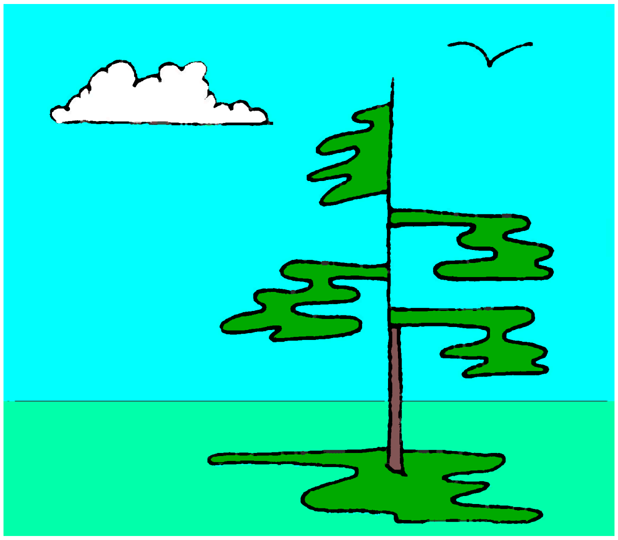
NorthWoods Software



Program Name: NGuardrail_BAR_No_Base

Project Number: -

Project Description: -

Project Designer: Dik

Last Revised (yy-mm-dd): 21.09.24

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**		

Defined Units:

$grav := 9.80665 \frac{m}{sec^2}$ — Acceleration

$K := kip$ — Force

$K\_ft := K\ ft \quad kN\_m := kN\ m \quad K\_in := K\ in \quad kN\_mm := kN\ mm \quad lb\_in := lbf\ in$ — Moment

$kNmpm := \frac{kN\_m}{m} \quad iKpi := \frac{K\_in}{in}$ — Moment per Unit Length

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

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

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

$Npsmm := \frac{N}{mm^2}$ — Pressure

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

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

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

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

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

c b a

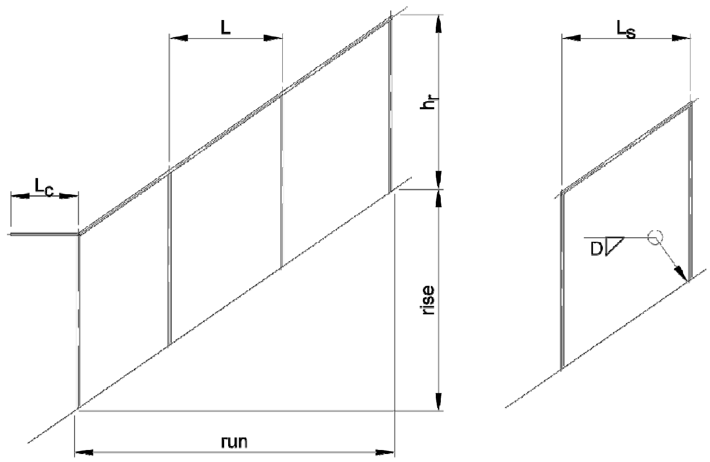
Material Property Factors:

$\varphi_s := 0.90$ Rolled Sections

$\varphi_w := 0.67$ Weld

$\varphi_b := 0.80$ Bolt

$\varphi_{br} := 0.80$ Bolt Bearing



Load Factors:

$\alpha_D := 1.25$

$\alpha_L := 1.5$

Steel Properties:

Rail Properties $stl_{NDX} := 1$

NDX des fy Fu

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

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

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

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

Base Properties $stl_{NDX} := 1$

$desI_2 := stl_{stl_{NDX}\ 2}$ $\quad F_{u2} := stl_{stl_{NDX}\ 4}$ $\quad f_{y2} := stl_{stl_{NDX}\ 3}$

Section Properties-BAR:

$d := 2\ \text{in}$ BAR Depth

$t := 0.5\ \text{in}$ BAR Width

$A := d \cdot t$ $\quad A = 1\ \text{in}^2$ $\quad A = 645.2\ \text{mm}^2$ BAR Area

$Sx := \dfrac{t \cdot d^2}{6}$ $\quad Sx = 0.3\ \text{in}^3$ $\quad Sx = 5462.4\ \text{mm}^3$ BAR Section Modulus

$Zx := \dfrac{t \cdot d^2}{4}$ $\quad Zx = 0.5\ \text{in}^3$ $\quad Zx = 8193.5\ \text{mm}^3$ BAR Plastic Modulus

Span Information:

$L := 48\ \text{in}$ $\quad L = 48\ \text{in}$ $\quad L = 1219.2\ \text{mm}$ Continuous Span

$L_s := 0\ \text{in}$ $\quad L_s = 0\ \text{in}$ $\quad L_s = 0.0\ \text{mm}$ Simple Span

$L_c := 0\ \text{in}$ $\quad L_c = 0\ \text{in}$ $\quad L_c = 0.0\ \text{mm}$ **Cantilever requires Backspan**

$h_r := 42\ \text{in}$ $\quad h_r = 42\ \text{in}$ $\quad h_r = 1066.8\ \text{mm}$ Height of Rail

Slope Information:

$rise := 0\ \text{in}$ $\quad rise = 0\ \text{in}$ $\quad rise = 0$ Rise

$run := 77\ \text{in}$ $\quad run = 77\ \text{in}$ $\quad run = 1.956\ \text{m}$ Run

$\phi := \text{atan}\left(\dfrac{rise}{run}\right)$ $\quad \phi = 0\ °$ Guardrail Angle

$\alpha_1 := \dfrac{1}{\cos(\phi)}$ $\quad \alpha_1 = 1$ Amplification Factor

Design Loads:

$q_D := 3\ plf$	$q_D = 3\ plf$	$q_D = 0.04\ kNpm$	DL
$q_L := 51\ plf$	$q_L = 51\ plf$	$q_L = 0.74\ kNpm$	Hor LL
$q_{L1} := 103\ plf$	$q_{L1} = 103\ plf$	$q_{L1} = 1.50\ kNpm$	Vert Top LL
$p_L := 225\ lb$	$p_L = 225\ lb$	$p_L = 1.00\ kN$	Horiz Point LL

Weld Electrodes: $we_{NDX} := 3$

$we :=$

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: $ws_{NDX} := 12$

$ws :=$

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

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

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

Factored Loads:

$q_{fD} := q_D \cdot \alpha_D$	$q_{fD} = 3.8\ plf$	$q_{fD} = 0.05\ kNpm$	fact Vert DL
$q_{fL} := q_L \cdot \alpha_L$	$q_{fL} = 76.5\ plf$	$q_{fL} = 1.12\ kNpm$	fact Hor LL
$q_{fL1} := q_{L1} \cdot \alpha_L$	$q_{fL1} = 154.5\ plf$	$q_{fL1} = 2.25\ kNpm$	fact Vert LL
$p_{fL} := p_L \cdot \alpha_L$	$p_{fL} = 0.34\ K$	$p_{fL} = 1.50\ kN$	fact Hor Point LL

Vertical (UDL):

Cantilever:

```
if  L = 0 in
    M_fcv := 0 K_ft
    R_fcv := 0 K
else
    M_fcv := ((q_fD + q_fL1) · L_c^2) / 2
    R_fcv := (q_fD + q_fL1) · L_c · (1 + L_c / (2 · L))
```

$M_{fcv} = 0.00\ K\_ft$ | $M_{fcv} = 0.00\ kN\_m$ | **Check**

$R_{fcv} = 0.00\ K$ | $R_{fcv} = 0.00\ kN$ | **Check**

Simple Span:

$M_{fsv} := \frac{(q_{fD} + q_{fL1}) \cdot L_s^{2}}{8}$ | $M_{fsv} = 0.00\ K\_ft$ | $M_{fsv} = 0.00\ kN\_m$ | **Check**

$R_{fsv} := (q_{fD} + q_{fL1}) \cdot 0.5 \cdot L_s$ | $R_{fsv} = 0.00\ K$ | $R_{fsv} = 0.00\ kN$ | **Check**

End Span:

$M_{fpv} := \frac{(q_{fD} + q_{fL1}) \cdot L^{2}}{9}$ | $M_{fpv} = 0.28\ K\_ft$ | $M_{fpv} = 0.38\ kN\_m$ | **Check**

$R_{fpv} := (q_{fD} + q_{fL1}) \cdot 1.1 \cdot L$ | $R_{fpv} = 0.70\ K$ | $R_{fpv} = 3.10\ kN$ | **Check**

Continuous Span:

$M_{fv} := \frac{(q_{fD} + q_{fL1}) \cdot L^{2}}{11}$ | $M_{fv} = 0.23\ K\_ft$ | $M_{fv} = 0.31\ kN\_m$ | **Check**

$R_{fv} := (q_{fD} + q_{fL1}) \cdot L$ | $R_{fv} = 0.63\ K$ | $R_{fv} = 2.82\ kN$ | **Check**

Horizontal (UDL):

Increased Span Lengths for Slope

$L' := \alpha_1 \cdot L$ | $L' = 48\ in$ | $L' = 1219.2\ mm$ | Cont Span

$L'_c := L_c$ | $L'_c = 0\ in$ | $L'_c = 0\ mm$ | Cant Span

$L'_s := \alpha_1 \cdot L_s$ | $L'_s = 0\ in$ | $L'_s = 0\ mm$ | Simple Span

Cantilever:

```
if  L' = 0 in
    M_fch := 0 K_ft
    R_fch := 0 K
else
    M_fch := ((q_fL) · L'_c^2) / 2
    R_fch := (q_fL) · L'_c · (1 + L'_c / (2 · L'))
```

$M_{fch} = 0.00\ K\_ft$ | $M_{fch} = 0.00\ kN\_m$ | **Check**

$R_{fch} = 0.00\ K$ | $R_{fch} = 0.00\ kN$ | **Check**

Simple Span:

$M_{fsh} := \frac{(q_{fL}) \cdot L'_s{}^2}{8}$ | $M_{fsh} = 0.00$ K_ft | $M_{fsh} = 0.00$ kN_m | **Check**

$R_{fsh} := (q_{fL}) \cdot 0.5 \cdot L'_s$ | $R_{fsh} = 0.00$ K | $R_{fsh} = 0.00$ kN | **Check**

End Span:

$M_{fph} := \frac{(q_{fL}) \cdot L'^2}{9}$ | $M_{fph} = 0.14$ K_ft | $M_{fph} = 0.18$ kN_m | **Check**

$R_{fph} := (q_{fL}) \cdot 1.1 \cdot L'$ | $R_{fph} = 0.34$ K | $R_{fph} = 1.5$ kN | **Check**

Continuous Span:

$M_{fh} := \frac{(q_{fL}) \cdot L'^2}{11}$ | $M_{fh} = 0.11$ K_ft | $M_{fh} = 0.15$ kN_m | **Check**

$R_{fh} := q_{fL} \cdot L'$ | $R_{fh} = 0.31$ K | $R_{fh} = 1.36$ kN | **Check**

Horizontal (Point Loading):

Cantilever:

if $L' = 0$ in
- $M_{fchp} := 0$ K_ft
- $R_{fchp} := 0$ K

else
- $M_{fchp} := (p_{fL}) \cdot L'_c$
- $R_{fchp} := p_{fL} \cdot \left(\frac{L'_c + L'}{L'}\right)$

$M_{fchp} = 0.00$ K_ft | $M_{fchp} = 0.00$ kN_m | **Check**

$R_{fchp} = 0.34$ K | $R_{fchp} = 1.50$ kN | **Check**

Simple Span:

$M_{fshp} := \frac{(p_{fL}) \cdot L'_s}{4}$ | $M_{fshp} = 0.00$ K_ft | $M_{fshp} = 0.00$ kN_m | **Check**

$R_{fshp} := (p_{fL})$ | $R_{fshp} = 0.34$ K | $R_{fshp} = 1.50$ kN | **Check**

End Span:

$M_{fphp} := \frac{(p_{fL}) \cdot L'}{5.2}$ | $M_{fphp} = 0.26$ K_ft | $M_{fphp} = 0.35$ kN_m | **Check**

$R_{fphp} := (p_{fL})$ | $R_{fphp} = 0.34$ K | $R_{fphp} = 1.50$ kN | **Check**

Continuous Span:

$M_{fhp} := \frac{(p_{fL}) \cdot L'}{5.2}$ | $M_{fhp} = 0.26$ K_ft | $M_{fhp} = 0.35$ kN_m | **Check**

$R_{fhp} := (p_{fL})$ | $R_{fhp} = 0.3375$ K | $R_{fhp} = 1.5$ kN | **Check**

Design of Rail:

Resistance of Rail:

$M_{rr} := Zx \cdot f_{y1} \cdot \varphi_s$ | $M_{rr} = 1.88$ K_ft | $M_{rr} = 2.54$ kN_m | **Check**

Resistance of Rail (Simple Span Stability): **from Roark**

$$M'_{rr} := \frac{\pi \cdot t^3 \cdot d \cdot \sqrt{\left(E_s \cdot G_s \cdot \left(1 - 0.63 \cdot \frac{t}{d}\right)\right)}}{6 \cdot L'}$$

$M'_{rr} = 3.75$ K_ft | $M'_{rr} = 5.09$ kN_m

Maximum Rail Moment:

$$M_{fr\_max} := \max\left(\left[\, M_{fcv}\ M_{fsv}\ M_{fv}\ M_{fch}\ M_{fsh}\ M_{fh}\ M_{fchp}\ M_{fshp}\ M_{fhp}\ M_{fpv}\ M_{fph}\ M_{fphp} \,\right]\right)$$

$M_{fr\_max} = 0.28$ K_ft $M_{fr\_max} = 0.38$ kN_m   **Check**

Design of Post:

Resistance of Post:

$M_{rp} := M_{rr}$ $M_{rp} = 1.88$ K_ft $M_{rp} = 2.54$ kN_m   **Check**

Resistance of Post (Cantilever Stability): from Roark

$$M'_{rp} := \frac{2.82 \cdot t^3 \cdot d \cdot \sqrt{\left(1 - .063 \cdot \frac{t}{d}\right) \cdot E_s \cdot G_s}}{h_r} \cdot \left(1 - \frac{\left(\frac{d}{2}\right)}{2 \cdot h_r} \cdot \sqrt{\frac{E_s}{G_s \cdot \left(1 - 0.63 \cdot \frac{t}{d}\right)}}\right)$$

$M'_{rp} = 24.44$ K_ft $M'_{rp} = 33.13$ kN_m

Maximum Horizontal Load at Top (Penultimate):

$$R_{fpr\_max} := \max\left(\left[\, R_{fph}\ R_{fphp}\ R_{fchp} \,\right]\right)$$

$R_{fpr\_max} = 0.34$ K $R_{fpr\_max} = 1.50$ kN   **Check**

Maximum Moment (Penultimate):

$M_{fpp} := R_{fpr\_max} \cdot h_r$ $M_{fpp} = 1.18$ K_ft $M_{fpp} = 1.60$ kN_m   **Check**

Maximum Horizontal Load at Top (Continuous):

$$R_{fr\_max} := \max\left(\left[\, R_{fch}\ R_{fsh}\ R_{fh}\ R_{fchp}\ R_{fshp}\ R_{fhp}\ R_{fph}\ R_{fphp} \,\right]\right)$$

$R_{fr\_max} = 0.34$ K $R_{fr\_max} = 1.50$ kN   **Check**

Maximum Moment (Continuous):

$M_{fp} := R_{fr\_max} \cdot h_r$ $M_{fp} = 1.18$ K_ft $M_{fp} = 1.60$ kN_m   **Check**

Maximum Vertical Load at Top:

$$R_{1v} := \max\left(\left[\, R_{fcv}\ R_{fsv}\ R_{fpv}\ R_{fv} \,\right]\right)$$

$R_{1v} = 0.6963$ K $R_{1v} = 3.0973$ kN   **Check**

Weld Design:

Weld Material Strength

$v_{rw} := \varphi_w \cdot 0.67 \cdot X_u \cdot \frac{1}{\sqrt{2}}$ $v_{rw} = 25.39$ ksi $v_{rw} = 175.08$ MPa

Base Metal Strength

$v_{rb1} := \varphi_w \cdot 0.67 \cdot F_{u1}$ $v_{rb1} = 29.18$ Ksi $v_{rb1} = 201.18$ MPa

$v_{rb2} := \varphi_w \cdot 0.67 \cdot F_{u2}$ $v_{rb2} = 29.18$ Ksi $v_{rb2} = 201.18$ MPa

Minimum Weld Capacity

$V_{rw} := \min\left(\left[\, v_{rw}\ v_{rb1}\ v_{rb2} \,\right]\right)$ $V_{rw} = 25.39$ Ksi $V_{rw} = 175.08$ MPa

Moment of Inertia of Weld (All Around):

$$Ix_w := (t + 2 \cdot D) \cdot \frac{\left(\frac{d}{\cos(\phi)} + 2 \cdot D\right)^3}{12} - t \cdot \frac{\left(\frac{d}{\cos(\phi)}\right)^3}{12}$$

$Ix_w = 1.83\ \text{in}^4$ $Ix_w = 7.63 \cdot 10^5\ \text{mm}^4$

Section Modulus of Weld (All Around):

$Sx_w := \frac{2 \cdot Ix_w}{(d + D)}$ $Sx_w = 1.54\ in^3$ $Sx_w = 25294.83\ mm^3$

Moment Resistance of Weld

$M_{rw} := v_{rw} \cdot Sx_w$ $M_{rw} = 3.27\ K\_ft$ $M_{rw} = 4.43\ kN\_m$ **Check**

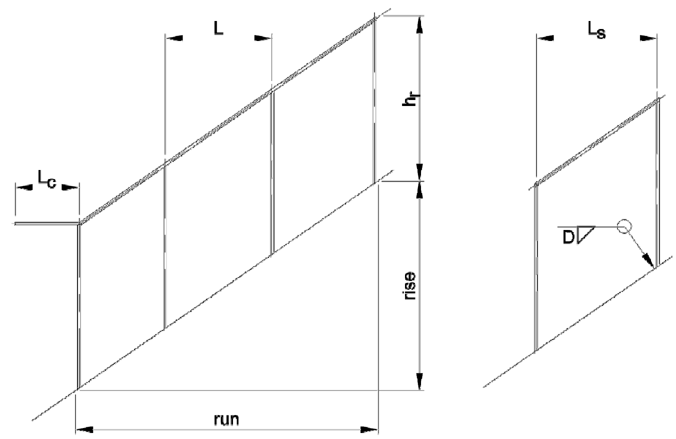
Moment at Base (Penultimate):

$M_{fpp} := R_{fpr\_max} \cdot h_r$ $M_{fpp} = 1.18\ K\_ft$ $M_{fpp} = 1.60\ kN\_m$ **Check**

Moment at Base (Continuous):

$M_{fp} := R_{fr\_max} \cdot h_r$ $M_{fp} = 1.18\ K\_ft$ $M_{fp} = 1.60\ kN\_m$ **Check**

Summary:



Material Property Factor

Steel	$\varphi_s = 0.90$
Weld	$\varphi_w = 0.67$
Dead Load Factor	$\alpha_D = 1.25$
Live Load Factor	$\alpha_L = 1.50$

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

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

Steel

Steel Designation Imperial (Rail)	$desI_1 = \text{"G40.21-350W"}$	
Steel Yield Strength (Rail)	$f_{y1} = 50\ ksi$	$f_{y1} = 345\ MPa$
Steel Ultimate Strength (Rail)	$F_{u1} = 65\ ksi$	$F_{u1} = 448\ MPa$
Steel Designation Imperial (Anchor Plate)	$desI_2 = \text{"G40.21-350W"}$	
Steel Yield Strength (Anchor Plate)	$f_{y2} = 50\ ksi$	$f_{y2} = 345\ MPa$
Steel Ultimate Strength (Anchor Plate)	$F_{u2} = 65\ ksi$	$F_{u2} = 448\ MPa$

Rail Section

Depth	$d = 2\ in$	$d = 50.8\ mm$
Thickness	$t = 0.5\ in$	$t = 12.7\ mm$
Area	$A = 1\ in^2$	$A = 645.2\ mm^2$
Plastic Modulus	$Zx = 0.5\ in^3$	$Zx = 8193.5\ mm^3$

Span Information

Continuous Span of Guardrail	$L = 4.000\ ft$	$L = 1.219\ m$
Simple Span of Guardrail	$L_s = 0.000\ ft$	$L_s = 0.000$
Cantilever Span of Guardrail	$L_c = 0.000\ ft$	$L_c = 0.000$
Height of Guardrail	$h_r = 3.500\ ft$	$h_r = 1.067\ m$
Rise	$rise = 0\ in$	$rise = 0$
Run	$run = 77\ in$	$run = 1.956\ m$
Guardrail Angle	$\phi = 0\ °$	
Amplification Factor	$\alpha_1 = 1$	

Weld

Electrode Designation (Imperial)	$desI_w = \text{"E80xx"}$	
Electrode Designation (Metric)	$desM_w = \text{"E55xx-x"}$	
Weld Metal Strength	$X_u = 80.00\ Ksi$	
Base Metal Strength	$F_{u2} = 65.00\ Ksi$	
Weld Size	$D = 0.38\ in$	$D = 9.53\ mm$

Design Loads

Dead Load $q_D = 3.00$ plf $q_D = 0.04$ kNpm

Live Load (Hor on Top of Rail) $q_L = 51.00$ plf $q_L = 0.74$ kNpm

Live Load (Vert on Top of Rail) $q_{L1} = 103.00$ plf $q_L = 0.74$ kNpm

Live Load (Load P on Top of Rail) $p_L = 225.00$ lb $p_L = 1.00$ kN

Design of Rail

Resistance of Rail Section $M_{rr} = 1.88$ K_ft $M_{rr} = 2.54$ kN_m

Max Rail Reaction $R_{fr\_max} = 0.34$ K $R_{fr\_max} = 1.5$ kN

Max Rail Moment $M_{fr\_max} = 0.28$ K_ft $M_{fr\_max} = 0.38$ kN_m

$Check\left(M_{rr} \geq M_{fr\_max}\right) =$ "...OK" $Check\left(\frac{M_{rr}}{\varphi_s} \geq M_{fr\_max}\right) =$ "...OK" Allow for Overload

Design of Post

Resistance of Post Section $M_{rp} = 1.88$ K_ft $M_{rp} = 2.54$ kN_m

Max Post Moment (Penultimate) $M_{fpp} = 1.18$ K_ft $M_{fpp} = 1.60$ kN_m

$Check\left(M_{rp} \geq M_{fpp}\right) =$ "...OK" $Check\left(\frac{M_{rp}}{\varphi_s} \geq M_{fpp}\right) =$ "...OK" Allow for Overload

Max Post Moment (Continuous) $M_{fp} = 1.18$ K_ft $M_{fp} = 1.60$ kN_m

$Check\left(M_{rp} \geq M_{fp}\right) =$ "...OK" $Check\left(\frac{M_{rp}}{\varphi_s} \geq M_{fp}\right) =$ "...OK" Allow for Overload

Design of Weld

Section Modulus of Weld (All Around) $Sx_w = 1.54$ in^3 $Sx_w = 25295$ mm^3

Moment Resistance (weld) $M_{rw} = 3.27$ K_ft $M_{rw} = 4.43$ kN_m

$Check\left(M_{rw} \geq \max\left(\left[\, M_{fpp} \;\; M_{fp} \,\right]\right)\right) =$ "...OK" $Check\left(\frac{M_{rw}}{\varphi_s} \geq \max\left(\left[\, M_{fpp} \;\; M_{fp} \,\right]\right)\right) =$ "...OK" Allow for Overload