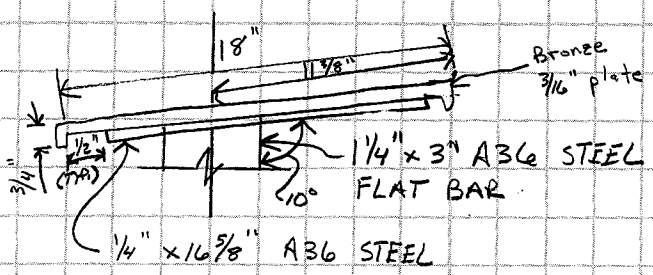
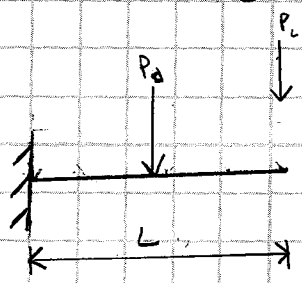
For	Inner belt	Job No.	49633	Sheet No.	1/3
Made by	ZTW	Checked by	JDL	Backchecked by	ZTW
Date	5/21/13	Date	6/14/13	Date	6/14/13

HNTB

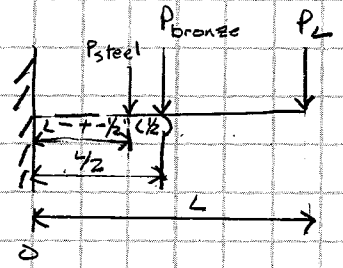
* - Design the railing "Leaning Plate" for AASHTO Pedestrian Loads, Look @ cantilever of plate & spanning b/t supports.

- Cantilever (Look @ Interpretive Panel, will control)

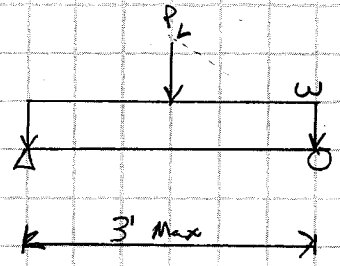




P_d = bronze plate + steel plate

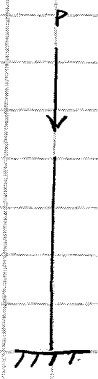


- Span (Longitudinal)

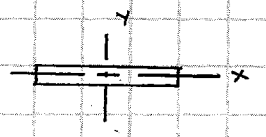


w = bronze plate + steel plate + live load

* Look @ post



P_d = bronze plate + steel plate + small support + channel

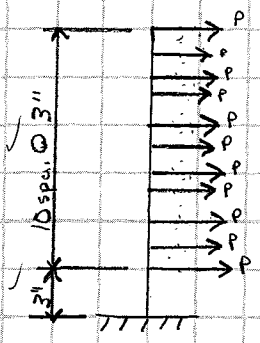


PLAN

For Innerbelt	Job No. 49633	Sheet No. 2/3
Made by ZTW	Checked by JDL	Backchecked by ZTW
Date 5/21/13	Date 6/11/13	Date 6/14/13

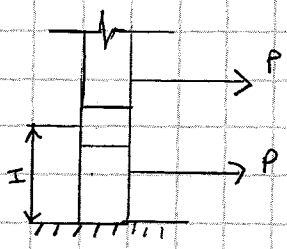
HNTB

* Design the end posts.

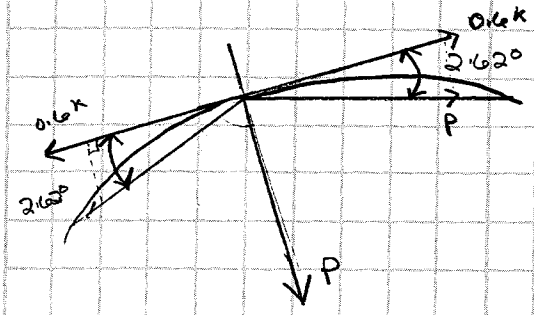


P = 0.60K (From Manufacturer's Specs. found online)

* Check shear flow in end post for weld



* Look at force from cable on intermediate post due to curvature



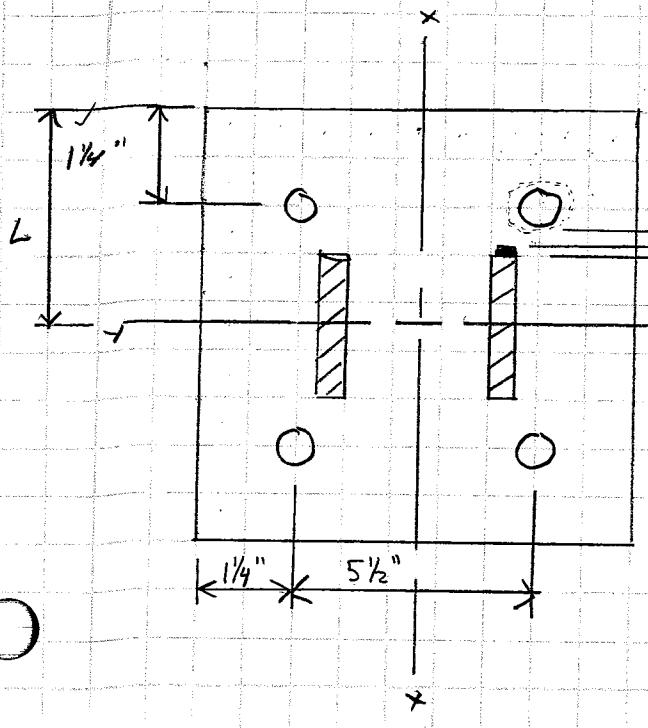
$P = (\tan\alpha)(0.6^K)$

101-1204

For	Innerbelt Railing	Job no.	49633	Sheet no.	3/3
Made by	ZTW	Checked by	JDL	Backchecked by	ZTW
Date	7/2/13	Date	7/2/13	Date	7/2/13

HNTB

Base Plate Geometry



¾" ⌀ Anchor Bolt ✓

AASHTO 6.13.2.4.2 ⇒ Oversized Holes ⇒ 15/16" ⌀

AASHTO 6.13.2.6.6 ⇒ 1¼" Edge Distance ✓

weld = ⅜" ✓

Min. Clear$_y$ = ¾" − ½ (15/16")
= 0.28125" ✓

Check Washer CLR.

AISC 7-15 ¾" ⌀ bolt ⇒ washer = 1 15/32" O.D.

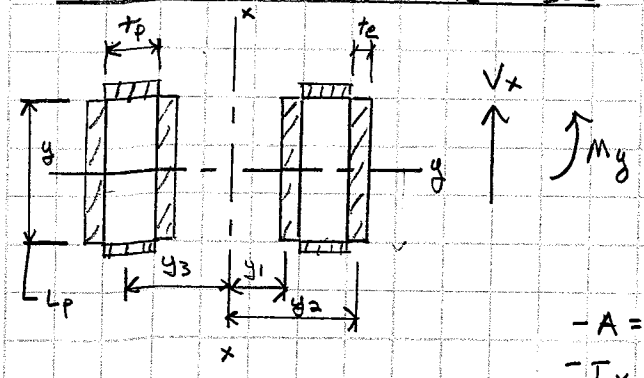
Washer CLR. = 1 15/32" (½) − (½)(15/16")
= 0.266" ✓

∴ Use 0.28125" ✓

L_{min} = 1¼" + ½(15/16") + 0.28125" + ⅜" + 1.5"
= 3.875" ✓

USE 4" ✓

END POST BASE PLATE WELD



- $A = 4(t_e)(L_p + t_p)$
- I_x = only use Ad^2, Assume Individual I_x is small
  ⇒ $(t_e)(L_p)(2)(y_1^2 + y_2^2) + 4(t_e)(t_p)(y_3)^2$
- $I_y = \frac{1}{12}(t_e)(L_p)^3 \cdot 4 + 4 \cdot (t_e)(t_p)(L_p/2 + t_e/2)^2$

Shear $\sigma_{vx} = V_x/A$ $\sigma_{vy} = V_y/A$ $\sigma_{vT} = \sqrt{\sigma_{vx}^2 + \sigma_{vy}^2}$

Tension $\sigma_{Tx} = (M_x)(y_2)/I_x$ $\sigma_{Ty} = (M_y)(L_p/2)/I_y$ $\sigma_{TT} = \sigma_{Tx} + \sigma_{Ty}$

TOTAL $\sigma_T = \sqrt{\sigma_{vT}^2 + \sigma_{TT}^2}$

* - Design the railing "Leaning Plate" for AASHTO Pedestrian loads. Look @ cantilever of plate and spanning between supports. LRFD Design.

Cantilever
(Look at Interpretive Panel, will control)

$L := 11.375in - \frac{3}{2}in = 9.875 \cdot in$ $E := 29000ksi$

$w_{bronze} := 554 \frac{lbf}{ft^3}$ (AISC 13th Edition) $\alpha := 10deg$

$b := 1ft$ $t_{bronzeplate} := \frac{3}{16}in$

$P_{bronzeplate} := w_{bronze} \cdot L \cdot b \cdot t_{bronzeplate} + w_{bronze} \cdot b \cdot t_{bronzeplate} \cdot (0.75in - t_{bronzeplate}) = 7.529 \times 10^{-3} \cdot kip$

$w_L := 0.050klf$ $p_L := 0.20kip$ (AASHTO 13.8.2)

$P_L := w_L \cdot b + p_L = 0.25 \cdot kip$

$w_{steel} := 490 \frac{lbf}{ft^3}$ $t_{steelplate} := 0.25in$ $L_{steelplate} := L - t_{bronzeplate} - 0.5in = 9.188 \cdot in$

$F_y := 36ksi$ (A36 Steel)

$P_{steelplate} := w_{steel} \cdot L_{steelplate} \cdot b \cdot t_{steelplate} = 7.816 \times 10^{-3} \cdot kip$

$M_u := 1.25 \frac{L_{steelplate} \cdot \cos(\alpha)}{2} \cdot P_{steelplate} + 1.25 \frac{L \cdot \cos(\alpha)}{2} \cdot P_{bronzeplate} + 1.75 L \cdot \cos(\alpha) \cdot P_L = 4.345 \cdot kip \cdot in$

$Check_{yielding} := \begin{cases} \text{"OK, Mn=Mp=Fy*Z"} & \text{if } \frac{L \cdot t_{steelplate}}{b^2} \le \frac{0.08 \cdot E}{F_y} \\ \text{"Lateral Torsional Buckling Controls"} & \text{otherwise} \end{cases} = \text{"OK, Mn=Mp=Fy*Z"}$ (AASHTO 6.12.2.2.7)

$Z_{steelplate} := \frac{b \cdot t_{steelplate}^2}{4} = 0.188 \cdot in^3$

$\phi_f := 1.00$ (AASHTO 6.5.4.2)

$S_{steelplate} := \frac{b \cdot t_{steelplate}^2}{6} = 0.125 \cdot in^3$

$M_y := F_y \cdot S_{steelplate} = 4.5 \cdot kip \cdot in$

$\phi M_n := \min(\phi_f \cdot F_y \cdot Z_{steelplate}, \phi_f \cdot 1.6 \cdot M_y) = 6.75 \cdot kip \cdot in$ (AASHTO 6.12.2.2.7-1)

$Check_M := \begin{cases} \text{"O.K."} & \text{if } \phi M_n \ge M_u \\ \text{"No Good"} & \text{otherwise} \end{cases} = \text{"O.K."}$

Weld @ support plate to "Post"

$\phi_{e2} := 0.80$ (AASHTO 6.5.4.2)

$F_{exx} := 60ksi$ (AISC J2.6)

$R_r := 0.6 \cdot \phi_{e2} \cdot F_{exx} = 28.8 \cdot ksi$ (AASHTO 6.13.3.2.4b-1)

$Fillet := \frac{3}{16}in$ $t_e := Fillet \cdot \sin(45deg) = 0.133 \cdot in$ $Length := 3in$

$Area_{weld} := t_e \cdot Length \cdot 2 = 0.795 \cdot in^2$

$I_{weld} := \frac{1}{12} \cdot t_e \cdot Length^3 \cdot 2 = 0.597 \cdot in^4$ $y_{weld} := \frac{Length}{2} = 1.5 \cdot in$

$$\sigma_b := \frac{\left[1.25 \frac{L_{steelplate} \cdot \cos(\alpha)}{2} \cdot P_{steelplate} + 1.25 \frac{L \cdot \cos(\alpha)}{2} \cdot P_{bronzeplate} + 1.75L \cdot \cos(\alpha) \cdot \left(w_L \cdot 3ft + p_L\right)\right] \cdot y_{weld}}{I_{weld}} = 15.202 \cdot ksi$$

(Stress for 3' span)

$V_u := 1.75 \cdot \left(w_L \cdot 3ft + p_L\right) = 0.612 \cdot kip$ $\sigma_v := \frac{V_u}{Area_{weld}} = 0.77 \cdot ksi$

$\sigma_T := \sqrt{\sigma_b^2 + \sigma_v^2} = 15.221 \cdot ksi$

$Check_{Weld} := \begin{cases} \text{"O.K."} & \text{if } \sigma_T \le R_r \\ \text{"NO GOOD"} & \text{otherwise} \end{cases} = \text{"O.K."}$

NOTE: Use 1/4" fillet weld per AASHTO 6.13.3.4-1

Span

(Longitudinal) (Look at Leaning Plate, will control)

$span := 3ft$

$b_{bronzeplate} := 10in$ $b_{steelplate} := b_{bronzeplate} - 2 \cdot \left(t_{bronzeplate} + 0.5in\right) = 8.625 \cdot in$

$w_d := w_{bronze} \cdot b_{bronzeplate} \cdot t_{bronzeplate} + w_{bronze} \cdot t_{bronzeplate} \cdot \left(0.75in - t_{bronzeplate}\right) \cdot 2 \ ... = 0.015 \cdot klf$
$+ w_{steel} \cdot b_{steelplate} \cdot t_{steelplate}$

$M_u := 1.25 \frac{w_d \cdot span^2}{8} + 1.75 \cdot \frac{w_L \cdot span^2}{8} + 1.75 \frac{p_L \cdot span}{4} = 4.59 \cdot kip \cdot in$

$$Check_{yielding} := \begin{cases} \text{"OK, Mn=Mp=Fy*Z"} & \text{if } \frac{span \cdot t_{steelplate}}{b_{steelplate}^2} \le \frac{0.08 \cdot E}{F_y} \\ \text{"Lateral Torsional Buckling Controls"} & \text{otherwise} \end{cases} = \text{"OK, Mn=Mp=Fy*Z"}$$

(AASHTO 6.12.2.2.7)

$Z_{plate} := \frac{b_{steelplate} \cdot t_{steelplate}^2}{4} = 0.135 \cdot in^3$

$$S_{plate} := \frac{b_{steelplate} \cdot t_{steelplate}^{2}}{6} = 0.09 \cdot in^{3}$$

$$M_y := F_y \cdot S_{plate} = 3.234 \cdot kip \cdot in$$

$$\phi M_n := \min\left(\phi_f \cdot F_y \cdot Z_{plate}, \phi_f \cdot 1.6 \cdot M_y\right) = 4.852 \cdot kip \cdot in \qquad \text{(AASHTO 6.12.2.2.7-1)}$$

$$Check_M := \begin{cases} \text{"O.K."} & \text{if } \phi M_n \geq M_u \\ \text{"NO GOOD"} & \text{otherwise} \end{cases} = \text{"O.K."}$$

Intermediate Post
(Check at Interpretive Panel)

$$tw_{channel} := 0.184in$$

$$L_{post} := 36in - tw_{channel} - 0.25in = 35.566 \cdot in \qquad t_{post} := 1.25in \qquad b_{post} := 3in$$

$$w_{channel} := 5.4\frac{lbf}{ft} \qquad E := 29000ksi$$

$$b_{bronzeplate} := 18in \qquad b_{steelplate} := b_{bronzeplate} - 2 \cdot \left(t_{bronzeplate} + 0.5in\right) = 16.625 \cdot in$$

$$P_d := w_{bronze} \cdot b_{bronzeplate} \cdot t_{bronzeplate} \cdot span \ldots = 0.102 \cdot kip$$
$$+ w_{bronze} \cdot t_{bronzeplate} \cdot \left(0.75in - t_{bronzeplate}\right) \cdot 2 \cdot span \ldots$$
$$+ w_{steel} \cdot b_{steelplate} \cdot t_{steelplate} \cdot span + w_{channel} \cdot span + w_{steel} \cdot 1.25in \cdot \left(2in + \frac{3}{16}in\right) \cdot 3in$$

$$P_L := p_L + w_L \cdot span = 0.35 \cdot kip$$

$$P_u := 1.25 \cdot P_d + 1.75 \cdot P_L = 0.74 \cdot kip$$

$$\phi_c := 0.90 \qquad \text{(AASHTO 6.5.4.2)}$$

$$K_x := 1.2 \qquad K_y := 2.1 \qquad \text{(Bending about respective axis)}$$

$$r_x := \frac{t_{post}}{\sqrt{12}} = 0.361 \cdot in \qquad r_y := \frac{b_{post}}{\sqrt{12}} = 0.866 \cdot in$$

$$\frac{K_x \cdot L_{post}}{r_x} = 118.276 \qquad \frac{K_y \cdot L_{post}}{r_y} = 86.243$$

$$Check_{6.9.3.x} := \begin{cases} \text{"Meets AASHTO 6.9.3"} & \text{if } \frac{K_x \cdot L_{post}}{r_x} \leq 120 \\ \text{"Does NOT meet AASHTO 6.9.3!!"} & \text{otherwise} \end{cases} = \text{"Meets AASHTO 6.9.3"}$$

$$Check_{6.9.3.y} := \begin{cases} \text{"Meets AASHTO 6.9.3"} & \text{if } \frac{K_y \cdot L_{post}}{r_y} \le 120 \\ \text{"Does NOT meet AASHTO 6.9.3!!"} & \text{otherwise} \end{cases} = \text{"Meets AASHTO 6.9.3"}$$

$$P_{ex} := \frac{\pi^2 \cdot E}{\left(\frac{K_x \cdot L_{post}}{r_x}\right)^2} \cdot b_{post} \cdot t_{post} = 76.725 \cdot kip$$

(AASHTO 6.9.4.1.2-1)

$$P_{ey} := \frac{\pi^2 \cdot E}{\left(\frac{K_y \cdot L_{post}}{r_y}\right)^2} \cdot b_{post} \cdot t_{post} = 144.305 \cdot kip$$

$$P_o := F_y \cdot t_{post} \cdot b_{post} = 135 \cdot kip$$

$$P_{nx} := \begin{cases} 0.658^{\left(\frac{P_o}{P_{ex}}\right)} \cdot P_o & \text{if } \frac{P_{ex}}{P_o} \ge 0.44 \\ 0.877 \cdot P_{ex} & \text{otherwise} \end{cases} = 64.639 \cdot kip$$

(AASHTO 6.9.4.1.1-1)

$$P_{ny} := \begin{cases} 0.658^{\left(\frac{P_o}{P_{ey}}\right)} \cdot P_o & \text{if } \frac{P_{ey}}{P_o} \ge 0.44 \\ 0.877 \cdot P_{ey} & \text{otherwise} \end{cases} = 91.26 \cdot kip$$

$$P_r := \phi_c \cdot \min\left(P_{nx}, P_{ny}\right) = 58.175 \cdot kip$$

$$Check_P := \begin{cases} \text{"O.K."} & \text{if } P_r \ge P_u \\ \text{"NO GOOD"} & \text{otherwise} \end{cases} = \text{"O.K."}$$

Check Combined Bending and Axial of Intermediate Post
(Assume a cantilever)

$$M_{ux} := 0 kip \cdot in$$

(AASHTO 6.12.2.2.7)

$$Check_{yieldingx} := \begin{cases} \text{"OK, Mn=Mp=Fy*Z"} & \text{if } \frac{L_{post} \cdot t_{post}}{b_{post}^2} \le \frac{0.08 \cdot E}{F_y} \\ \text{"Lateral Torsional Buckling Controls"} & \text{otherwise} \end{cases} = \text{"OK, Mn=Mp=Fy*Z"}$$

$$Z_{postx} := \frac{b_{post} \cdot t_{post}^2}{4} = 1.172 \cdot in^3$$

$M_{px} := \phi_f \cdot F_y \cdot Z_{postx} = 42.187 \cdot kip \cdot in$

$S_{postx} := \frac{b_{post} \cdot t_{post}^2}{6} = 0.781 \cdot in^3$

$M_{yx} := F_y \cdot S_{postx} = 28.125 \cdot kip \cdot in$

$M_{rx} := \min\left(M_{px}, \phi_f \cdot 1.6 \cdot M_{yx}\right) = 42.187 \cdot kip \cdot in$ (AASHTO 6.12.2.2.7-1)

$H_{rail} := 42in$

$M_{uy} := 1.75 \cdot H_{rail} \cdot \left(span \cdot w_L + p_L\right) = 25.725 \cdot kip \cdot in$

$Check_{yieldingy} := \begin{cases} \text{"OK, Mn=Fy*Z"} & \text{if } \frac{L_{post} \cdot b_{post}}{t_{post}^2} \le \frac{0.08 \cdot E}{F_y} \\ \text{"Lateral Torsional Buckling Controls"} & \text{otherwise} \end{cases} = \text{"Lateral Torsional Buckling Controls"}$

$M_{mid} := \frac{1}{2} \cdot L_{post} \cdot 1.75 \cdot \left(span \cdot w_L + p_L\right) = 10.892 \cdot kip \cdot in$

$M_1 := 0kip \cdot in$

$C_{by} := \begin{cases} 1.0 & \text{if } \frac{M_{mid}}{M_{uy}} > 1 \\ 1.75 - 1.05 \cdot \left(\frac{M_1}{M_{uy}}\right) + 0.3 \cdot \left(\frac{M_1}{M_{uy}}\right)^2 & \text{otherwise} \end{cases} = 1.75$ (AASHTO A6.3.3-7)

$S_{posty} := \frac{t_{post} \cdot b_{post}^2}{6} = 1.875 \cdot in^3$

$M_{yy} := F_y \cdot S_{posty} = 67.5 \cdot kip \cdot in$

$F_{cry} := \frac{1.9 \cdot E \cdot C_{by}}{\left(\frac{L_{post} \cdot b_{post}}{t_{post}^2}\right)} = 1.412 \times 10^3 \cdot ksi$

$M_{ny} := \begin{cases} C_{by} \cdot \left[1.52 - 0.274 \cdot \left(\frac{L_{post} \cdot b_{post}}{t_{post}^2}\right) \cdot \left(\frac{F_y}{E}\right)\right] \cdot M_{yy} & \text{if } \frac{0.08 \cdot E}{F_y} < \frac{L_{post} \cdot b_{post}}{t_{post}^2} < \frac{1.9 \cdot E}{F_y} \\ F_{cry} \cdot S_{posty} & \text{otherwise} \end{cases} = 176.806 \cdot kip \cdot in$

$Z_{posty} := \frac{t_{post} \cdot b_{post}^2}{4} = 2.812 \cdot in^3$

$M_{ry} := \min\left(M_{ny}, \phi_f \cdot F_y \cdot Z_{posty}\right) = 101.25 \cdot kip \cdot in$

$\frac{P_u}{P_r} = 0.013$

$$Combined := \begin{cases} \frac{P_u}{2 \cdot P_r} + \left(\frac{M_{ux}}{M_{rx}} + \frac{M_{uy}}{M_{ry}}\right) & \text{if } \frac{P_u}{P_r} < 0.2 \quad = 0.26 \\ \frac{P_u}{P_r} + \frac{8}{9} \cdot \left(\frac{M_{ux}}{M_{rx}} + \frac{M_{uy}}{M_{ry}}\right) & \text{otherwise} \end{cases}$$ (AASHTO 6.9.2.2)

$$Check_{Combined} := \begin{cases} \text{"O.K."} & \text{if } Combined \le 1.0 \quad = \text{"O.K."} \\ \text{"NO GOOD"} & \text{otherwise} \end{cases}$$

Weld @ base of Post to base plate
(Check bending in post as a cantilever)

$\phi_{e2} := 0.80$ (AASHTO 6.5.4.2)

$F_{exx} := 60ksi$ (AISC J2.6)

$R_r := 0.6 \cdot \phi_{e2} \cdot F_{exx} = 28.8 \cdot ksi$ (AASHTO 6.13.3.2.4b-1)

$Fillet := \frac{1}{2}in$ $t_e := Fillet \cdot \sin(45deg) = 0.354 \cdot in$ $Length := b_{post} = 3 \cdot in$

$Area_{weld} := t_e \cdot Length \cdot 2 = 2.121 \cdot in^2$

$I_{weld} := \frac{1}{12} \cdot t_e \cdot Length^3 \cdot 2 = 1.591 \cdot in^4$ $y_{weld} := \frac{Length}{2} = 1.5 \cdot in$

$\sigma_b := \frac{M_{uy} \cdot y_{weld}}{I_{weld}} = 24.254 \cdot ksi$

$V_u := 1.75 \cdot \left(w_L \cdot span + p_L\right) = 0.612 \cdot kip$ $\sigma_v := \frac{V_u}{Area_{weld}} = 0.289 \cdot ksi$

$\sigma_T := \sqrt{\sigma_b^{\,2} + \sigma_v^{\,2}} = 24.255 \cdot ksi$

$$Check_{Weld} := \begin{cases} \text{"O.K."} & \text{if } \sigma_T \le R_r \quad = \text{"O.K."} \\ \text{"NO GOOD"} & \text{otherwise} \end{cases}$$

End Post
(Check bending in post as a cantilever)

$P_{cable} := 0.60kip$ $t_{endpost} := 1.25in$ $b_{endpost} := 3in$ $separation := 3in$

$i := 0 .. 11$ $arm_i := i \cdot 3$

$M_{eachcable} := P_{cable} \cdot arm \cdot in =$

	0
0	0
1	1.8
2	3.6
3	5.4
4	7.2
5	9
6	10.8
7	12.6
8	14.4
9	16.2
10	18
11	19.8

$\cdot kip \cdot in$

$M_u := \sum M_{eachcable} \cdot 1.25 = 148.5 \cdot kip \cdot in$

$Z_{endpost} := \frac{b_{endpost}}{4} \cdot \left[\left(separation + 2 \cdot t_{endpost} \right)^2 - separation^2 \right] = 15.937 \cdot in^3$

$\phi M_n := \phi_f \cdot F_y \cdot Z_{endpost} = 573.75 \cdot kip \cdot in$

$Check_M := \begin{cases} \text{"O.k."} & \text{if } \phi M_n \geq M_u \\ \text{"No Good"} & \text{otherwise} \end{cases} = \text{"O.k."}$

Check Combined Bending and Axial of End Post
(Assume a cantilever)

$M_{uxend} := M_u = 148.5 \cdot kip \cdot in$ (AASHTO 6.12.2.2.7)

$Check_{yieldingx} := \begin{cases} \text{"OK, Mn=Mp=Fy*Z"} & \text{if } \frac{L_{post} \cdot t_{endpost}}{b_{endpost}^2} \leq \frac{0.08 \cdot E}{F_y} \\ \text{"Lateral Torsional Buckling Controls"} & \text{otherwise} \end{cases} = \text{"OK, Mn=Mp=Fy*Z"}$

$Z_{endpostx} := Z_{endpost} = 15.937 \cdot in^3$

$M_{pxend} := \phi_f \cdot F_y \cdot Z_{endpostx} = 573.75 \cdot kip \cdot in$

$S_{endpostx} := b_{endpost} \cdot \frac{\left[\left(2 \cdot t_{endpost} + separation \right)^3 - separation^3 \right]}{6 \cdot \left(2 \cdot t_{endpost} + separation \right)} = 12.67 \cdot in^3$

$M_{yxend} := F_y \cdot S_{endpostx} = 456.136 \cdot kip \cdot in$

$M_{rxend} := \min\left(M_{pxend}, \phi_f \cdot 1.6 \cdot M_{yxend} \right) = 573.75 \cdot kip \cdot in$ (AASHTO 6.12.2.2.7-1)

$$M_{uyend} := 1.75 \cdot H_{rail} \cdot \left(\frac{1}{2} span \cdot w_L + p_L \right) = 20.213 \cdot kip \cdot in$$

$$Check_{yieldingy} := \begin{cases} \text{"OK, Mn=Fy*Z"} & \text{if } \frac{L_{post} \cdot b_{endpost}}{t_{endpost}^2} \le \frac{0.08 \cdot E}{F_y} \\ \text{"Lateral Torsional Buckling Controls"} & \text{otherwise} \end{cases} = \text{"Lateral Torsional Buckling Controls"}$$

$$M_{midend} := \frac{1}{2} \cdot H_{rail} \cdot 1.75 \cdot \left(\frac{1}{2} span \cdot w_L + p_L \right) = 10.106 \cdot kip \cdot in \qquad M_1 := 0 kip \cdot in$$

$$C_{by} := \begin{cases} 1.0 & \text{if } \frac{M_{midend}}{M_{uyend}} > 1 \\ 1.75 - 1.05 \cdot \left(\frac{M_1}{M_{uyend}} \right) + 0.3 \cdot \left(\frac{M_1}{M_{uyend}} \right)^2 & \text{otherwise} \end{cases} = 1.75$$

(AASHTO A6.3.3-7)

$$S_{endposty} := \frac{t_{endpost} \cdot b_{endpost}^2}{6} \cdot 2 = 3.75 \cdot in^3$$

$$M_{yyend} := F_y \cdot S_{endposty} = 135 \cdot kip \cdot in$$

$$F_{cryend} := \frac{1.9 \cdot E \cdot C_{by}}{\left(\frac{L_{post} \cdot b_{endpost}}{t_{endpost}^2} \right)} = 1.412 \times 10^3 \cdot ksi$$

$$M_{nyend} := \begin{cases} C_{by} \cdot \left[1.52 - 0.274 \cdot \left(\frac{L_{post} \cdot b_{endpost}}{t_{endpost}^2} \right) \cdot \left(\frac{F_y}{E} \right) \right] \cdot M_{yyend} & \text{if } \frac{0.08 \cdot E}{F_y} < \frac{L_{post} \cdot b_{endpost}}{t_{endpost}^2} < \frac{1.9 \cdot E}{F_y} \\ F_{cryend} \cdot S_{endposty} & \text{otherwise} \end{cases} = 353.613 \cdot kip \cdot in$$

$$Z_{endposty} := \frac{t_{endpost} \cdot b_{endpost}^2}{4} \cdot 2 = 5.625 \cdot in^3$$

$$M_{ryend} := \min\left(M_{nyend}, \phi_f \cdot F_y \cdot Z_{endposty} \right) = 202.5 \cdot kip \cdot in$$

$$P_{dend} := w_{bronze} \cdot b_{bronzeplate} \cdot t_{bronzeplate} \cdot \frac{1}{2} span \ ... = 0.051 \cdot kip$$
$$+ w_{bronze} \cdot t_{bronzeplate} \cdot \left(0.75in - t_{bronzeplate} \right) \cdot 2 \cdot \frac{1}{2} span \ ...$$
$$+ w_{steel} \cdot b_{steelplate} \cdot t_{steelplate} \cdot \frac{1}{2} span + w_{channel} \cdot \frac{1}{2} span + w_{steel} \cdot 0.625in \cdot \left(2in + \frac{3}{16} in \right) \cdot 3in$$

$$P_{Lend} := p_L + w_L \cdot \frac{1}{2} span = 0.275 \cdot kip$$

$P_{uend} := 1.25 \cdot P_{dend} + 1.75 \cdot P_{Lend} = 0.545 \cdot kip$

$\phi_c := 0.90$ (AASHTO 6.5.4.2)

$K_{xend} := 1.2$ (Bending about respective axis) $K_{yend} := 2.1$

$r_{xend} := \sqrt{\frac{\left(2 \cdot t_{endpost} + separation\right)^3 - separation^3}{12 \cdot \left[\left(2 \cdot t_{endpost} + separation\right) - separation\right]}} = 2.155 \cdot in$ $r_{yend} := \frac{b_{endpost}}{\sqrt{12}} = 0.866 \cdot in$

$\frac{K_{xend} \cdot L_{post}}{r_{xend}} = 19.801$ $\frac{K_{yend} \cdot L_{post}}{r_{yend}} = 86.243$

$KLr_{mx} = \sqrt{\left(\frac{K_{xend} \cdot L_{post}}{r_{xend}}\right)^2 + 0.82 \cdot \frac{\alpha_x^2}{1 + \alpha_x^2} \cdot \left(\frac{a}{r_{ix}}\right)^2}$ (AASHTO 6.9.4.3.1-1)

$\alpha = \frac{h_x}{2 \cdot r_{ix}}$ $h_x := t_{endpost} + separation = 4.25 \cdot in$ $r_{ix} := \frac{t_{endpost}}{\sqrt{12}} = 0.361 \cdot in$

$\alpha_x := \frac{h_x}{2 \cdot r_{ix}} = 5.889$ $a := arm_1 \cdot in = 3 \cdot in$

$KLr_{mx} := \sqrt{\left(\frac{K_{xend} \cdot L_{post}}{r_{xend}}\right)^2 + 0.82 \cdot \frac{\alpha_x^2}{1 + \alpha_x^2} \cdot \left(\frac{a}{r_{ix}}\right)^2} = 21.146$

$r_{iy} := \frac{b_{endpost}}{\sqrt{12}} = 0.866 \cdot in$ $h_y := 0in$ $\alpha_y := \frac{h_y}{2 \cdot r_{iy}} = 0$

$KLr_{my} := \sqrt{\left(\frac{K_{yend} \cdot L_{post}}{r_{yend}}\right)^2 + 0.82 \cdot \frac{\alpha_y^2}{1 + \alpha_y^2} \cdot \left(\frac{a}{r_{iy}}\right)^2} = 86.243$

$Check_{6.9.3.x} := \begin{cases} \text{"Meets AASHTO 6.9.3"} & \text{if } KLr_{mx} \le 120 \\ \text{"Does NOT meet AASHTO 6.9.3!!"} & \text{otherwise} \end{cases} = \text{"Meets AASHTO 6.9.3"}$

$Check_{6.9.3.y} := \begin{cases} \text{"Meets AASHTO 6.9.3"} & \text{if } KLr_{my} \le 120 \\ \text{"Does NOT meet AASHTO 6.9.3!!"} & \text{otherwise} \end{cases} = \text{"Meets AASHTO 6.9.3"}$

$P_{exend} := \frac{\pi^2 \cdot E}{\left(KLr_{mx}\right)^2} \cdot b_{endpost} \cdot t_{endpost} \cdot 2 = 4.801 \times 10^3 \cdot kip$ (AASHTO 6.9.4.1.2-1)

$P_{eyend} := \frac{\pi^2 \cdot E}{\left(KLr_{my}\right)^2} \cdot b_{endpost} \cdot t_{endpost} \cdot 2 = 288.61 \cdot kip$

$P_{oend} := F_y \cdot t_{endpost} \cdot b_{endpost} \cdot 2 = 270 \cdot kip$

$$P_{nxend} := \begin{cases} 0.658^{\left(\frac{P_{oend}}{P_{exend}}\right)} \cdot P_{oend} & \text{if } \frac{P_{exend}}{P_{oend}} \geq 0.44 \\ 0.877 \cdot P_{exend} & \text{otherwise} \end{cases} = 263.718 \cdot kip$$

(AASHTO 6.9.4.1.1-1)

$$P_{nyend} := \begin{cases} 0.658^{\left(\frac{P_{oend}}{P_{eyend}}\right)} \cdot P_{oend} & \text{if } \frac{P_{eyend}}{P_{oend}} \geq 0.44 \\ 0.877 \cdot P_{eyend} & \text{otherwise} \end{cases} = 182.52 \cdot kip$$

$P_{rend} := \phi_c \cdot \min\left(P_{nxend}, P_{nyend}\right) = 164.268 \cdot kip$

$$Check_{Pend} := \begin{cases} \text{"O.K."} & \text{if } P_{rend} \geq P_{uend} \\ \text{"NO GOOD"} & \text{otherwise} \end{cases} = \text{"O.K."}$$

$\frac{P_{uend}}{P_{rend}} = 3.319 \times 10^{-3}$

$$Combined := \begin{cases} \frac{P_{uend}}{2 \cdot P_{rend}} + \left(\frac{M_{uxend}}{M_{rxend}} + \frac{M_{uyend}}{M_{ryend}}\right) & \text{if } \frac{P_{uend}}{P_{rend}} < 0.2 \\ \frac{P_{uend}}{P_{rend}} + \frac{8}{9} \cdot \left(\frac{M_{uxend}}{M_{rxend}} + \frac{M_{uyend}}{M_{ryend}}\right) & \text{otherwise} \end{cases} = 0.36$$

(AASHTO 6.9.2.2)

$$Check_{Combined} := \begin{cases} \text{"O.K."} & \text{if Combined} \leq 1.0 \\ \text{"NO GOOD"} & \text{otherwise} \end{cases} = \text{"O.K."}$$

End Post

(Check shear flow for design of weld)

$q = \frac{V \cdot Q}{I}$

$V := 11 \cdot P_{cable} = 6.6 \cdot kip$

$A' := t_{endpost} \cdot b_{endpost} = 3.75 \cdot in^2$

$y' := \frac{1}{2} \cdot t_{endpost} + \frac{1}{2} \cdot separation = 2.125 \cdot in$

$Q := A' \cdot y' = 7.969 \cdot in^3$

$I := b_{endpost} \cdot \frac{\left[\left(2 \cdot t_{endpost} + separation\right)^3 - separation^3\right]}{12} = 34.844 \cdot in^4$

$q := \frac{V \cdot Q}{I} = 1.509 \cdot \frac{kip}{in}$

$H := arm_1 \cdot in + \frac{1}{2} \cdot arm_1 \cdot in = 4.5 \cdot in$

$V_{weld} := q \cdot H = 6.792 \cdot kip$

$\phi_{e2} := 0.80$ (AASHTO 6.5.4.2)

$F_{exx} := 60ksi$ (AISC J2.6)

$Fillet := \frac{3}{16} in$ $t_e := Fillet \cdot \sin(45deg) = 0.133 \cdot in$ $Length := 1.5in$

$Area_{weld} := t_e \cdot Length \cdot 2 = 0.398 \cdot in^2$

$R_r := 0.6 \cdot \phi_{e2} \cdot F_{exx} \cdot Area_{weld} = 11.455 \cdot kip$ (AASHTO 6.13.3.2.4b-1)

$V_u := 1.25 \cdot V_{weld} = 8.49 \cdot kip$

$Check_{Weld} := \begin{cases} \text{"O.K."} & \text{if } V_u \le R_r \\ \text{"NO GOOD"} & \text{otherwise} \end{cases} = \text{"O.K."}$

NOTE: Use 1/4" fillet weld per AASHTO 6.13.3.4-1

Weld @ base of Endpost to base plate
(Check bending in post as a cantilever)

$\phi_{e2} := 0.80$ (AASHTO 6.5.4.2)

$F_{exx} := 60ksi$ (AISC J2.6)

$R_r := 0.6 \cdot \phi_{e2} \cdot F_{exx} = 28.8 \cdot ksi$ (AASHTO 6.13.3.2.4b-1)

$Fillet := \frac{3}{8} in$ $t_e := Fillet \cdot \sin(45deg) = 0.265 \cdot in$ $y_1 := 0.5 \cdot separation - 0.5 \cdot t_e = 1.367\,in$

$y_2 := 0.5 \cdot separation + t_{endpost} + 0.5 \cdot t_e = 2.883\,in$ $y_3 := 0.5 \cdot (separation + t_{endpost}) = 2.125\,in$

$Area_{weld} := 4 t_e \cdot (b_{endpost} + t_{endpost}) = 4.508 \cdot in^2$

$I_{weldx} := t_e \cdot b_{endpost} \cdot 2 \cdot \left({y_1}^2 + {y_2}^2 \right) + 4 \cdot t_e \cdot t_{endpost} \cdot {y_3}^2 = 22.182 \cdot in^4$

$I_{weldy} := \frac{4}{12} \cdot t_e \cdot {b_{endpost}}^3 + 4 \cdot t_e \cdot t_{endpost} \cdot \left(\frac{b_{endpost}}{2} + \frac{t_e}{2} \right)^2 = 5.92 \cdot in^4$

$M_{ux} := M_{uxend} = 148.5 \cdot kip \cdot in$ $M_{uy} := M_{uyend} = 20.213 \cdot kip \cdot in$

$V_{ux} := 1.25 \cdot V = 8.25 \cdot kip$ $\sigma_{vx} := \frac{V_{ux}}{Area_{weld}} = 1.83 \cdot ksi$

$V_{uy} := 1.75 \cdot \left(w_L \cdot \frac{1}{2} span + p_L \right) = 0.481 \cdot kip$

$\sigma_{vy} := \frac{V_{uy}}{Area_{weld}} = 0.107 \cdot ksi$

$\sigma_{VT} := \sqrt{\sigma_{vx}^2 + \sigma_{vy}^2} = 1.833 \cdot ksi$

$\sigma_{tx} := \frac{M_{ux} \cdot y_2}{I_{weldx}} = 19.298 \cdot ksi$

$\sigma_{ty} := \frac{M_{uy} \cdot b_{endpost} \cdot 0.5}{I_{weldy}} = 5.121 \cdot ksi$

$\sigma_{TT} := \sigma_{tx} + \sigma_{ty} = 24.419 \cdot ksi$

$\sigma_T := \sqrt{\sigma_{VT}^2 + \sigma_{TT}^2} = 24.488 \cdot ksi$

$Check_{Weld} := \begin{cases} \text{"O.K."} & \text{if } \sigma_T \le R_r \\ \text{"NO GOOD"} & \text{otherwise} \end{cases} = \text{"O.K."}$

End Post

(Check connecting plate of built-up end post)

$K := 0.65$ $a = 3 \cdot in$ $r_i := \frac{t_{endpost}}{\sqrt{12}} = 0.361 \cdot in$

$Kar_{ix} := \frac{K \cdot a}{r_i} = 5.404$

$Check := \begin{cases} \text{"OK, meets AASHTO 6.9.4.3"} & \text{if } Kar_{ix} < 0.75 \cdot \max\left(KLr_{mx}, KLr_{my}\right) \\ \text{"Adjust Spacing"} & \text{otherwise} \end{cases} = \text{"OK, meets AASHTO 6.9.4.3"}$

$Check := \begin{cases} \text{"OK, meets AISC E6.2"} & \text{if } a < \min\left(12in, 0.75 \cdot \sqrt{\frac{E}{F_y}} \cdot t_{endpost}\right) \\ \text{"Adjust Spacing"} & \text{otherwise} \end{cases} = \text{"OK, meets AISC E6.2"}$

$Spacer_t := 0.5in$

$Check := \begin{cases} \text{"OK, meets AISC E6.2"} & \text{if } Spacer_t > \frac{1}{50} \cdot a \\ \text{"Make spacer plate thicker"} & \text{otherwise} \end{cases} = \text{"OK, meets AISC E6.2"}$

$V_{nspacer} := 0.6 \cdot F_y \cdot Spacer_t \cdot Length \cdot C_v$ $C_v := 1.0$

$Check := \begin{cases} \text{"OK, meets AISC E6.2"} & \text{if } V_{nspacer} > 0.02 \cdot P_{rend} \\ \text{"Make spacer plate thicker"} & \text{otherwise} \end{cases} = \text{"OK, meets AISC E6.2"}$

Anchor Bolts

(Check endpost and use for intermediate also)

$F_u := 58ksi$ ASTM A307 Grade C (AASHTO 6.4.3.1)

$Dia := \frac{3}{4}in$ $A_{anchor} := \frac{\pi}{4}\cdot Dia^2 = 0.442\cdot in^2$

$R_n = 0.48\cdot A_{anchor}\cdot F_u\cdot N_s$ (AASHTO 6.13.2.12-1)

$N_s := 1$ $\phi_s := 0.75$ (AASHTO 6.5.4.2)

$\phi R_n := \phi_s\cdot 0.48\cdot A_{anchor}\cdot F_u\cdot N_s\cdot 4 = 36.898\cdot kip$ (4 anchors per plate)

$V_u := V_{ux} = 8.25\cdot kip$

$Check_V := \begin{cases} \text{"OK"} & \text{if } \phi R_n \geq V_u \\ \text{"NO GOOD"} & \text{otherwise} \end{cases} = \text{"OK"}$

$\phi_t := 0.80$ (AASHTO 6.5.4.2)

$w_{plate} := 8in$ $Edge := 1.25in$

$S_{anchor} := w_{plate} - 2\cdot Edge = 5.5\,in$ (Both directions)

$T_u := \frac{M_{uxend} + M_{uyend}}{S_{anchor}}\cdot\frac{1}{2} = 15.338\cdot kip$ (2 anchors)

$\phi T_n := \begin{cases} \phi_t\cdot 0.76\cdot A_{anchor}\cdot F_u & \text{if } \frac{V_u\cdot 0.25}{\frac{\phi R_n}{\phi_s}} \leq 0.33 \\ \phi_t\cdot 0.76\cdot A_{anchor}\cdot F_u\cdot\sqrt{1 - \frac{V_u\cdot 0.25}{\phi R_n}} & \text{otherwise} \end{cases} = 15.579\cdot kip$ (AASHTO 6.13.2.11)

$Check_T := \begin{cases} \text{"OK"} & \text{if } \phi T_n \geq T_u \\ \text{"NO GOOD"} & \text{otherwise} \end{cases} = \text{"OK"}$

Check force from cables on intermediate posts due to curvature

$angle := 2.62deg$

$P := P_{cable} \cdot \tan(angle) = 0.027 \cdot kip$

$M_{eachcable} := P \cdot arm \cdot in =$

	0
0	0
1	0.082
2	0.165
3	0.247
4	0.329
5	0.412
6	0.494
7	0.577
8	0.659
9	0.741
10	0.824
11	0.906

$\cdot kip \cdot in$

$M_u := \sum M_{eachcable} \cdot 1.25 = 6.795 \cdot kip \cdot in$

$Check_{post} := \begin{cases} \text{"OK, Moment < design moment"} & \text{if } M_u \le M_{uyend} \\ \text{"No Good, Moment > design moment"} & \text{otherwise} \end{cases} = \text{"OK, Moment < design moment"}$