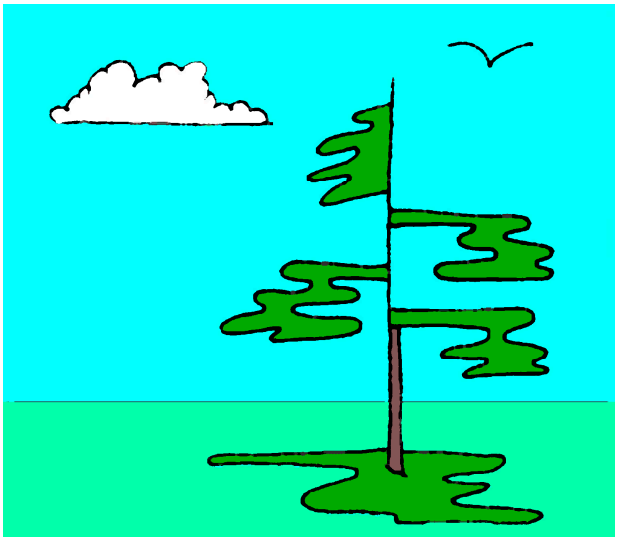
NorthWoods Software



Program Name: Composite-W_PL

Project Name: -

Project Number: -

Project Description: -

Project Designer: Dik

Last Revised (yy-mm-dd): 21-04-11

Reference: NBCC

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

Menu:

..... Input Data ..... Important Output ..... Logical Constructs **Blue** **Units**

..... Sum / For **Red** **Important Note**

Defined Units:

K := kip — Force

K_ft := K ft kN_m := kN m K_in := K in kN_mm := kN mm lb_in := lbf in — Moment

$pcf := \frac{lbf}{ft^3}$ $kNpcm := \frac{kN}{m^3}$ $kgpcm := \frac{kg}{m^3}$ — Density

$Klf := \frac{K}{ft}$ $plf := \frac{lbf}{ft}$ $kNpm := \frac{kN}{m}$ $Kpi := \frac{K}{in}$ $kNpmm := \frac{kN}{mm}$ — Force/Unit Length

$psf := \frac{lbf}{ft^2}$ $Ksf := \frac{K}{ft^2}$ $Ksi := \frac{K}{in^2}$ $kNpsm := \frac{kN}{m^2}$ $psi := \frac{lbf}{in^2}$ — Pressure

$pci := \frac{lbf}{in^3}$ — Subgrade Modulus

$psfpf := \frac{psf}{ft}$ $kPapm := \frac{kPa}{m}$ — Pressure per Depth

$pmcf := \frac{lb}{ft^3}$ lb := lbf — Force

$mph := \frac{mi}{hr}$ $kph := \frac{km}{hr}$ — Velocity

$ispf := \frac{in^2}{ft}$ $mmspm := \frac{mm^2}{m}$ — Area per Unit Length

User Defined Functions: *c* *b* *a*

```
Check(arg) := if arg = 1
                Check := "...OK"
              else
                Check := "...NG"
```

Check(2 = 3) = "...NG"

Check(2 ≠ 3) = "...OK"

Check(2 ≤ 3) = "...OK"

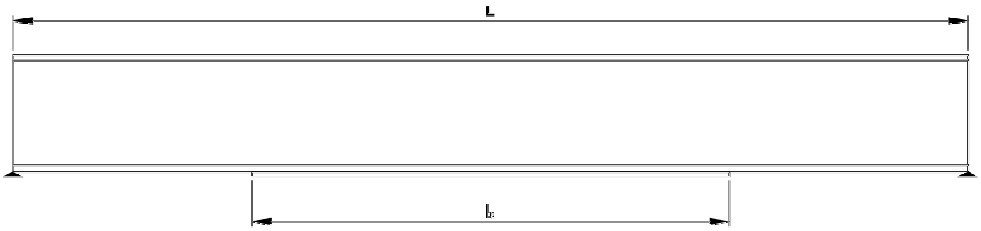
Check(3 ≥ 2) = "...OK"

Input Data

Material Property Factors:

$\varphi_s := 0.90$

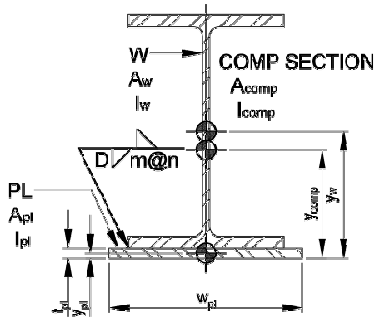
$\varphi_w := 0.67$



Load Factors:

$\alpha_L := 1.50$

$\alpha_D := 1.25$



Steel Properties:

W Properties $stl_{NDX} := 1$

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

$desI_1 := stl_{stl_{NDX},2}$ $f_{y1} := stl_{stl_{NDX},3}$

$F_{u1} := stl_{stl_{NDX},4}$ $E_s := 29000\ \text{Ksi}$

$\nu := 0.3$ $G_s := \frac{E_s}{2 \cdot (1 + \nu)}$ $G_s := 11154\ \text{Ksi}$ $\gamma_s := 489\ \text{pcf}$

PL Properties $stl_{NDX} := 1$

Weld: $desI_2 := stl_{stl_{NDX},2}$ $F_{u2} := stl_{stl_{NDX},4}$ $f_{y2} := stl_{stl_{NDX},3}$

Beam Span: $L := 19.33\ \text{ft}$ $L = 5.89\ \text{m}$ Span Length

Electrodes $we_{NDX} := 2$

$$we := \begin{bmatrix} \text{NDX} & \text{DesI} & \text{DesM} & \text{UTS} \\ 1 & \text{"E60xx"} & \text{"E410xx"} & 60\ \text{ksi} \\ 2 & \text{"E70xx"} & \text{"E480xx"} & 70\ \text{ksi} \\ 3 & \text{"E80xx"} & \text{"E550xx"} & 80\ \text{ksi} \\ 4 & \text{"E90xx"} & \text{"E620xx"} & 90\ \text{ksi} \end{bmatrix}$$

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

$desM_w := we_{we_{NDX},3}$

Size $ws_{NDX} := 4$

$ws :=$

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

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

$D := ws_{ws_{NDX},4}$

$m := 3\ in$ $m = 76.2\ mm$ Weld Length

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

W Section

$desI_w := "W16x26"$

$desM_w := "W410x39"$

$d_w := 15.69\ in$ $d_w = 398.5\ mm$ W Beam Depth

$b_w := 5.50\ in$ $b_w = 139.7\ mm$ W Beam Width

$t_w := 0.345\ in$ $t_w = 8.8\ mm$ W Beam Depth

$w_w := 0.25\ in$ $w_w = 6.35\ mm$ W Beam Width

$A_w := 2 \cdot b_w \cdot t_w + \left(d_w - 2 \cdot t_w\right) \cdot w_w$

$A_w = 7.545\ in^2$ $A_w = 4868\ mm^2$ W Beam Area

$Ix_w := \frac{1}{12} \cdot \left(b_w \cdot d_w^{\,3} - \left(b_w - w_w\right) \cdot \left(d_w - 2 \cdot t_w\right)^3\right)$ W Beam Ix

$Ix_w = 294\ in^4$ $Ix_w = 1.22 \cdot 10^8\ mm^4$

$y_w := \frac{d_w}{2}$ $y_w = 7.85\ in$ $y_w = 199.3\ mm$ W Centroid Distance

$Sx_w := \frac{1}{6 \cdot d_w} \cdot \left(b_w \cdot d_w^{\,3} - \left(b_w - w_w\right) \cdot \left(d_w - 2 \cdot t_w\right)^3\right)$ W Beam Sx

$Sx_w = 37.4\ in^3$ $Sx_w = 6.14 \cdot 10^5\ mm^3$

PL Section

$desI_{pl} := "PL\ .25x6"$

$desM_{pl} := "PL\ 6x150"$

$w_{pl} := 6.0\ in$ $w_{pl} = 152.4\ mm$ PL Width

$t_{pl} := 0.25\ in$ $t_{pl} = 6.4\ mm$ PL Thickness

$A_{pl} := w_{pl} \cdot t_{pl}$ $\quad A_{pl} = 1.500\ \text{in}^2$ $\quad A_{pl} = 967.7\ \text{mm}^2$ PL Area

$Ix_{pl} := \frac{w_{pl} \cdot t_{pl}^3}{12}$ $\quad Ix_{pl} = 0.008\ \text{in}^4$ $\quad Ix_{pl} = 3251.8\ \text{mm}^4$ PL Ix

$y_{pl} := \frac{t_{pl}}{2}$ $\quad y_{pl} = 0.125\ \text{in}$ $\quad y_{pl} = 3.2\ \text{mm}$ PL Centroid Dist

Composite Section Centroid

$A_{comp} := A_w + A_{pl}$ $\quad A_{comp} = 9.05\ \text{in}^2$ $\quad A_{comp} = 5835\ \text{mm}^2$

$y_b := \frac{A_w \cdot \left(y_w + t_{pl}\right) + A_{pl} \cdot y_{pl}}{A_{comp}}$ $\quad y_b = 6.77\ \text{in}$ $\quad y_b = 172.0\ \text{mm}$

Moment of Inertia (x-Axis)

$Ix_{comp} := Ix_w + \left(A_w \cdot \left(y_w + t_{pl} - y_b\right)^2\right) + Ix_{pl} + \left(A_{pl} \cdot \left(y_{pl} - y_b\right)^2\right)$

$Ix_{comp} = 373\ \text{in}^4$ $\quad Ix_{comp} = 1.55 \cdot 10^8\ \text{mm}^4$

Design shear stress is determined based on the uniform distributed load that produces the maximum resisting moment for the fully braced span under consideration.

Section Modulus (x-Axis)

$y_t := d_w + t_{pl} - y_b$ $\quad y_t = 9.17\ \text{in}$ $\quad y_t = 232.8\ \text{mm}$

$Sx_t := \frac{Ix_{comp}}{y_t}$ $\quad Sx_t = 40.7\ \text{in}^3$ $\quad Sx_t = 6.67 \cdot 10^5\ \text{mm}^3$

$Sx_b := \frac{Ix_{comp}}{y_b}$ $\quad Sx_b = 55.1\ \text{in}^3$ $\quad Sx_b = 9.03 \cdot 10^5\ \text{mm}^3$

Moment Resistance

$M_{rt} := \varphi_s \cdot Sx_t \cdot f_{y1}$ $\quad M_{rt} = 152.7\ \text{K\_ft}$ $\quad M_{rt} = 207.0\ \text{kN\_m}$

$M_{rb} := \varphi_s \cdot Sx_b \cdot f_{y2}$ $\quad M_{rb} = 206.6\ \text{K\_ft}$ $\quad M_{rb} = 280.2\ \text{kN\_m}$

$M_r := \min\left(\left[\begin{array}{cc} M_{rt} & M_{rb} \end{array}\right]\right)$ $\quad M_r = 152.7\ \text{K\_ft}$ $\quad M_r = 207\ \text{kN\_m}$

Maximum UDL

$Q_{max} := \frac{8 \cdot M_r}{\frac{L}{2}^2}$ $\quad Q_{max} = 3.3\ \text{Klf}$ $\quad Q_{max} = 47.7\ \text{kNpm}$

Maximum Reaction (Shear)

$V_{max} := Q_{max} \cdot \frac{L}{2}$ $\quad V_{max} = 31.6\ \text{K}$ $\quad V_{max} = 140.5\ \text{kN}$

Shear Stress at W and WT Junction

$A' := A_{pl}$

$y_{bar} := y_b - \frac{t_{pl}}{2}$

$\tau := \frac{V_{max}}{Ix_{comp} \cdot \min\left(\left[\begin{array}{cc} w_{pl} & b_w \end{array}\right]\right)} \cdot A' \cdot \left(y_{bar}\right)$

$\tau = 0.15\ \text{Ksi}$ $\quad \tau = 1.06\ \text{MPa}$

Weld Design:

Weld Material Strength

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

Weld Material Strength / Unit Length

$V_{rw} := v_{rw} \cdot D$ $V_{rw} = 4.17\ \text{Kpi}$ $V_{rw} = 0.73\ \text{kNpmm}$

Base Metal Strength

$v_{rb} := \varphi_s \cdot \min\left(\begin{bmatrix} f_{y1} & f_{y2} \end{bmatrix}\right)$ $v_{rb} = 45.00\ \text{Ksi}$ $v_{rb} = 310.26\ \text{MPa}$

Base Metal Strength / Unit Length

$V_{rb} := v_{rb} \cdot D$ $V_{rb} = 8.44\ \text{Kpi}$ $V_{rb} = 1.48\ \text{kNpmm}$

Minimum Weld Capacity

$V_{rmin} := \min\left(\begin{bmatrix} V_{rw} & V_{rb} \end{bmatrix}\right)$ $V_{rmin} = 4.17\ \text{Kpi}$ $V_{rmin} = 0.73\ \text{kNpmm}$

Connection Shear per Unit Length

$\tau' := \left(\tau \cdot n \cdot \min\left(\begin{bmatrix} w_{pl} & b_w \end{bmatrix}\right)\right)$

$\tau' = 10.1\ \text{K}$ $\tau' = 45.1\ \text{kN}$

Weld Provided

$\tau_r := 2 \cdot V_{rmin} \cdot m$ $\tau_r = 25.0\ \text{K}$ $\tau_r = 111.2\ \text{kN}$

Connection Force at End:

Length of Reinforcment

$M_{rw} := \varphi_s \cdot f_{y1} \cdot Sx_w$ $M_{rw} = 140.4\ K\_ft$ $M_{rw} = 190.4\ kN\_m$

$M_{rcomp} := \varphi_s \cdot f_{y1} \cdot Sx_b$ $M_{rcomp} = 206.6\ K\_ft$ $M_{rcomp} = 280.2\ kN\_m$

$\Delta_M := M_{rcomp} - M_{rw}$ $\Delta_M = 66.2\ K\_ft$ $\Delta_M = 89.8\ kN\_m$

$l_r := \sqrt{\frac{8 \cdot \Delta_M}{Q_{max}}}$ $l_r = 12.73\ ft$ $l_r = 3.88\ m$

Stress at Bottom of Reinforcement

$\sigma_b := \frac{M_{rcomp} \cdot y_b}{Ix_{comp}}$ $\sigma_b = 45.00\ Ksi$ $\sigma_b = 310.26\ MPa$

Stress at Top of Reinforcment

$\sigma_t := \frac{M_{rcomp} \cdot \left(y_b - t_{pl}\right)}{Ix_{comp}}$ $\sigma_t = 43.3391\ Ksi$ $\sigma_t = 298.8123\ MPa$

Force Centroid

$$e_c := \frac{\sigma_t \cdot t_{pl} \cdot \frac{t_{pl}}{2} + \left(\sigma_b - \sigma_t\right) \cdot \frac{t_{pl}}{2} \cdot \frac{2 \cdot t_{pl}}{3}}{\sigma_t \cdot t_{pl} + \left(\sigma_b - \sigma_t\right) \cdot \frac{t_{pl}}{2}}$$

$e_c = 0.126\ in$ $e_c = 3.19\ mm$

$F_e := w_{pl} \cdot t_{pl} \cdot \frac{\left(\sigma_t + \sigma_b\right)}{2}$ $F_e = 66.25\ K$ $F_e = 294.71\ kN$

Connection Force

$F_c := F_e \cdot e_c \cdot \frac{2}{l_r}$ $F_c = 0.11\ K$ $F_c = 0.49\ kN$

Summary:

Material Property Factor (Welds)	$\varphi_w = 0.67$	
Material Property Factor (Steel)	$\varphi_s = 0.9$	
Dead Load Factor	$\alpha_D = 1.25$	
Live Load Factor	$\alpha_L = 1.5$	
Steel		
Designation (Beam)	$desI_1 = \text{"G40.21-350W"}$	
Yield Strength (Beam)	$f_{y1} = 50\ \text{Ksi}$	$f_{y1} = 345\ \text{MPa}$
Ultimate Strength (Beam)	$F_{u1} = 65\ \text{Ksi}$	$F_{u1} = 448\ \text{MPa}$
Young's Modulus	$E_s = 29000\ \text{Ksi}$	$E_s = 1.9995 \cdot 10^{5}\ \text{MPa}$
Shear Modulus	$G_s = 11154\ \text{Ksi}$	$G_s = 76904\ \text{MPa}$
Density	$\gamma_s = 489\ \text{pcf}$	$\gamma_s = 76.8\ \text{kNpcm}$
Welds		
Electrode Designation (Imperial)	$desI_w = \text{"W16x26"}$	
Electrode Designation (Metric)	$desM_w = \text{"W410x39"}$	
Ultimate Strength (Welding Electrode)	$X_u = 70\ \text{Ksi}$	$X_u = 483\ \text{MPa}$
Size Designation	$desI_D = \text{"3/16"}$	$desM_D = \text{""}$
Fillet Weld Size	$D = 0.1875\ \text{in}$	$D = 4.7625\ \text{mm}$
W Section		
Designation	$desI_w = \text{"W16x26"}$	$desM_w = \text{"W410x39"}$
Depth	$d_w = 15.7\ \text{in}$	$d_w = 398.5\ \text{mm}$
Area	$A_w = 7.5\ \text{in}^2$	$A_w = 4867.7\ \text{mm}^2$
Moment of Inertia (x-axis)	$Ix_w = 293.8\ \text{in}^4$	$Ix_w = 1.2 \cdot 10^{8}\ \text{mm}^4$
Centroid Distance	$y_w = 7.8\ \text{in}$	$y_w = 199.3\ \text{mm}$
PL Section		
Designation (Imperial)	$desI_{pl} = \text{"PL .25x6"}$	
Designation (Metric)	$desM_{pl} = \text{"PL 6x150"}$	
Width	$w_{pl} = 6\ \text{in}$	$w_{pl} = 152.4\ \text{mm}$
Thickness	$t_{pl} = 0.250\ \text{in}$	$t_{pl} = 6.4\ \text{mm}$
Area	$A_{pl} = 1.5\ \text{in}^2$	$A_{pl} = 967.7\ \text{mm}^2$
Moment of Inertia (x-axis)	$Ix_{pl} = 0\ \text{in}^4$	$Ix_{pl} = 3251.8\ \text{mm}^4$
Centroid Distance	$y_{pl} = 0.1\ \text{in}$	$y_{pl} = 3.2\ \text{mm}$
Composite Section		
Area	$A_{comp} = 9.05\ \text{in}^2$	$A_{comp} = 5835\ \text{mm}^2$
Moment of Inertia (x-axis)	$Ix_{comp} = 373\ \text{in}^4$	$Ix_{comp} = 1.55 \cdot 10^{8}\ \text{mm}^4$
Centroid Distance (top)	$y_t = 9.17\ \text{in}$	$y_t = 232.8\ \text{mm}$
Centroid Distance (bottom)	$y_b = 6.77\ \text{in}$	$y_b = 172.0\ \text{mm}$

Section Modulus (top)	$Sx_t = 40.7\ in^3$	$Sx_t = 6.67 \cdot 10^5\ mm^3$
Section Modulus (bottom)	$Sx_b = 55.1\ in^3$	$Sx_b = 9.03 \cdot 10^5\ mm^3$
Composite Connection Design		
Beam Span	$L = 19.33\ ft$	$L = 5.892\ m$
Resisting Moment (top) based on fy1	$M_{rt} = 152.7\ K\_ft$	$M_{rt} = 207\ kN\_m$
Maximum Resisting (bottom) based on fy2	$M_{rb} = 206.6\ K\_ft$	$M_{rb} = 280.2\ kN\_m$
Minimum Resisting Moment	$M_r = 152.7\ K\_ft$	$M_r = 207\ kN\_m$
Maximum Uniformly Distributed Load	$Q_{max} = 3.3\ Klf$	$Q_{max} = 47.7\ kNpm$
Maximum Design Shear	$V_{max} = 31.6\ K$	$V_{max} = 140.5\ kN$
Shear Stress at Interface	$\tau = 0.153\ Ksi$	$\tau = 1.058\ MPa$
Shear Resistance per Unit Length		
Weld Length	$m = 3\ in$	$m = 76.2\ mm$
Weld Spacing	$n = 12\ in$	$n = 304.8\ mm$
Total Shear per Unit Length	$\tau' = 10.1\ K$	$\tau' = 45.1\ kN$
Minimum Weld Capacity	$V_{rmin} = 4.17\ Kpi$	$V_{rmin} = 0.73\ kNpmm$
Shear Resistance per Unit Length	$\tau_r = 25\ K$	$\tau_r = 111.2\ kN$

$Check\left(\tau_r \geq \tau'\right) = "...OK"$

Connection at End		
Moment Resistance of Unreinforced Section	$M_{rw} = 140.4\ K\_ft$	$M_{rw} = 190.4\ kN\_m$
Moment Resistance of Composite Section	$M_{rcomp} = 206.6\ K\_ft$	$M_{rcomp} = 280.2\ kN\_m$
Moment Difference	$\Delta_M = 66.2\ K\_ft$	$\Delta_M = 89.8\ kN\_m$
Equivalent Span	$l_r = 12.73\ ft$	$l_r = 3.880\ m$
Force Eccentricity in Reinforcing	$e_c = 0.126\ in$	$e_c = 3.2\ mm$
Total Force in Reinforcing	$F_e = 66.3\ K$	$F_e = 294.7\ kN$
Connection Force at End of Reinforcing	$F_c = 0.11\ K$	$F_c = 0.49\ kN$