{rnet}) \quad V_r = 166.82 \cdot kip$$

$$R_{VrBB_j} := \frac{0.9V_r - DL_j \cdot \left| \frac{PV_{DL}}{N} \right|}{LL_j \cdot \left| \frac{PV_{LL}}{N} \right|} \cdot (HS) \quad R_{VrBB} = \begin{pmatrix} 76.6 \\ 127.86 \end{pmatrix} \cdot Ton$$

$$RF_{VrBB_j} := \frac{0.9V_r - DL_j \cdot \left| \frac{PV_{DL}}{N} \right|}{LL_j \cdot \left| \frac{PV_{LL}}{N} \right|} \quad RF_{VrBB} = \begin{pmatrix} 2.13 \\ 3.55 \end{pmatrix}$$

SECTION C-C: Load rating, along Section C-C. Mirror of Section B-B



Section B-B

$$\text{Area}_{CC} := N \cdot [g_d \cdot (g_t - C_{CC})] \quad \text{Area}_{CC} = 26 \cdot \text{in}^2$$

Unsupported length to thickness ratio:

$$\text{Ratio} := \frac{g_{ulCC}}{(g_t - C_{CC})} \quad \text{Ratio} = 46.13$$

$$\text{Edge} := \begin{cases} \text{"PASS"} & \text{if } \frac{11000}{\sqrt{F_y \cdot \left(\frac{1}{1 \cdot \text{psi}}\right)}} \geq \text{Ratio} \\ \text{"FAIL"} & \text{otherwise} \end{cases} \quad \text{(AASHTO Guide Specifications for Strength Design Section 1.11)}$$

Edge = "PASS"

Summation of Vertical Forces:

$$\text{For Dead Load:} \quad P_{V_{DL}} := P_{1_{DL}} \cdot \left(\frac{Y_1}{L_{P1}}\right) \quad P_{V_{DL}} = -29.4 \cdot \text{kip}$$

$$\text{For Live Load:} \quad P_{V_{LL}} := P_{1_{LL}} \cdot \left(\frac{Y_1}{L_{P1}}\right) \quad P_{V_{LL}} = -34.241 \cdot \text{kip}$$

Gross Section Shear Yielding Resistance:

$$V_{rgross} := \frac{\text{Area}_{CC} \cdot f_v}{N} \quad V_{rgross} = 166.82 \cdot \text{kip}$$

Net Section Shear Fracture Resistance:

Use T = 1 when line through the bolts for Vertical member passes through the bolts for Chord member, otherwise, use T = 2.

T := 2

$$N_{\text{holes}} := \begin{cases} \max(N_{\text{holesT4}}, N_{\text{holesV12}}) & \text{if } T \neq 1 \\ ((N_{\text{holesT4}} + N_{\text{holesV12}})) & \text{otherwise} \end{cases}$$

$$V_{\text{rnet}} := \left[\frac{\text{Area}_{\text{CC}}}{N} - g_t \cdot [(N_{\text{holes}}) \cdot (\phi_b + 0.125\text{in})] \right] \cdot 0.85 \cdot 0.58 \cdot F_U \quad V_{\text{rnet}} = 319.89 \cdot \text{kip}$$

Controlling Shear Resistance:

$$V_r := \min(V_{\text{rgross}}, V_{\text{rnet}}) \quad V_r = 166.82 \cdot \text{kip}$$

$$R_{VrCC_j} := \frac{0.9V_r - DL_j \cdot \left| \frac{PV_{DL}}{N} \right|}{LL_j \cdot \left| \frac{PV_{LL}}{N} \right|} \cdot (\text{HS}) \quad R_{VrCC} = \begin{pmatrix} 126.96 \\ 211.92 \end{pmatrix} \cdot \text{Ton}$$

$$RF_{VrCC_j} := \frac{0.9V_r - DL_j \cdot \left| \frac{PV_{DL}}{N} \right|}{LL_j \cdot \left| \frac{PV_{LL}}{N} \right|} \quad RF_{VrCC} = \begin{pmatrix} 3.53 \\ 5.89 \end{pmatrix}$$

Gusset Plate Rating Summary

Left Diagonal - Member 1 - Rating:

Block Shear

$$R_{T_{en,block1}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 111.37 \\ \hline 2 & 185.91 \\ \hline \end{array} \cdot \text{Ton}$$

$$R_{F_{T_{en,block1}}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 3.09 \\ \hline 2 & 5.16 \\ \hline \end{array}$$

Gross Section Yielding

$$R_{Y_{ielding1}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 87.22 \\ \hline 2 & 145.60 \\ \hline \end{array} \cdot \text{Ton}$$

$$R_{F_{Y_{ielding1}}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 2.42 \\ \hline 2 & 4.04 \\ \hline \end{array}$$

Buckling

$$R_{B_{uckling1}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & \text{"NA"} \\ \hline 2 & \text{"NA"} \\ \hline \end{array} \cdot \text{Ton}$$

$$R_{F_{B_{uckling1}}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & \text{"NA"} \\ \hline 2 & \text{"NA"} \\ \hline \end{array}$$

Fastener Capacity

$$R_{F_{astener1}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 22.04 \\ \hline 2 & 36.79 \\ \hline \end{array} \cdot \text{Ton}$$

$$R_{F_{F_{astener1}}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 0.61 \\ \hline 2 & 1.02 \\ \hline \end{array}$$

Vertical - Member 2 - Rating:

Block Shear

$$R_{T_{en,block2}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 146.20 \\ \hline 2 & 244.05 \\ \hline \end{array} \cdot \text{Ton}$$

$$R_{F_{T_{en,block2}}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 4.06 \\ \hline 2 & 6.78 \\ \hline \end{array}$$

Gross Section Yielding

$$R_{Y_{ielding2}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 118.35 \\ \hline 2 & 197.55 \\ \hline \end{array} \cdot \text{Ton}$$

$$R_{F_{Y_{ielding2}}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 3.29 \\ \hline 2 & 5.49 \\ \hline \end{array}$$

Buckling

$$R_{B_{uckling2}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & \text{"NA"} \\ \hline 2 & \text{"NA"} \\ \hline \end{array} \cdot \text{Ton}$$

$$R_{F_{B_{uckling2}}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & \text{"NA"} \\ \hline 2 & \text{"NA"} \\ \hline \end{array}$$

Fastener Capacity

$$R_{F_{astener2}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 33.09 \\ \hline 2 & 55.23 \\ \hline \end{array} \cdot \text{Ton}$$

$$R_{F_{F_{astener2}}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 0.92 \\ \hline 2 & 1.53 \\ \hline \end{array}$$

Gusset Plate Rating Summary (continued)

Right Diagonal - Member 3 - Rating:

Block Shear

$$R_{T_{en,block3}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & "NA" \\ \hline 2 & "NA" \\ \hline \end{array} \cdot \text{Ton}$$

$$R_{F_{T_{en,block3}}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & "NA" \\ \hline 2 & "NA" \\ \hline \end{array}$$

Gross Section Yielding

$$R_{Y_{ielding3}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & "NA" \\ \hline 2 & "NA" \\ \hline \end{array} \cdot \text{Ton}$$

$$R_{F_{Y_{ielding3}}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & "NA" \\ \hline 2 & "NA" \\ \hline \end{array}$$

Buckling

$$R_{B_{uckling3}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 29.20 \\ \hline 2 & 48.75 \\ \hline \end{array} \cdot \text{Ton}$$

$$R_{F_{B_{uckling3}}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 0.81 \\ \hline 2 & 1.35 \\ \hline \end{array}$$

Fastener Capacity

$$R_{F_{astener3}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 20.66 \\ \hline 2 & 34.49 \\ \hline \end{array} \cdot \text{Ton}$$

$$R_{F_{F_{astener3}}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 0.57 \\ \hline 2 & 0.96 \\ \hline \end{array}$$

Left Chord - Member 4 - Rating:

Block Shear

$$R_{T_{en,block4}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & "NA" \\ \hline 2 & "NA" \\ \hline \end{array} \cdot \text{Ton}$$

$$R_{F_{T_{en,block4}}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & "NA" \\ \hline 2 & "NA" \\ \hline \end{array}$$

Gross Section Yielding

$$R_{Y_{ielding4}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & "NA" \\ \hline 2 & "NA" \\ \hline \end{array} \cdot \text{Ton}$$

$$R_{F_{Y_{ielding4}}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & "NA" \\ \hline 2 & "NA" \\ \hline \end{array}$$

Buckling

$$R_{B_{uckling4}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 26.56 \\ \hline 2 & 44.34 \\ \hline \end{array} \cdot \text{Ton}$$

$$R_{F_{B_{uckling4}}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 0.74 \\ \hline 2 & 1.23 \\ \hline \end{array}$$

Fastener Capacity

$$R_{F_{astener4}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 11.89 \\ \hline 2 & 19.85 \\ \hline \end{array} \cdot \text{Ton}$$

$$R_{F_{F_{astener4}}} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 0.33 \\ \hline 2 & 0.55 \\ \hline \end{array}$$



Gusset Plate Rating Summary (continued)

Section A-A

$$R_{VrAA} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 422.49 \\ \hline 2 & 705.24 \\ \hline \end{array} \cdot \text{Ton}$$

$$R_{FVrAA} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 11.74 \\ \hline 2 & 19.59 \\ \hline \end{array}$$

Section B-B

$$R_{VrBB} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 76.60 \\ \hline 2 & 127.86 \\ \hline \end{array} \cdot \text{Ton}$$

$$R_{FVrBB} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 2.13 \\ \hline 2 & 3.55 \\ \hline \end{array}$$

Section C-C

$$R_{VrCC} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 126.96 \\ \hline 2 & 211.92 \\ \hline \end{array} \cdot \text{Ton}$$

$$R_{FVrCC} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 3.53 \\ \hline 2 & 5.89 \\ \hline \end{array}$$

Truss Member Rating Summary

Left Diagonal - Member 1 - Tension or Compression Rating:

$$R_{mFastener1} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 22.0 \\ \hline 2 & 36.8 \\ \hline \end{array} \cdot \text{Ton}$$

$$R_{mTen.block1} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 55.9 \\ \hline 2 & 93.3 \\ \hline \end{array} \cdot \text{Ton}$$

$$RF_{mFastener1} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 0.6 \\ \hline 2 & 1.0 \\ \hline \end{array}$$

$$RF_{mTen.block1} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 1.6 \\ \hline 2 & 2.6 \\ \hline \end{array}$$

Vertical - Member 2 - Tension or Compression Rating:

$$R_{mFastener2} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 33.1 \\ \hline 2 & 55.2 \\ \hline \end{array} \cdot \text{Ton}$$

$$R_{mTen.block2} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 94.8 \\ \hline 2 & 158.2 \\ \hline \end{array} \cdot \text{Ton}$$

$$RF_{mFastener2} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 0.9 \\ \hline 2 & 1.5 \\ \hline \end{array}$$

$$RF_{mTen.block2} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 2.6 \\ \hline 2 & 4.4 \\ \hline \end{array}$$

Right Diagonal - Member 3 - Tension or Compression Rating:

$$R_{mFastener3} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 20.7 \\ \hline 2 & 34.5 \\ \hline \end{array} \cdot \text{Ton}$$

$$R_{mTen.block3} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & \text{"NA"} \\ \hline 2 & \text{"NA"} \\ \hline \end{array} \cdot \text{Ton}$$

$$RF_{mFastener3} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & 0.6 \\ \hline 2 & 1.0 \\ \hline \end{array}$$

$$RF_{mTen.block3} = \begin{array}{|c|c|} \hline & 1 \\ \hline 1 & \text{"NA"} \\ \hline 2 & \text{"NA"} \\ \hline \end{array}$$



Truss Member Rating Summary (continued)

Left Chord - Member 4 - Tension or Compression Rating:

$$R_{mFastener4} =$$

	1
1	11.9
2	19.8

$$\cdot \text{Ton}$$

$$R_{mTen.block4} =$$

	1
1	"NA"
2	"NA"

$$\cdot \text{Ton}$$

$$R_{F_{mFastener4}} =$$

	1
1	0.3
2	0.6

$$R_{F_{mTen.block4}} =$$

	1
1	"NA"
2	"NA"

Controlling Gusset Plate Rating Summary



Gusset Plate Controlling Rating:

Case	Conn _{Inv} = 22.04·Ton	Conn _{Opr} = 36.79·Ton
1 -Inventory		
2 -Operating	Conn _{InvF} = 0.61	Conn _{OprF} = 1.02



InvControl_{Gusset} = "Member 1 Controls the Inventory Rating"

OprControl_{Gusset} = "Member 1 Controls the Operating Rating"

InvRFControl_{Gusset} = "Member 1 Controls the Inventory Rating Factor"

OprRFControl_{Gusset} = "Member 1 Controls the Operating Rating Factor"

Truss Member Controlling Rating:

Case	Conn _{mInv} = 22.04·Ton	Conn _{mOpr} = 36.79·Ton
1 -Inventory		
2 -Operating	Conn _{mInvF} = 0.61	Conn _{mOprF} = 1.02



InvControl_{TrussMember} = "Truss Member 1 Controls the Inventory Rating"

OprControl_{TrussMember} = "Truss Member 1 Controls the Operating Rating"

InvRFControl_{TrussMember} = "Truss Member 1 Controls the Inventory Rating Factor"

OprRFControl_{TrussMember} = "Truss Member 1 Controls the Operating Rating Factor"

Operating Rating results shall be greater than HS = 36·Ton otherwise structure requires posting according to VDOT guidelines