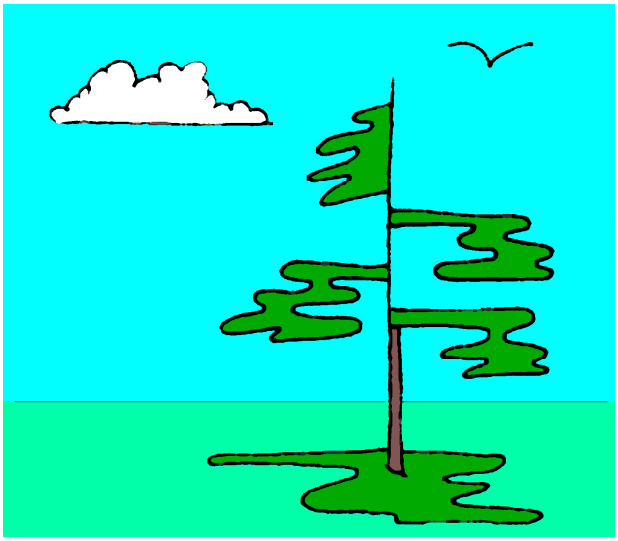
NorthWoods Software



Program Name: Prop-W_BU_T2T (Flange-Toe to Toe)

Project Number: -

Project Description: -

Project Designer: Dik

Last Revised (yy-mm-dd): 22.01.03

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:

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..... Sum / For	Red Important Note	Gray Temporary Variables	

Input Data

Material Property Factors:

$\varphi_s := 0.90$

$\varphi_w := 0.67$

Load Factors:

$\alpha_L := 1.50$

$\alpha_D := 1.25$

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

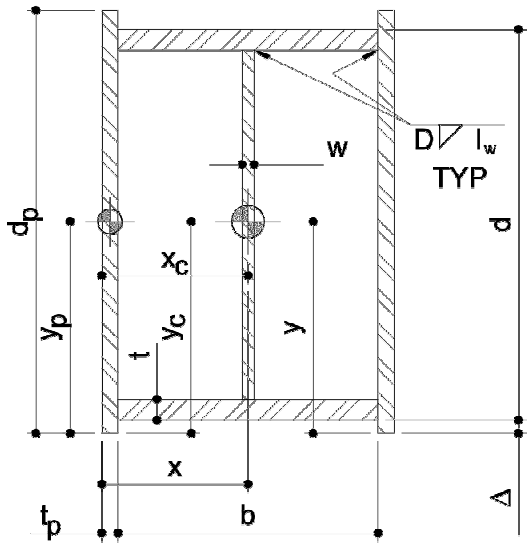
$Check\left(\alpha_L \geq 1.5\right) = \text{"...OK"}$

Steel Properties:

Built Up Column: $st_{NDX} := 2$

$st :=$

NDX	des	fy	Fu
1	"G40.21-350W"	50 Ksi	65 Ksi
2	"G40.21-300W"	44 Ksi	65 Ksi
3	"A36"	36 Ksi	58 Ksi



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

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

$\gamma_s := 489\ pcf$

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

Added Toe Plates: $st_{NDX} := 2$

c b a

Section Properties:

Built Up Section:

$desI_{BU} := \text{"Custom"}$	$desI_{BU} = \text{"Custom"}$		Designation Imperial
$desM_{BU} := \text{"Custom"}$	$desM_{BU} = \text{"Custom"}$		Designation Metric
$d := 13\ in$	$d = 13.00\ in$	$d = 330.2\ mm$	BU Depth
$b := 8\ in$	$b = 8\ in$	$b = 203.2\ mm$	BU Width
$t := 1.00\ in$	$t = 1.00\ in$	$t = 25.4\ mm$	BU Flange Thickness
$w := 0.375\ in$	$w = 0.38\ in$	$w = 9.5\ mm$	BU Web Thickness

Added Toe Plates:

$d_p := 14\ in$	$d_p = 14.00\ in$	$d_p = 355.6\ mm$	Toe Plate Depth
$t_p := .5\ in$	$t_p = 0.5\ in$	$t_p = 12.7\ mm$	Toe Plate Thickness
$\Delta := \frac{d_p - d}{2}$	$\Delta = 0.50\ in$	$\Delta = 12.70\ mm$	Delta to W Section

$Check\left(d_p \geq d\right) = \text{"...OK"}$

Composite Section:

$A_c := 2 \cdot b \cdot t + 2 \cdot d_p \cdot t_p + w \cdot (d - 2 \cdot t)$ **Check**

$A_c = 34.13\ in^2$ $A_c = 22016.09\ mm^2$ Area

$wt_c := A_c \cdot \gamma_s$ $wt_c = 115.88\ plf$ $wt_c = 1.69\ kNpm$ Weight per Unit Length

$$x_c := \frac{2 \cdot b \cdot t \cdot \left(\frac{b}{2} + t_p\right) + d_p \cdot t_p \cdot \frac{t_p}{2} + d_p \cdot t_p \cdot \left(t_p + b + \frac{t_p}{2}\right) + (d - 2 \cdot t) \cdot w \cdot \left(t_p + \frac{b}{2}\right)}{A_c}$$ **Check**

$x_c = 4.50\ in$ $x_c = 114.30\ mm$ X-Axis Centroid Distance

$$y_c := \frac{b \cdot t \cdot \left(\frac{t}{2} + \Delta\right) + b \cdot t \cdot \left(d_p - \Delta - \frac{t}{2}\right) + 2 \cdot d_p \cdot t_p \cdot \frac{d_p}{2} + (d - 2 \cdot t) \cdot w \cdot \left(\frac{d}{2} + \Delta\right)}{A_c}$$ **Check**

$y_c = 7.00\ in$ $y_c = 177.80\ mm$ Y-Axis Centroid Distance

$$Ix_{c1} := b \cdot \frac{t^3}{12} + w \cdot \frac{(d - 2 \cdot t)^3}{12} + b \cdot \frac{t^3}{12} + t_p \cdot \frac{d_p^3}{12} + t_p \cdot \frac{d_p^3}{12} + b \cdot t \cdot \left(y_c - \left(\Delta + \frac{t}{2}\right)\right)^2 + w \cdot (d - 2 \cdot t) \cdot \left(y_c - \left(\Delta + \frac{d}{2}\right)\right)^2$$

$$Ix_c := Ix_{c1} + b \cdot t \cdot \left(y_c - \left(\Delta + d - \frac{t}{2}\right)\right)^2 + d_p \cdot t_p \cdot \left(y_c - \left(\frac{d_p}{2}\right)\right)^2 + d_p \cdot t_p \cdot \left(y_c - \left(\frac{d_p}{2}\right)\right)^2$$

$Ix_c = 847.59\ in^4$ $Ix_c = 3.53 \cdot 10^8\ mm^4$ Moment of Inertia (X-Axis) **Check**

$rx_c := \sqrt{\frac{Ix_c}{A_c}}$ $rx_c = 4.98\ in$ $rx_c = 126.59\ mm$ Radius of Gyration (X-Axis) **Check**

$Sx_c := \frac{Ix_c}{y_c}$ $Sx_c = 121.08\ in^3$ $Sx_c = 1.98 \cdot 10^6\ mm^3$ Section Modulus (X-Axis) **Check**

$$Zx_c := \frac{1}{4} \cdot \left(b \cdot d^2 - (b - w) \cdot (d - 2 \cdot t)^2\right) + t_p \cdot \frac{d_p^2}{2}$$

$Zx_c = 156.34\ in^3$ $Zx_c = 2.56 \cdot 10^6\ mm^3$ Plastic Section (X-Axis) **Check**

$$Iy_c := t \cdot \frac{b^3}{12} + (d - 2 \cdot t) \cdot \frac{w^3}{12} + t \cdot \frac{b^3}{12} + d_p \cdot \frac{t_p^3}{12} + d_p \cdot \frac{t_p^3}{12} + b \cdot t \cdot \left(x_c - \left(t_p + \frac{b}{2}\right)\right)^2 + w \cdot (d - 2 \cdot t) \cdot \left(x_c - \left(t_p + \frac{b}{2}\right)\right)^2$$

$$Iy_c := Iy_c + b \cdot t \cdot \left(x_c - \left(t_p + \frac{b}{2}\right)\right)^2 + d_p \cdot t_p \cdot \left(x_c - \left(\frac{t_p}{2}\right)\right)^2 + d_p \cdot t_p \cdot \left(x_c - \left(t_p + b + \frac{t_p}{2}\right)\right)^2$$

	$Iy_c = 338.55\ \text{in}^4$	$Iy_c = 1.41 \cdot 10^8\ \text{mm}^4$	Moment of Inertia (Y-Axis)	**Check**
$Sy_c := \frac{Iy_c}{x_c}$	$Sy_c = 75.23\ \text{in}^3$	$Sy_c = 1.23 \cdot 10^6\ \text{mm}^3$	Section Modulus (Y-Axis)	**Check**
$ry_c := \sqrt{\frac{Iy_c}{A_c}}$	$ry_c = 3.15\ \text{in}$	$ry_c = 80.00\ \text{mm}$	Radius of Gyration (Y-Axis)	**Check**
$Ip_c := Ix_c + Iy_c$	$Ip_c = 1186.14\ \text{in}^4$	$Ip_c = 4.94 \cdot 10^8\ \text{mm}^4$	Polar Moment of Inertia	**Check**

$$Zy_c := t_p \cdot d_p \cdot \left(b + t_p\right) + \frac{d \cdot b^2}{4} - 2 \cdot (d - 2 \cdot t) \cdot \left(\frac{b - w}{2}\right) \cdot \left(\left(\frac{b - w}{4}\right) + \frac{w}{2}\right)$$

$Zy_c = 91.89\ \text{in}^3$	$Zy_c = 1.51 \cdot 10^6\ \text{mm}^3$	Plastic Section (Y-Axis)	**Check**

Class of Section

$bt_1 := \frac{145}{\sqrt{\frac{f_{y1}}{\text{MPa}}}}$	$bt_1 = 8.325$	b/t Ratio Class 1
$bt_2 := \frac{170}{\sqrt{\frac{f_{y1}}{\text{MPa}}}}$	$bt_2 = 9.7603$	b/t Ratio Class 2
$bt_3 := \frac{200}{\sqrt{\frac{f_{y1}}{\text{MPa}}}}$	$bt_3 = 11.4827$	b/t Ratio Class 3
$dw_1 := \frac{1600}{\sqrt{\frac{f_{y1}}{\text{MPa}}}}$	$dw_1 = 91.8616$	d/w Ratio Class 1
$dw_2 := \frac{1700}{\sqrt{\frac{f_{y1}}{\text{MPa}}}}$	$dw_2 = 97.603$	d/w Ratio Class 2
$dw_3 := \frac{1900}{\sqrt{\frac{f_{y1}}{\text{MPa}}}}$	$dw_3 = 109.0857$	d/w Ratio Class 3

```
if (b/(2·t)) ≤ bt_1 ∧ min([[d/w · ((d_p − 2·Δ)/t_p)]]) ≤ dw_1
  Class := 1
else
  if (b/(2·t)) ≤ bt_2 ∧ min([[d/w · ((d_p − 2·Δ)/t_p)]]) ≤ dw_2
    Class := 2
  else
    if b/(2·√t) ≤ bt_3 ∧ min([[d/w · ((d_p − 2·Δ)/t_p)]]) ≤ dw_3
      Class := 3
    else
      Class := 4
```

$$Class = 1$$

$$A_p := \left(d - \min\left(\left[\begin{array}{cc} t & t_p \end{array}\right]\right)\right)\cdot\left(b - \min\left(\left[\begin{array}{cc} t & t_p \end{array}\right]\right)\right)$$

$$p := 2\cdot\left(\left(d - \min\left(\left[\begin{array}{cc} t & t_p \end{array}\right]\right)\right) + \left(b - \min\left(\left[\begin{array}{cc} t & t_p \end{array}\right]\right)\right)\right)$$

$$J_c := \frac{4\cdot A_p^{\,2}\cdot t}{p} \qquad J_c = 878.91\ \text{in}^4 \qquad J_c = 3.66\cdot 10^{8}\ \text{mm}^4$$

Approx Torsional Constant

$$Cw_c := \frac{b^{\,2}\cdot d^{\,2}}{24}\cdot\frac{\left(b\cdot t_p - d\cdot t\right)^2}{\left(b\cdot t_p + d\cdot t\right)^2}\cdot\left(b\cdot t - d\cdot t_p\right)$$

$$Cw_c = 189.47\ \text{in}^6 \qquad Cw_c = 5.09\cdot 10^{10}\ \text{mm}^6$$

$$r_c := \left(\frac{\left(\frac{Iy_c}{2} - \left(\left(\frac{\left(d - 2\cdot t\right)}{3}\right)\cdot w^{\,3}\right)\right)}{\frac{A_c}{2} - \left(\left(\frac{\left(d - 2\cdot t\right)}{3}\right)\cdot w\right)}\right)^{0.5}$$

$$r_c = 3.28\ \text{in} \qquad r_c = 83.43\ \text{mm}$$

rt Constant

c b a

Summary:

Material Property Factors:

$\varphi_s := 0.90$ (Steel)

$\varphi_w := 0.67$ (Weld)

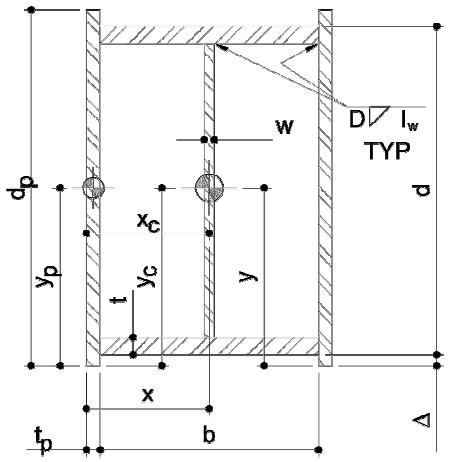
Load Factors

$\alpha_L = 1.50$ Dead Load

$\alpha_D = 1.25$ Live Load

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

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



Steel Properties

Built Up Column

Designation	$desM_{st1} = "G40.21-300W"$	
Yield Strength	$f_{y1} = 44\ Ksi$	$f_{y1} = 303\ MPa$
Ultimate Strength	$F_{u1} = 65\ Ksi$	$F_{u1} = 448\ MPa$

Added Toe Plates

Designation	$desM_{st2} = "G40.21-300W"$	
Yield Strength	$f_{y2} = 44\ Ksi$	$f_{y2} = 303\ MPa$
Ultimate Strength	$F_{u2} = 65\ Ksi$	$F_{u2} = 448\ MPa$
Young's Modulus	$E_s = 29000\ Ksi$	$E_s = 2.00 \cdot 10^{5}\ MPa$
Poisson's Ratio	$\nu = 0.3$	
Shear Modulus	$G_s = 11154\ Ksi$	$G_s = 76903\ MPa$
Density	$\gamma_s = 489\ pcf$	$\gamma_s = 76.8\ kNpcm$

Composite Section Properties

Designation	$desI_{BU} = "Custom"$	$desM_{BU} = "Custom"$
Area	$A_c = 34.13\ in^2$	$A_c = 22016\ mm^2$
Weight per Unit Length	$wt_c = 115.9\ plf$	$wt_c = 1.69\ kNpm$
Moment of Inertia (X-Axis)	$Ix_c = 847.6\ in^4$	$Ix_c = 3.53 \cdot 10^{8}\ mm^4$
Section Modulus (X-Axis)	$Sx_c = 121.1\ in^3$	$Sx_c = 1.98 \cdot 10^{6}\ mm^3$
Radius of Gyration (X-Axis)	$rx_c = 4.98\ in$	$rx_c = 127\ mm$
Plastic Section (X-Axis)	$Zx_c = 156.3\ in^3$	$Zx_c = 2.56 \cdot 10^{6}\ mm^3$
Moment of Inertia (Y-Axis)	$Iy_c = 338.5\ in^4$	$Iy_c = 1.41 \cdot 10^{8}\ mm^4$
Section Modulus (Y-Axis)	$Sy_c = 75.23\ in^3$	$Sy_c = 1.23 \cdot 10^{6}\ mm^3$
Radius of Gyration (Y-Axis)	$ry_c = 3.15\ in$	$ry_c = 80\ mm$
Plastic Section (Y-Axis)	$Zy_c = 91.89\ in^3$	$Zy_c = 1.51 \cdot 10^{6}\ mm^3$
Moment of Inertia (Polar)	$Ip_c = 1186.1\ in^4$	$Ip_c = 4.94 \cdot 10^{8}\ mm^4$
Class of Section	$Class = 1$	
Approximate Torsional Constant	$J_c = 878.91\ in^4$	$J_c = 3.66 \cdot 10^{8}\ mm^4$
rt Constant	$r_c = 3.28\ in$	$r_c = 83.43\ mm$
Warping Constant	$Cw_c = 189.4671\ in^6$	$Cw_c = 5.0879 \cdot 10^{10}\ mm^6$