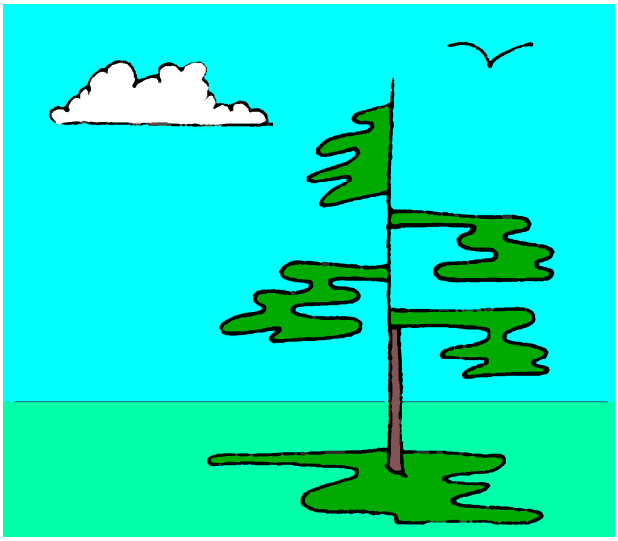
NorthWoods Software



Program Name: Comp-W_T

Project Number: -

Project Description: -

Project Designer: Dik

Last Revised (yy-mm-dd): 23.01.14

Reference: NBCC, CSA S16

Disclaimer:
Created using SMath Studio, a MathCAD workalike from https://en.smath.info/view/SMathStudio. The User is responsible to verify data and calculations using an alternative method

Menu:

..... Input Data	..... Important Output	..... Logical Constructs	Blue Units
..... Sum / For	Red Important Note	Gray Temporary Variables	

c b a

Input Data

Material Property Factors:

$\varphi_s := 0.90$

$\varphi_w := 0.67$

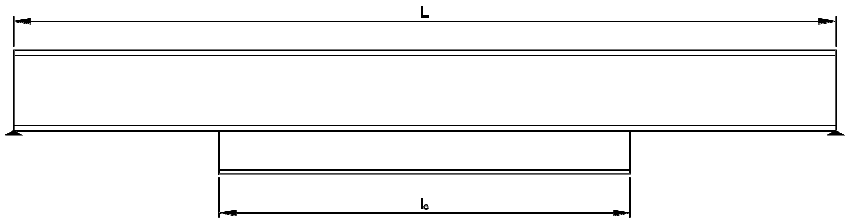
Load Factors:

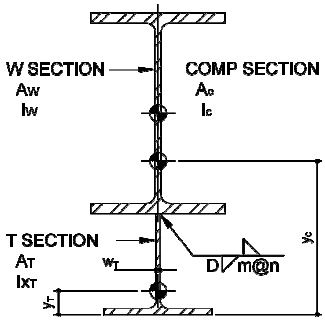
$\alpha_L := 1.50$

$\alpha_D := 1.25$

$Check\left(\alpha_D \geq 1.25\right) = "...OK"$

$Check\left(\alpha_L \geq 1.5\right) = "...OK"$





Steel Properties:

W Section: $st_{NDX} := 1$

$$st := \begin{bmatrix} \text{NDX} & \text{des} & \text{fy} & \text{Fu} \\ 1 & \text{"G40.21-350W"} & 50\ \text{Ksi} & 65\ \text{Ksi} \\ 2 & \text{"G40.21-300W"} & 44\ \text{Ksi} & 65\ \text{Ksi} \\ 3 & \text{"A36"} & 36\ \text{Ksi} & 58\ \text{Ksi} \end{bmatrix}$$

$desM_{st1} := st_{st_{NDX},2}$ $f_{y1} := st_{st_{NDX},3}$ $F_{u1} := st_{st_{NDX},4}$

$G_s := \frac{E_s}{2\cdot(1+\nu)}$ $\gamma_s := 489\ \text{pcf}$ $\nu := 0.3$ $E_s := 29000\ \text{Ksi}$

T Section: $st_{NDX} := 2$ $desM_{st2} := st_{st_{NDX},2}$ $f_{y2} := st_{st_{NDX},3}$ $F_{u2} := st_{st_{NDX},4}$

Beam Span:

$L := 20\ ft$ $L = 20.00\ ft$ $L = 6.10\ m$ Span Length

Factored Design Moment:

$M_f := 330\ K\_ft$ $M_f = 330.00\ K\_ft$ $M_f = 447.42\ kN\_m$ Factored Design Moment

Welding:

Weld Electrodes: $we_{NDX} := 2$

$we :=$

NDX	DesI	DesM	UTS
1	"E60xx"	"E43xx"	60 ksi
2	"E70xx"	"E49xx"	70 ksi
3	"E80xx"	"E55xx-x"	80 ksi
4	"E90xx"	"E62xx-x"	90 ksi

$desI_w := we_{we_{NDX},2}$ $desM_w := we_{we_{NDX},3}$ $X_u := we_{we_{NDX},4}$

Weld Sizes: $ws_{NDX} := 7$

$ws :=$

NDX	desI	desM	D
1	""	"3mm"	0.11811 in
2	"1/8"	""	0.125 in
3	""	"4mm"	0.15748 in
4	"3/16"	""	0.1875 in
5	""	"5mm"	0.19685 in
6	""	"6mm"	0.23622 in
7	"1/4"	""	0.25 in
8	""	"7mm"	0.275591 in
9	"5/16"	""	0.3125 in
10	""	"8mm"	0.314961 in
11	""	"9mm"	0.354331 in
12	"3/8"	""	0.375 in
13	""	"10mm"	0.3937 in
14	""	"11mm"	0.4331 in
15	"7/16"	""	0.4375 in
16	""	"12mm"	0.4724 in
17	"1/2"	""	0.50 in

$desI_D := ws_{ws_{NDX},2}$ $desM_D := ws_{ws_{NDX},3}$ $D := ws_{ws_{NDX},4}$

$m := 8\ in$ $m = 8.0\ in$ $m = 203.2\ mm$ Weld Length

$n := 12\ in$ $n = 12.0\ in$ $n = 304.8\ mm$ Weld Spacing

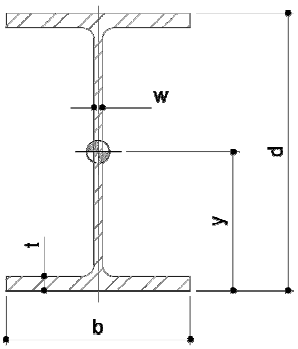
Section Properties:

W Section: $be_{NDX} := 2$ **Section Properties (from CISC Handbook):**

$be :=$

NDX	desI	desM	d	b	t	w
1	"W16x36"	"W410x54"	15.86 in	6.98 in	0.43 in	0.295 in
2	"W14x38"	"W360x57"	14.1 in	6.77 in	0.515 in	0.310 in

$desI_W := be_{be_{NDX},2}$ $desM_W := be_{be_{NDX},3}$ $d_W := be_{be_{NDX},4}$ $b_W := be_{be_{NDX},5}$ $t_W := be_{be_{NDX},6}$ $w_W := be_{be_{NDX},7}$



$desI_W = "W14x38"$ $desM_W = "W360x57"$ Designation

$d_W = 14.10\ in$ $d_W = 358.1\ mm$ Depth

$b_W = 6.77\ in$ $b_W = 172\ mm$ Flange Width

$t_W = 0.52\ in$ $t_W = 13.1\ mm$ Flange Thickness

$w_W = 0.31\ in$ $w_W = 7.9\ mm$ Web Thickness

$y_W := \frac{d_W}{2}$ $y_W = 7.05\ in$ $y_W = 179.1\ mm$ Depth to Outer Fibre

$A_W := 2 \cdot b_W \cdot t_W + \left(d_W - 2 \cdot t_W\right) \cdot w_W$

$A_W = 11.02\ in^2$ $A_W = 7113\ mm^2$ Area

$Ix_W := \frac{1}{12} \cdot \left(b_W \cdot d_W^{\,3} - \left(b_W - w_W\right) \cdot \left(d_W - 2 \cdot t_W\right)^3\right)$

$Ix_W = 379.56\ in^4$ $Ix_W = 1.58 \cdot 10^8\ mm^4$ Moment of Inertia (X-Axis)

$Sx_W := \frac{Ix_W}{y_W}$ $Sx_W = 53.84\ in^3$ $Sx_W = 8.82 \cdot 10^5\ mm^3$ Section Modulus (X-Axis)

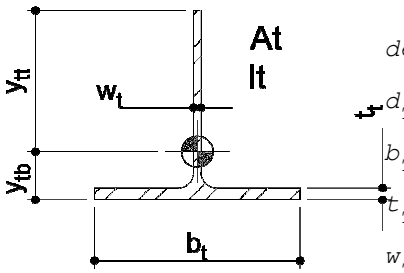
Moment Resistance

$M_{rW} := \varphi_s \cdot f_{y2} \cdot Sx_W$ $M_{rW} = 177.7\ K\_ft$ $M_{rW} = 240.9\ kN\_m$ Moment Resistance

T Section: $te_{NDX} := 1$ **Section Properties (from CISC Handbook):**

	NDX	desI	desM	d	b	t	w
$te :=$	1	"WT6x29"	"WT155x43"	6.095 in	10.01 in	0.64 in	0.36 in

$desI_T := te_{te_{NDX},2}$ $desM_T := te_{te_{NDX},3}$ $d_T := te_{te_{NDX},4}$ $b_T := te_{te_{NDX},5}$ $t_T := te_{te_{NDX},6}$ $w_T := te_{te_{NDX},7}$



$desI_T = \text{"WT6x29"}$ $desM_T = \text{"WT155x43"}$ Designation

$d_T = 6.1\ in$ $d_T = 154.8\ mm$ Beam Depth

$b_T = 10.01\ in$ $b_T = 254.3\ mm$ Flange Width

$t_T = 0.64\ in$ $t_T = 16.3\ mm$ Flange Thickness

$w_T = 0.4\ in$ $w_T = 9.1\ mm$ Web Thickness

$A_T := b_T \cdot t_T + w_T \cdot \left(d_T - t_T\right)$ $A_T = 8.37\ in^2$ $A_T = 5400\ mm^2$ Area

$y_{Tt} := \left(\frac{1}{2} \cdot \left(\frac{b_T \cdot d_T \cdot t_T}{A_T} + d_T - t_T\right)\right)$

$y_{Tt} = 5.06\ in$ $y_{Tt} = 129\ mm$ Centroid Dist. to Top

$y_{Tb} := d_T - y_{Tt}$ $y_{Tb} = 1.03\ in$ $y_{Tb} = 26\ mm$ Centroid Dist to Bottom

$Ix_T := \frac{1}{12} \cdot \left(b_T \cdot t_T^{\,3} + w_T \cdot \left(d_T - t_T\right)^3 + \frac{3 \cdot b_T \cdot w_T \cdot t_T \cdot \left(d_T\right)^2 \cdot \left(d_T - t_T\right)}{A_T}\right)$ Moment of Inertia (X-Axis)

$Ix_T = 19.05\ in^4$ $Ix_T = 7.93 \cdot 10^6\ mm^4$

$Sx_{Tt} := \frac{Ix_T}{y_{Tt}}$ $Sx_{Tt} = 3.76\ in^3$ $Sx_{Tt} = 61686.87\ mm^3$ Section Modulus to Top

$Sx_{Tb} := \frac{Ix_T}{y_{Tb}}$ $Sx_{Tb} = 18.40\ in^3$ $Sx_{Tb} = 3.02 \cdot 10^5\ mm^3$ Section Modulus to Bottom

Composite Section Centroid

$A_c := A_W + A_T$ $A_c = 19.40\ in^2$ $A_c = 12513\ mm^2$ Composite Area

$y_{cb} := \frac{A_W \cdot \left(y_W + d_T\right) + A_T \cdot y_{Tb}}{A_c}$ $y_{cb} = 7.9\ in$ $y_{cb} = 201.1\ mm$ Composite Centroid Bottom

$y_{ct} := d_W + d_T - y_{cb}$ $y_{ct} = 12.3\ in$ $y_{ct} = 311.8\ mm$ Composite Centroid Top

$Ix_c := Ix_W + \left(A_W \cdot \left(y_W + d_T - y_{cb}\right)^2\right) + Ix_T + \left(A_T \cdot \left(y_{Tb} - y_{cb}\right)^2\right)$

$Ix_c = 1096\ in^4$ $Ix_c = 4.56 \cdot 10^8\ mm^4$ Composite Moment of Inertia

$Sx_{ct} := \frac{Ix_c}{y_{ct}}$ $Sx_{ct} = 89.3\ in^3$ $Sx_{ct} = 1.46 \cdot 10^6\ mm^3$ Section Modulus of Top Fibre

$Sx_{cb} := \frac{Ix_c}{y_{cb}}$ $Sx_{cb} = 138.5\ in^3$ $Sx_{cb} = 2.27 \cdot 10^6\ mm^3$ Section Modulus of Bot Fibre

Moment Resistance

$M_{rc} := \left(\varphi_s \cdot \min\left(\left[\begin{array}{cc} f_{y1} \cdot Sx_{ct} & f_{y2} \cdot Sx_{cb} \end{array}\right]\right)\right)$

$M_{rc} = 334.9\ K\_ft$ $M_{rc} = 454.1\ kN\_m$ Moment Resistance

Weld Capacity:

$v_{rw} := \varphi_w \cdot 0.67 \cdot X_u \cdot \frac{1}{\sqrt{2}}$ $v_{rw} = 22.22\ ksi$ $v_{rw} = 153.20\ MPa$ Weld Material Strength:

$v_{rb1} := \varphi_w \cdot 0.67 \cdot F_{u1}$ $v_{rb1} = 29.18\ Ksi$ $v_{rb1} = 201.18\ MPa$ W Section Base Metal Strength

$v_{rb2} := \varphi_w \cdot 0.67 \cdot F_{u2}$ $v_{rb2} = 29.18\ Ksi$ $v_{rb2} = 201.18\ MPa$ T Section Base Metal Strength

$V_{rw} := \min\left(\left[\begin{array}{ccc} v_{rw} & v_{rb1} & v_{rb2} \end{array}\right]\right)$ $V_{rw} = 22.22\ Ksi$ $V_{rw} = 153.2\ MPa$ Minimum Weld Capacity

Maximum UDL:

$q_f := \frac{8 \cdot M_{rc}}{L^2}$ $q_f = 6.7\ Klf$ $q_f = 97.8\ kNpm$

Maximum Reaction (Shear):

$V_f := q_f \cdot \frac{L}{2}$ $V_f = 67.0\ K$ $V_f = 297.9\ kN$

Length of Reinforcing:

$\Delta M := M_f - M_{rW}$ $\Delta M = 152.34\ K\_ft$ $\Delta M = 206.54\ kN\_m$ Moment Prov by Composite

$l_c := \sqrt{\frac{8 \cdot \Delta M}{q_f}}$ $l_c = 13.4887\ ft$ $l_c = 13.4887\ ft$ Length of Reinforcing

Shear Stress at W and T Junction

$A' := A_W$

$y_{bar} := d_T + y_W - y_{cb}$

$\tau := \frac{V_f}{Ix_c \cdot w_T} \cdot A_T \cdot \left(y_{cb} - y_{Tb}\right)$ $\tau = 9.78\ Ksi$ $\tau = 67.42\ MPa$

Connection Shear per Unit Length

$\tau' := \left(\tau \cdot n \cdot w_T\right)$ $\tau' = 42.2\ K$ $\tau' = 187.9\ kN$

Weld Provided

$\tau_r := 2 \cdot V_{rw} \cdot D \cdot m$ $\tau_r = 88.9\ K$ $\tau_r = 395.3\ kN$

End Connection Force:

$\sigma_1 := \frac{M_f \cdot \left(y_{cb} - d_T\right)}{Ix_c}$ $\sigma_1 = 6.59\ Ksi$ $\sigma_1 = 45.4\ MPa$ Stress at Bot of W Section

$\sigma_2 := \frac{M_f \cdot \left(y_{cb} - t_T\right)}{Ix_c}$ $\sigma_2 = 26.29\ Ksi$ $\sigma_2 = 181.3\ MPa$ Stress at Top of T Flange

$\sigma_3 := \frac{M_f \cdot y_{cb}}{Ix_c}$ $\sigma_3 = 28.60\ Ksi$ $\sigma_3 = 197.2\ MPa$ Stress at Bot of Comp Section

$F_{flb} := \sigma_1 \cdot w_T \cdot \left(d_T - t_T\right) + \left(\frac{\sigma_2 - \sigma_1}{2}\right) \cdot w_T \cdot \left(d_T - t_T\right)$

$F_{flb} = 32.28\ \text{K}$ $F_{flb} = 143.60\ \text{kN}$ Force in T Stem

$M_{fs} := \sigma_1 \cdot w_T \cdot \left(d_T - t_T\right) \cdot \frac{\left(d_T - t_T\right)}{2} + \left(\frac{\sigma_2 - \sigma_1}{2}\right) \cdot w_T \cdot \frac{2 \cdot \left(\left(d_T - t_T\right)^2\right)}{3}$

$M_{fs} = 105.64\ \text{K\_in}$ $M_{fs} = 11935.72\ \text{kN\_mm}$ Moment from Force in T Stem

$F_{fld} := \left(\frac{\sigma_3 + \sigma_2}{2}\right) \cdot b_T \cdot t_T$ $F_{fld} = 175.83\ \text{K}$ $F_{fld} = 782.14\ \text{kN}$ Force in T Flange

$F_{fT} := F_{flb} + F_{fld}$ $F_{fT} = 208.11\ \text{K}$ $F_{fT} = 925.74\ \text{kN}$ Tensile Force in T Section

$M_{ff} := \left(\frac{\sigma_3 + \sigma_2}{2}\right) \cdot b_T \cdot t_T \cdot \left(d_T - \frac{t_T}{2}\right)$

$M_{ff} = 1015.43\ \text{K\_in}$ $M_{ff} = 1.15 \cdot 10^5\ \text{kN\_mm}$ Moment from Force in T Flange

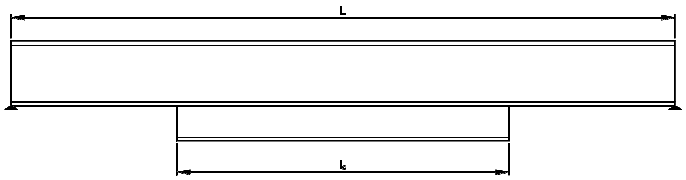
$M_{fT} := M_{fs} + M_{ff}$ $M_{fT} = 1121.07\ \text{K\_in}$ $M_{fT} = 1.27 \cdot 10^5\ \text{kN\_mm}$ Moment from Force in T Section

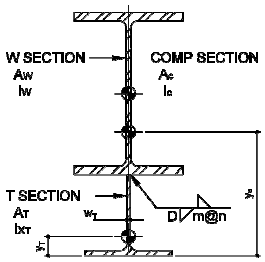
$F_{fe} := \frac{2 \cdot \left(M_{fT}\right)}{L}$ $F_{fe} = 9.34\ \text{K}$ $F_{fe} = 41.56\ \text{kN}$ End Connection Force

$l_e := \max\left(\left\lceil \frac{F_{fe}}{D \cdot V_{rw}}\ \text{in} \right\rceil\right)$ $l_e = 1.68\ \text{in}$ $l_e = 42.72\ \text{mm}$ Length of Weld Required

c b a

Summary:





Material Property Factor

(Welds) $\varphi_w = 0.67$

(Steel) $\varphi_s = 0.9$

Dead Load Factor $\alpha_D = 1.25$

Live Load Factor $\alpha_L = 1.5$

$Check\left(\alpha_D \geq 1.25\right) = "...OK"$

$Check\left(\alpha_L \geq 1.5\right) = "...OK"$

Steel Properties

W Section

Designation $desM_{st1} = "G40.21\text{-}350W"$

Yield Strength $f_{y1} = 50\ Ksi$ $f_{y1} = 345\ MPa$

Ultimate Strength $F_{u1} = 65\ Ksi$ $F_{u1} = 448\ MPa$

T Section

Designation $desM_{st2} = "G40.21\text{-}300W"$

Yield Strength $f_{y2} = 44\ Ksi$ $f_{y2} = 303\ MPa$

Ultimate Strength $F_{u2} = 65\ Ksi$ $F_{u2} = 448\ MPa$

Young's Modulus $E_s = 29000\ Ksi$ $E_s = 1.9995 \cdot 10^{5}\ MPa$

Shear Modulus $G_s = 11153.8462\ Ksi$ $G_s = 76903\ MPa$

Density $\gamma_s = 489\ pcf$ $\gamma_s = 76.8\ kNpcm$

Beam Span Length $L = 20.00\ ft$ $L = 6.10\ m$

Factored Design Moment $M_f = 330.00\ K\_ft$ $M_f = 447.42\ kN\_m$

Welds

Designation (Welding Electrode) $desI_w = "E70xx"$ $desM_w = "E49xx"$

Ultimate Strength (Welding Electrode) $X_u = 70\ Ksi$ $X_u = 483\ MPa$

Designation (Fillet Weld Size) $desI_D = "1/4"$ $desM_D = ""$

Fillet Weld Size $D = 0.25\ in$ $D = 6.35\ mm$

Weld Length $m = 8\ in$ $m = 203.2\ mm$

Weld Spacing $n = 12\ in$ $n = 304.8\ mm$

$Check\left((m \geq 1.5\ in) \wedge (m \geq 4 \cdot D)\right) = "...OK"$

$Check\left((n - m) \leq 12\ in\right) = "...OK"$ **≤ 12" for Compression Attachment**

$Check\left((n - m) \leq 18\ in\right) = "...OK"$ **≤ 18" for Tension Attachment**

W Section

Designation $desI_W = "W14x38"$ $desM_W = "W360x57"$

Depth $d_W = 14.10\ in$ $d_W = 358.1\ mm$

Area $A_W = 11.02\ in^2$ $A_W = 7112.8\ mm^2$

Moment of Inertia (x-axis) $Ix_W = 379.56\ in^4$ $Ix_W = 1.58 \cdot 10^{8}\ mm^4$

Centroid Distance $y_W = 7.05\ in$ $y_W = 179.1\ mm$

Moment Resistance $M_{rW} = 177.7\ K\_ft$ $M_{rW} = 240.9\ kN\_m$

$Check\left(M_{rW} \le M_f\right) = "...OK"$

T Section

Designation	$desI_T = "WT6x29"$	$desM_T = "WT155x43"$
Depth	$d_T = 6.10\ in$	$d_T = 154.8\ mm$
Web Width	$w_T = 0.36\ in$	$w_T = 9.1\ mm$
Area	$A_T = 8.37\ in^2$	$A_T = 5400.1\ mm^2$
Moment of Inertia (x-axis)	$Ix_T = 19.05\ in^4$	$Ix_T = 7.93 \cdot 10^6\ mm^4$
Centroid Distance	$y_{Tt} = 5.06\ in$	$y_{Tt} = 128.5\ mm$
Centroid Distance	$y_{Tb} = 1.03\ in$	$y_{Tb} = 26.3\ mm$

Composite Section

Area	$A_c = 19.4\ in^2$	$A_c = 12513\ mm^2$
Moment of Inertia (x-axis)	$Ix_c = 1096\ in^4$	$Ix_c = 4.56 \cdot 10^8\ mm^4$
Centroid Distance (top)	$y_{ct} = 12.3\ in$	$y_{ct} = 312\ mm$
Centroid Distance (bot)	$y_{cb} = 7.9\ in$	$y_{cb} = 201\ mm$
Section Modulus (design x-axis)	$Sx_{ct} = 89.3\ in^3$	$Sx_{ct} = 1.46 \cdot 10^6\ mm^3$
Section Modulus (design x-axis)	$Sx_{cb} = 138.5\ in^3$	$Sx_{cb} = 2.27 \cdot 10^6\ mm^3$
Moment Resistance	$M_{rc} = 334.9\ K\_ft$	$M_{rc} = 454.1\ kN\_m$

$Check\left(M_{rc} \ge M_f\right) = "...OK"$ $Check\left(\frac{M_{rc}}{\varphi_s} \ge M_f\right) = "...OK"$ **Allow for Overload**

Maximum UDL	$q_f = 6.7\ Klf$	$q_f = 97.8\ kNpm$
Maximum Reaction (Shear)	$V_f = 67.0\ K$	$V_f = 297.9\ kN$
Length of Reinforcing	$l_c = 13.4887\ ft$	$l_c = 13.4887\ ft$

$Check\left(l_c \le L\right) = "...OK"$

Shear Stress at W and T Junction based on Max Shear	$\tau = 9.78\ Ksi$	$\tau = 67.42\ MPa$
Minimum Weld Capacity	$V_{rw} = 22.22\ Ksi$	$V_{rw} = 153.2\ MPa$
Connection Shear per Unit Length	$\tau' = 42.2\ K$	$\tau' = 187.9\ kN$
Minimum Weld Capacity	$V_{rw} = 22.22\ Ksi$	$V_{rw} = 153.20\ MPa$
Weld Resistance per Unit Length	$\tau_r = 88.9\ K$	$\tau_r = 395.3\ kN$

$Check\left(\tau_r \ge \tau'\right) = "...OK"$ $Check\left(\frac{\tau_r}{\varphi_s} \ge \tau'\right) = "...OK"$ **Allow for Overload**

End Connection Force:

Stress at Bot of W Section	$\sigma_1 = 6.59\ Ksi$	$\sigma_1 = 45.4\ MPa$
Stress at Top of T Flange	$\sigma_2 = 26.29\ Ksi$	$\sigma_2 = 181.3\ MPa$
Stress at Bot of Comp Section	$\sigma_3 = 28.60\ Ksi$	$\sigma_3 = 197.2\ MPa$
Tensile Force in T Section	$F_{fT} = 208.11\ K$	$F_{fT} = 925.74\ kN$
Moment from Force in T Section	$M_{fT} = 1121.07\ K\_in$	$M_{fT} = 1.27 \cdot 10^5\ kN\_mm$
End Connection Force	$F_{fe} = 9.34\ K$	$F_{fe} = 41.56\ kN$
Length of Weld Required	$l_e = 1.68\ in$	$l_e = 42.72\ mm$