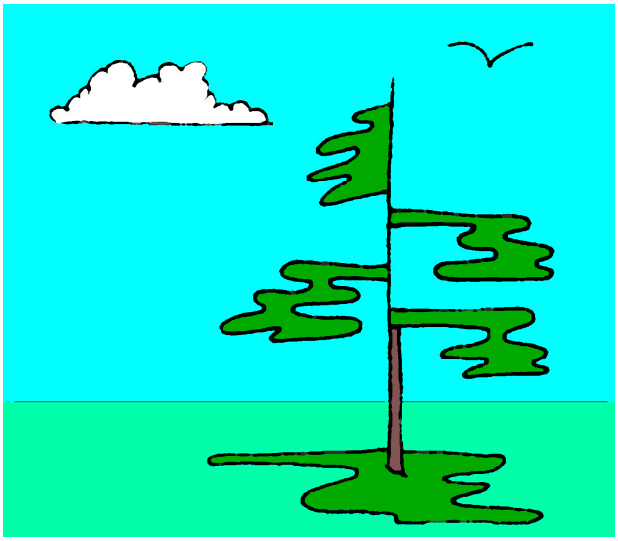
NorthWoods Software



Program Name: NGuardrail-HSSc_Post_to_Stringer

Project Name: -

Project Number: -

Project Description: -

Project Designer: Dik

Last Revised (yy-mm-dd): 21.07.06

Reference: NBCC, CSA S16

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**	Gray Temporary Variables	

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

$Npsmm := \frac{N}{mm^2}$ — 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:

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

c

$Check(2 = 3) = \text{"...NG"}$

$Check(2 \neq 3) = \text{"...OK"}$

b

$Check(2 \leq 3) = \text{"...OK"}$

$Check(3 \geq 2) = \text{"...OK"}$

a

Input Data

Material Property Factors:

$\varphi_s := 0.90$

$\varphi_b := 0.8$

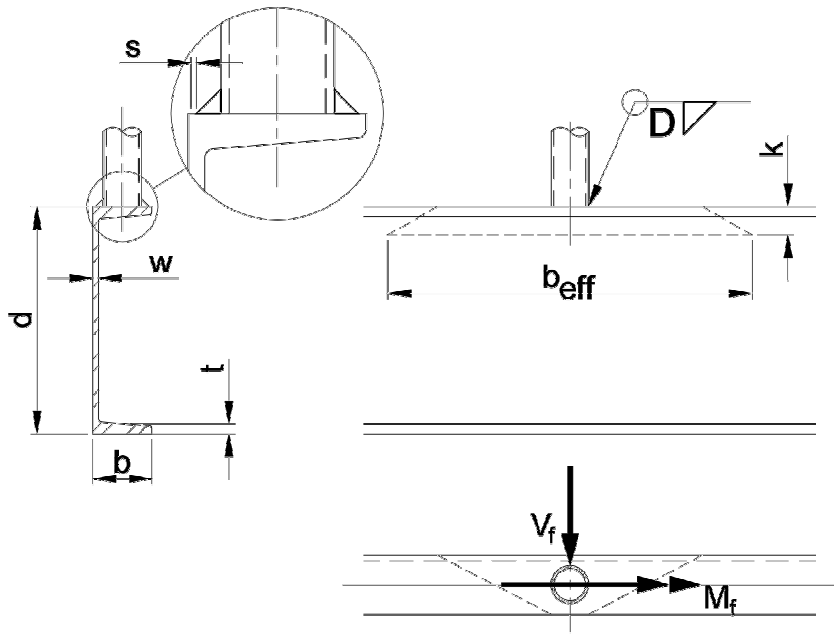
$\varphi_w := 0.67$

$\varphi_{br} := 0.8$

Load Factors:

$\alpha_L := 1.50$

$\alpha_D := 1.25$



Steel Properties:

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

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

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

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

C Section: $st_{NDX} := 2$

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

Section Properties-HSSc (Circular): $pp_{NDX} := 6$

	NDX	desI	desM	d	t
pp :=	1	"HSS 1.90x0.188"	"HSS 48.3x4.8"	1.90 in	0.188 in
	2	"HSS 1.90x0.145"	"HSS 48.3x3.8"	1.90 in	0.150 in
	3	"HSS 1.90x0.125"	"HSS 48.3x3.2"	1.90 in	0.125 in
	4	"HSS 1.66x0.191"	"HSS 42.2x4.9"	1.66 in	0.191 in
	5	"HSS 1.66x0.140"	"HSS 42.2x3.6"	1.66 in	0.140 in
	6	"HSS 1.66x0.125"	"HSS 42.2x3.2"	1.66 in	0.125 in
	7	"HSS 1.32x0.125"	"HSS 33.4x3.2"	1.315 in	0.125 in

$desI_p := pp_{pp_{NDX},2}$ $desM_p := pp_{pp_{NDX},3}$

$\phi_{od} := pp_{pp_{NDX},4}$ $t_p := pp_{pp_{NDX},5}$

	$\phi_{od} = 1.66\ in$	$\phi_{od} = 42.2\ mm$	HSSc Outer ϕ
	$t_p = 0.125\ in$	$t_p = 3.2\ mm$	HSSc Wall Thickness
$\phi_{id} := \phi_{od} - 2\cdot t_p$	$\phi_{id} = 1.41\ in$	$\phi_{id} = 35.8\ mm$	HSSc Inner ϕ
$A_p := \pi\cdot\frac{\left(\phi_{od}^{\ 2} - \phi_{id}^{\ 2}\right)}{4}$	$A_p = 0.6028\ in^2$	$A_p = 389\ mm^2$	HSSc Area
$Z_p := \frac{\left(\phi_{od}^{\ 3} - \phi_{id}^{\ 3}\right)}{6}$	$Z_p = 0.2952\ in^3$	$Z_p = 4837\ mm^3$	HSSc Plastic Section

Factored Loading:

$V_f := 2\ K$	$V_f = 2.00\ K$	$V_f = 8.90\ kN$
$M_f := 1.0\ K\_ft$	$M_f = 12.00\ K\_in$	$M_f = 1355.82\ kN\_mm$

Slope Information:

$rise := 0\ in$	$rise = 0\ in$	$rise = 0$	Rise
$run := 703.5\ in$	$run = 703.5\ in$	$run = 17.869\ m$	Run
$\phi := \operatorname{atan}\left(\frac{rise}{run}\right)$	$\phi = 0\ °$		Guardrail Angle
$\alpha_1 := \frac{1}{\cos(\phi)}$	$\alpha_1 = 1$		Amplification Factor

C Section Geometry:

$desI_c := "C10x15.3"$	$desI_c = "C10x15.3"$		Imperial Beam Designation
$desM_c := "C250x23"$	$desM_c = "C250x23"$		Metric Beam Designation
$d := 10.00\ in$	$d = 10.00\ in$	$d = 254.0\ mm$	Depth
$b := 2.60\ in$	$b = 2.60\ in$	$b = 66.0\ mm$	Width
$t := 0.436\ in$	$t = 0.44\ in$	$t = 11.1\ mm$	Flange Thickness
$w := 0.240\ in$	$w = 0.24\ in$	$w = 6.1\ mm$	Web Thickness
$k := 1.00\ in$	$k = 1.00\ in$	$k = 25.4\ mm$	Web Fillet Distance

Weld:

Electrodes: $we_{NDX} := 2$

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

$we :=$ (above)

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

Sizes: $ws_{NDX} := 7$

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

$ws :=$ (above)

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

Moment Resistance of Channel (from AISC DG 34):

$b_{eff} := \phi_{od} + 2 \cdot 2.5 \cdot \left(\left(k - \frac{t}{2}\right) + b\right)$ **Equation 7.1**

$b_{eff} = 18.57\ in$ $\quad b_{eff} = 471.7\ mm$

$Zx := \frac{b_{eff} \cdot t^2}{4}$ $\quad Zx = 0.88\ in^3$ $\quad Zx = 14462\ mm^3$

$M_{rc} := \varphi_s \cdot f_{y2} \cdot Zx$ $\quad M_{rc} = 34.95\ K\_in$ $\quad M_{rc} = 3949\ kN\_mm$

Moment Capacity HSSc:

$M_{rp} := \varphi_s \cdot f_{y1} \cdot Z_p$ $M_{rp} = 13.28\ \text{K\_in}$ $M_{rp} = 1501\ \text{kN\_mm}$

Weld Design:

$s := \frac{1}{16}\ \text{in}$ $s = 0.0625\ \text{in}$ $s = 1.6\ \text{mm}$ Shelf Distance

$b_{min} := \phi_{od} + 2 \cdot (D + s)$ $b_{min} = 2.29\ \text{in}$ $b_{min} = 58.0\ \text{mm}$ Minimum Width of C Section

Weld Material Strength

$v_{rw} := \varphi_w \cdot 0.67 \cdot X_u \cdot \frac{1}{\sqrt{2}}$ $v_{rw} = 22.2\ \text{ksi}$ $v_{rw} = 153.2\ \text{MPa}$

Base Metal Strength

$v_{rb1} := \varphi_w \cdot 0.67 \cdot F_{u1}$ $v_{rb1} = 29.2\ \text{Ksi}$ $v_{rb1} = 201.2\ \text{MPa}$ HSSc Section

$v_{rb2} := \varphi_w \cdot 0.67 \cdot F_{u2}$ $v_{rb2} = 29.2\ \text{Ksi}$ $v_{rb2} = 201.2\ \text{MPa}$ C Section

Minimum Weld Capacity

$V_{rw} := \min\left(\left[\begin{array}{ccc} v_{rw} & v_{rb1} & v_{rb2} \end{array}\right]\right)$ $V_{rw} = 22.2\ \text{Ksi}$ $V_{rw} = 153.2\ \text{MPa}$

Section Properties of Weld:

$A_w := \frac{\pi \cdot \left(\left(\phi_{od} + 2 \cdot D\right)^2 - \phi_{od}^{\ 2}\right)}{4}$ $A_w = 1.50\ \text{in}^2$ $A_w = 968\ \text{mm}^2$

$Ix_w := \frac{\pi}{4} \cdot \left(\left(\frac{\frac{\phi_{od}}{2}}{\cos(\phi)} + D\right) \cdot \left(\frac{\phi_{od}}{2} + D\right)^3 - \frac{\frac{\phi_{od}}{2}}{\cos(\phi)} \cdot \left(\frac{\phi_{od}}{2}\right)^3\right)$ $Ix_w = 0.70\ \text{in}^4$ $Ix_w = 2.90 \cdot 10^5\ \text{mm}^4$

$Sx_w := \frac{2 \cdot Ix_w}{\left(\phi_{od} + 2 \cdot D\right)}$ $Sx_w = 0.64\ \text{in}^3$ $Sx_w = 10557\ \text{mm}^3$

Stress due to Shear

$\sigma_v := \frac{V_f}{A_w}$ $\sigma_v = 1.3\ \text{Ksi}$ $\sigma_v = 9.2\ \text{MPa}$

Stress due to Flexure

$\sigma_f := \frac{M_f}{Sx_w}$ $\sigma_f = 18.6\ \text{Ksi}$ $\sigma_f = 128.4\ \text{MPa}$

Combined Stress

$\sigma := \sqrt{\sigma_v^{\ 2} + \sigma_f^{\ 2}}$ $\sigma = 18.7\ \text{Ksi}$ $\sigma = 128.8\ \text{MPa}$

Moment Resistance of Weld

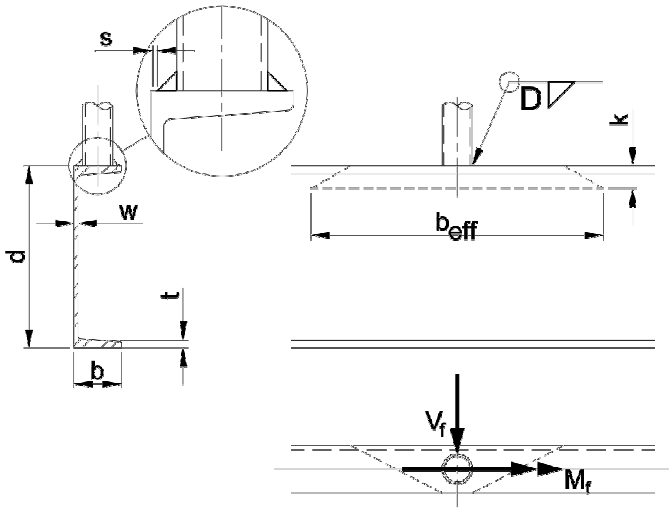
$M_{rw} := V_{rw} \cdot Sx_w$ $M_{rw} = 14.3\ \text{K\_in}$ $M_{rw} = 1617.4\ \text{kN\_mm}$

Minimum Moment Resistance

$M_r := \min\left(\left[\begin{array}{ccc} M_{rc} & M_{rp} & M_{rw} \end{array}\right]\right)$ $M_r = 13.28\ \text{K\_in}$ $M_r = 1501\ \text{kN\_mm}$

$\text{Check}\left(M_r \geq M_f\right) = \text{"...OK"}$

Summary:



Material Property Factors

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

HSSr Post

Yield Strength	$f_{y1} = 50\ Ksi$	$f_{y1} = 345\ MPa$
Ultimate Strength	$F_{u1} = 65\ Ksi$	$F_{u1} = 448\ MPa$

C Section

Yield Strength	$f_{y2} = 44\ Ksi$	$f_{y2} = 303\ MPa$
Ultimate Strength	$F_{u2} = 65\ Ksi$	$F_{u2} = 448\ MPa$
Young's Modulus	$E_s = 29000\ Ksi$	$E_s = 2.00 \cdot 10^5\ MPa$
Shear Modulus	$G_s = 11153.8462\ Ksi$	$G_s = 76903\ MPa$
Density	$\gamma_s = 489\ pcf$	$\gamma_s = 76.8\ kNpcm$

Section Properties

HSSr Section

Designation (Imperial)	$desI_p = "HSS\ 1.66x0.125"$	
Designation (Metric)	$desM_p = "HSS\ 42.2x3.2"$	
HSSc Outer ϕ	$\phi_{od} = 1.66\ in$	$\phi_{od} = 42.2\ mm$
HSSc Wall Thickness	$t_p = 0.125\ in$	$t_p = 3.2\ mm$
HSSc Inner ϕ	$\phi_{id} = 1.41\ in$	$\phi_{id} = 35.8\ mm$
HSSc Area	$A_p = 0.6028\ in^2$	$A_p = 389\ mm^2$
HSSc Plastic Section	$Z_p = 0.2952\ in^3$	$Z_p = 4837\ mm^3$

C Section

Designation (Imperial)	$desI_c = "C10x15.3"$	
Designation (Metric)	$desM_c = "C250x23"$	
Depth	$d = 10.00\ in$	$d = 254\ mm$
Width	$b = 2.60\ in$	$b = 66\ mm$
Flange Thickness	$t = 0.44\ in$	$t = 11.1\ mm$
Web Thickness	$w = 0.24\ in$	$w = 6.1\ mm$
Web Fillet Distance	$k = 1.00\ in$	$k = 25.4\ mm$
Shelf Distance	$s = 0.06\ in$	$s = 1.6\ mm$
Minimum Width of C Section	$b_{min} = 2.29\ in$	$b_{min} = 58.0\ mm$

$Check\left(b \geq b_{min}\right) = "...OK"$

Slope Information

Rise	$rise = 0\ in$	$rise = 0$
Run	$run = 703.5\ in$	$run = 17.869\ m$
Guardrail Angle	$\phi = 0\ °$	
Amplification Factor	$\alpha_l = 1$	

Factored Loads

Factored Moment	$M_f = 1\ K\_ft$	$M_f = 1.4\ kN\_m$
Factored Shear	$V_f = 2\ K$	$V_f = 8.9\ kN$

Welding

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	$D = 0.25\ in$	$D = 6.35\ mm$
Minimum Weld Capacity	$V_{rw} = 22.2\ Ksi$	$V_{rw} = 153.2\ MPa$

Section Properties of Weld:

Area	$A_w = 1.50\ in^2$	$A_w = 968\ mm^2$
Moment of Inertia	$Ix_w = 0.70\ in^4$	$Ix_w = 2.90 \cdot 10^5\ mm^4$
Section Modulus	$Sx_w = 0.64\ in^3$	$Sx_w = 10557\ mm^3$

Weld Stresses

Stress due to Shear	$\sigma_v = 1.3\ Ksi$	$\sigma_v = 9.2\ MPa$
Stress due to Flexure	$\sigma_f = 18.6\ Ksi$	$\sigma_f = 128.4\ MPa$
Combined Stress	$\sigma = 18.7\ Ksi$	$\sigma = 128.8\ MPa$

$Check\left(V_{rw} \geq \sigma\right) = "...OK"$ $Check\left(\frac{V_{rw}}{\varphi_s} \geq \sigma\right) = "...OK"$ **Allow for Overload**

Moment Resistance

C Section	$M_{rc} = 34.9\ K\_in$	$M_{rc} = 3949\ kN\_mm$
HSSc Section	$M_{rp} = 13.3\ K\_in$	$M_{rp} = 1501\ kN\_mm$
Weld	$M_{rw} = 14.3\ K\_in$	$M_{rw} = 1617\ kN\_mm$
Minimum	$M_r = 13.3\ K\_in$	$M_r = 1501\ kN\_mm$

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