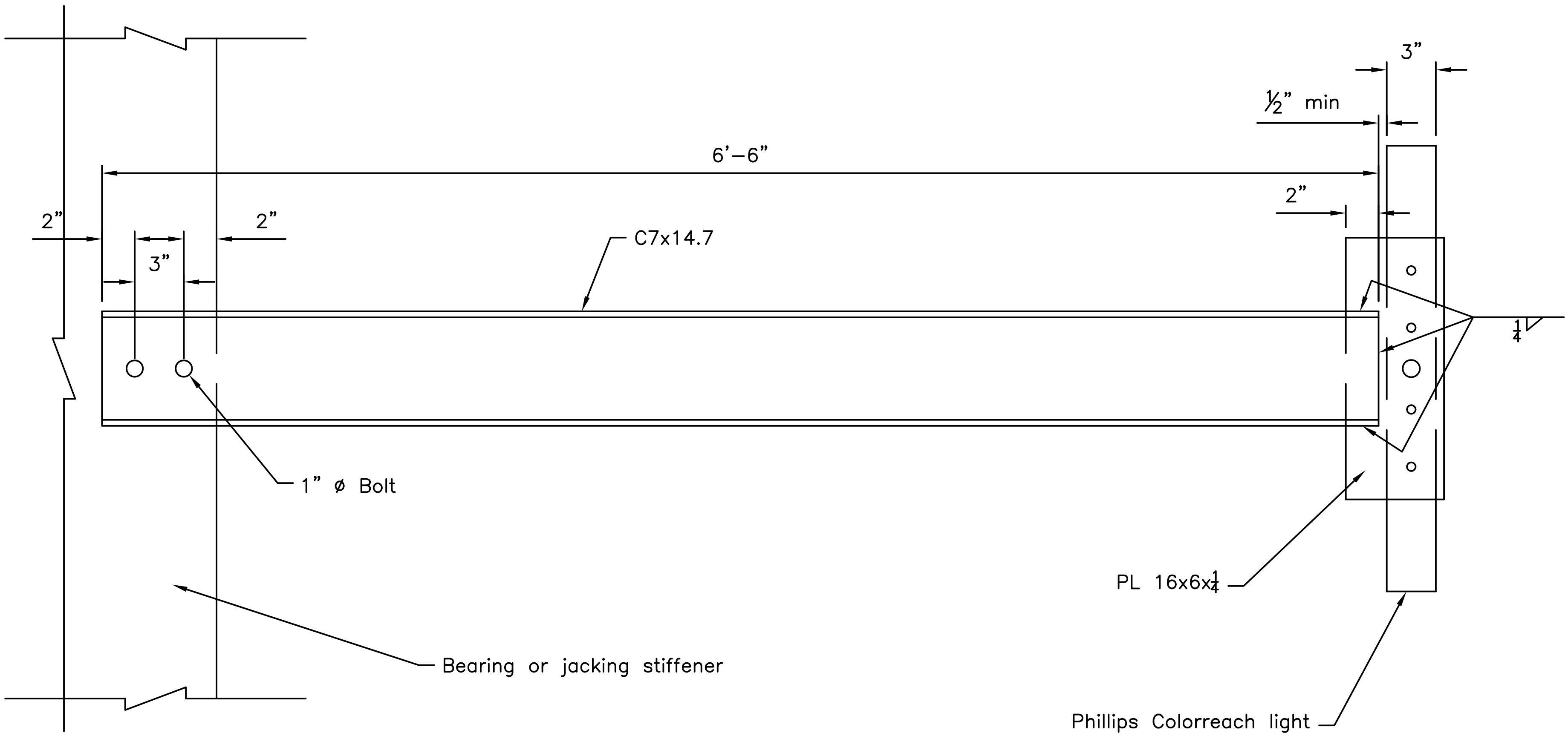
Project: Cleveland Innerbelt	Made by:	DSB	8/29/11	HNTB
For: Unit 2/Unit 3	Checked by:	LER	9/7/11	
For: Lighting Bracket Details	Back Checked by:	DSB	9/7/11	Job No: 49633



Lighting Bracket at Stiffeners

NOTES:

Steel shall conform to the requirements of ASTM A709, Grade 50.

Steel shall be designated "CVN"

Steel shall be painted with an Izeu coating system

High strength bolts shall be 1" diameter A325 Type I bolts

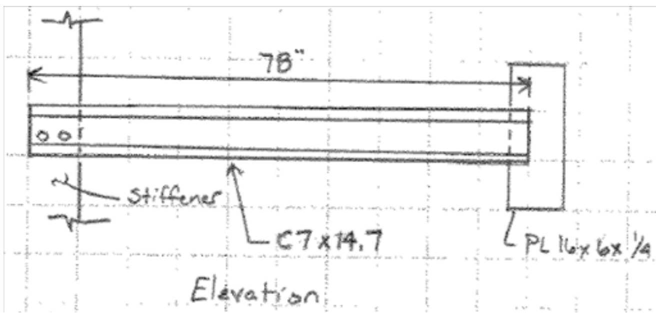
Use standard holes

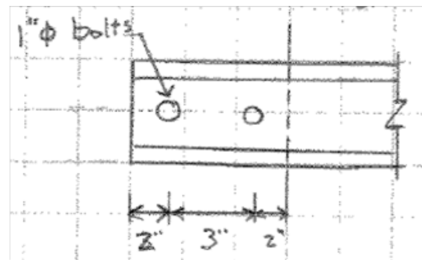
Light Bracket Design at Stiffeners

Design the lighting bracket thats connects to jacking/bearing stiffeners.

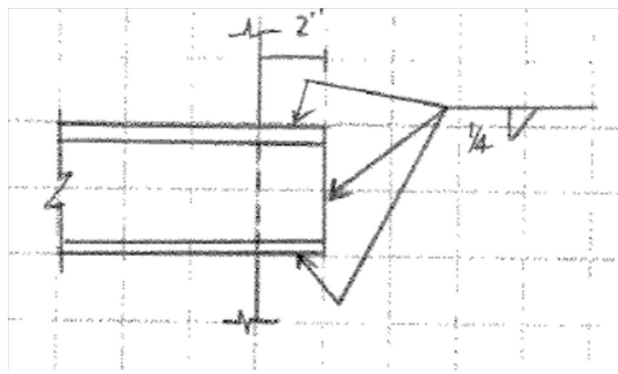
Reference: AASHTO LRFD Bridge Design Specifications - Fifth Edition 2010

Sketches





Channel Section Properties C7x14.7



$wt := 14.7 \frac{lbf}{ft}$

$A := 4.33in^2$

$t_w := 0.419in$

$b_f := 2.30in$

$t_f := 0.366in$

$I_x := 27.2in^4$ $\quad I_y := 1.37in^4$

$S_x := 7.78 \cdot in^3$ $\quad S_y := 0.772in^3$

$r_x := 2.51in$ $\quad r_y := 0.561in$

$Z_x := 9.75in^3$ $\quad Z_y := 1.63in^3$

$J := 0.267in^4$

$C_w := 13.1in^6$

$h_o := 6.63in$

$d := 7in$

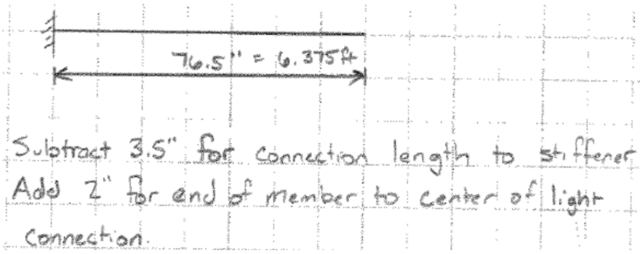
Material Properties

$F_y := 50ksi$

$F_u := 65ksi$

$E := 29000ksi$

<u>Model</u>



$l := 76.5in$

LOADS

<u>Dead Loads DL</u>

Channel - $w_{DL.ch} := wt = 14.7 \cdot \frac{lbf}{ft}$

Plates - $P_{DL.pl} := (16in) \cdot (6in) \cdot (0.25in) \cdot 490 \frac{lbf}{ft^3} = 6.806\,lbf$

Luminary - $P_{DL.lu} := 75lbf$

$$V_{DL} := w_{DL.ch} \cdot l + P_{DL.pl} + P_{DL.lu} = 0.176 \cdot kip$$

$$M_{DL} := \frac{w_{DL.ch} \cdot l^2}{2} + \left(P_{DL.pl} + P_{DL.lu}\right) \cdot l = 0.82 \cdot kip \cdot ft$$

<u>Ice Loads ICE</u>

Use 3 psf over surface area
Use DL load factors

Channel - $w_{ICE.ch} := 2 \cdot \left(d + 2b_f\right) \cdot 3psf = 5.8 \cdot \frac{lbf}{ft}$

Plates - $P_{ICE.pl} := 2(16in) \cdot (6in) \cdot 3psf = 4\,lbf$

Luminary - $P_{ICE.lu} := (30in) \cdot (18in) \cdot 2 \cdot 3psf = 22.5\,lbf$

$$V_{ICE} := w_{ICE.ch} \cdot l + P_{ICE.pl} + P_{ICE.lu} = 0.063 \cdot kip$$

$$M_{ICE} := \frac{w_{ICE.ch} \cdot l^2}{2} + \left(P_{ICE.pl} + P_{ICE.lu}\right) \cdot l = 0.287 \cdot kip \cdot ft$$

Wind Loads WS

Use 50 psf for horizontal and vertical wind pressure
Conservatively use surface areas in vertical plane for both horizontal and vertical wind loads
Consider horizontal and vertical wind loads in separate cases

Channel - $w_{WS.ch} := d \cdot 50psf = 29.167 \cdot \frac{lbf}{ft}$

Plates - $P_{WS.pl} := (16in) \cdot (6in) \cdot 50psf = 33.333\,lbf$

Luminary - $P_{WS.lu} := (30in) \cdot (18in) \cdot 50psf = 187.5\,lbf$

$$V_{WS} := w_{WS.ch} \cdot l + P_{WS.pl} + P_{WS.lu} = 0.407 \cdot kip$$

$$M_{WS} := \frac{w_{WS.ch} \cdot l^2}{2} + \left(P_{WS.pl} + P_{WS.lu}\right) \cdot l = 2 \cdot kip \cdot ft$$

Factored Loads

Use Strength III for flexure design
Use Service I for bolt slip (conservative) and deflection
Use importance factor of 1.05 for Strength load case

Strength (Vertical wind)

$$V_{u.v.st.1} := 1.05 \cdot \left[1.25 \cdot \left(V_{DL} + V_{ICE}\right) + 1.4 \cdot \left(V_{WS}\right)\right] = 0.912 \cdot kip$$

$$V_{u.h.st.1} := 0kip$$

$$M_{u.v.st.1} := 1.05 \cdot \left[1.25 \cdot \left(M_{DL} + M_{ICE}\right) + 1.4 \cdot \left(M_{WS}\right)\right] = 4.394 \cdot kip \cdot ft$$

$$M_{u.h.st.1} := 0kip \cdot ft$$

Strength (Horizontal wind)

$$V_{u.v.st.2} := 1.05 \cdot \left[1.25 \cdot \left(V_{DL} + V_{ICE}\right)\right] = 0.314 \cdot kip$$

$$V_{u.h.st.2} := 1.05 \cdot 1.4 \cdot V_{WS} = 0.598 \cdot kip$$

$$M_{u.v.st.2} := 1.05 \cdot \left[1.25 \cdot \left(M_{DL} + M_{ICE}\right)\right] = 1.453 \cdot kip \cdot ft$$

$$M_{u.h.st.2} := 1.05 \cdot 1.4 \cdot M_{WS} = 2.941 \cdot kip \cdot ft$$

Service (Vertical wind)

$$V_{u.v.se.1} := 1.0\cdot\left[1.0\cdot\left(V_{DL} + V_{ICE}\right) + 0.3\cdot\left(V_{WS}\right)\right] = 0.361\cdot kip$$

$$V_{u.h.se.1} := 0kip$$

$$M_{u.v.se.1} := 1.0\cdot\left[1.0\cdot\left(M_{DL} + M_{ICE}\right) + 0.3\cdot\left(M_{WS}\right)\right] = 1.707\cdot kip\cdot ft$$

$$M_{u.h.se.1} := 0kip\cdot ft$$

Service (Horizontal wind)

$$V_{u.v.se.2} := 1.00\cdot\left[1.0\cdot\left(V_{DL} + V_{ICE}\right)\right] = 0.239\cdot kip$$

$$V_{u.h.se.2} := 1.0\cdot 0.3\cdot V_{WS} = 0.122\cdot kip$$

$$M_{u.v.se.2} := 1.0\cdot\left[1.0\cdot\left(M_{DL} + M_{ICE}\right)\right] = 1.107\cdot kip\cdot ft$$

$$M_{u.h.se.2} := 1.0\cdot 0.3\cdot M_{WS} = 0.6\cdot kip\cdot ft$$

FLEXURE DESIGN

Vertical Bending (AASHTO 6.12.2.2.5)

$$L_b := l = 6.375\ ft$$

$$r_{ts} := \sqrt{\frac{\sqrt{I_y\cdot C_w}}{S_x}} = 0.738\cdot in$$

$$c := \frac{h_o}{2}\cdot\sqrt{\frac{I_y}{C_w}} = 1.072$$

$$L_r := 1.95\cdot r_{ts}\cdot\frac{E}{0.7\cdot F_y}\cdot\sqrt{\frac{J\cdot c}{S_x\cdot h_o}}\cdot\sqrt{1 + \sqrt{1 + 6.76\cdot\left(\frac{0.7\cdot F_y}{E}\cdot\frac{S_x\cdot h_o}{J\cdot c}\right)^2}} = 10.849\ ft$$

$$L_p := 1.76\cdot r_y\cdot\sqrt{\frac{E}{F_y}} = 1.982\ ft$$

$$L_p < L_b < L_r$$

$$M_{p.vert} := F_y\cdot Z_x = 40.625\cdot kip\cdot ft$$

$$C_b := 1.0$$

$$M_{n.vert} := \min\left[C_b \cdot \left[M_{p.vert} - \left(M_{p.vert} - 0.7 \cdot F_y \cdot S_x\right) \cdot \frac{\left(L_b - L_p\right)}{\left(L_r - L_p\right)}\right], M_{p.vert}\right] = 31.74 \cdot kip \cdot ft$$

$$\phi_f := 1.0$$

$$\phi M_{n.vert} := \phi_f \cdot M_{n.vert} = 31.74 \cdot kip \cdot ft$$

$$check_1 := \begin{vmatrix} \text{"OK"} & \text{if } \phi M_{n.vert} \geq M_{u.v.st.1} \\ \text{"NG"} & \text{otherwise} \end{vmatrix} = \text{"OK"}$$

<u>Horizontal Bending (AASHTO 6.12.2.2.5, 6.12.2.2.1)</u>

$$\lambda_f := \frac{b_f}{t_f} = 6.284$$

$$\lambda_{pf} := 0.38 \cdot \sqrt{\frac{E}{F_y}} = 9.152$$

$$check_2 := \begin{vmatrix} \text{"OK, use plastic moment"} & \text{if } \lambda_f \leq \lambda_{pf} \\ \text{"NG"} & \text{otherwise} \end{vmatrix} = \text{"OK, use plastic moment"}$$

$$\frac{d}{t_w} = 16.706$$

$$\lambda_{pw} := 3.76 \cdot \sqrt{\frac{E}{F_y}} = 90.553$$

$$check_3 := \begin{vmatrix} \text{"OK"} & \text{if } \frac{d}{t_w} \leq \lambda_{pw} \\ \text{"NG"} & \text{otherwise} \end{vmatrix} = \text{"OK"}$$

$$M_{p.horiz} := \min\left(F_y \cdot Z_y, 1.6 \cdot F_y \cdot S_y\right) = 5.147 \cdot kip \cdot ft$$

$$M_{n.horiz} := M_{p.horiz} = 5.147 \cdot kip \cdot ft$$

$$\phi M_{n.horiz} := \phi_f \cdot M_{n.horiz} = 5.147 \cdot kip \cdot ft$$

$$check_4 := \begin{vmatrix} \text{"OK"} & \text{if } \phi M_{n.horiz} \geq M_{u.h.st.2} \\ \text{"NG"} & \text{otherwise} \end{vmatrix} = \text{"OK"}$$

Combined Vertical and Horizontal Bending (AASHTO 6.12.1.2.2)

$$Comb := \frac{M_{u.v.st.2}}{\phi M_{n.vert}} + \frac{M_{u.h.st.2}}{\phi M_{n.horiz}} = 0.617$$

$$check_5 := \begin{cases} \text{"OK"} & \text{if } Comb \le 1.0 \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

SHEAR DESIGN (AASHTO 6.12.1.2.3, 6.10.9.2)

Vertical

$D := d = 7 \cdot in$

$t_w = 0.419 \cdot in$

$V_{p.v} := 0.58 \cdot F_y \cdot D \cdot t_w = 85.057 \cdot kip$

$k := 5$

$$C := \begin{cases} 1 & \text{if } \frac{D}{t_w} \le 1.12 \cdot \sqrt{\frac{E \cdot k}{F_y}} \\ \left[\frac{1.57}{\left(\frac{D}{t_w}\right)^2} \cdot \left(\frac{E \cdot k}{F_y}\right)\right] & \text{if } \frac{D}{t_w} > 1.40 \cdot \sqrt{\frac{E \cdot k}{F_y}} \\ \left[\frac{1.12}{\left(\frac{D}{t_w}\right)} \cdot \sqrt{\frac{E \cdot k}{F_y}}\right] & \text{otherwise} \end{cases}$$

$C = 1$

$V_{n.vert} := C \cdot V_{p.v} = 85.057 \cdot kip$

$\phi_v := 1.0$

$\phi V_{n.vert} := \phi_v \cdot V_{n.vert} = 85.057 \cdot kip$

$$check_6 := \begin{cases} \text{"OK"} & \text{if } \phi V_{n.vert} \ge V_{u.v.st.1} \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Horizontal

$D := b_f = 2.3 \cdot in$

$t_{w.h} := 2 \cdot t_f = 0.732 \cdot in$

$V_{p.h} := 0.58 \cdot F_y \cdot D \cdot t_{w.h} = 48.824 \cdot kip$

$k = 5$

$$C := \begin{cases} 1 & \text{if } \frac{D}{t_{w.h}} \le 1.12 \cdot \sqrt{\frac{E \cdot k}{F_y}} \\ \left[\frac{1.57}{\left(\frac{D}{t_{w.h}}\right)^2} \cdot \left(\frac{E \cdot k}{F_y}\right)\right] & \text{if } \frac{D}{t_{w.h}} > 1.40 \cdot \sqrt{\frac{E \cdot k}{F_y}} \\ \left[\frac{1.12}{\left(\frac{D}{t_{w.h}}\right)} \cdot \sqrt{\frac{E \cdot k}{F_y}}\right] & \text{otherwise} \end{cases}$$

$C = 1$

$V_{n.horiz} := C \cdot V_{p.h} = 48.824 \cdot kip$

$\phi V_{n.horiz} := \phi_v \cdot V_{n.horiz} = 48.824 \cdot kip$

$$check_7 := \begin{cases} \text{"OK"} & \text{if } \phi V_{n.horiz} \ge V_{u.h.st.2} \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

BOLTED CONNECTION DESIGN (AASHTO 6.13.2)

$\phi_{bolt} := 1in$

$A_b := \frac{\pi}{4} \cdot (\phi_{bolt})^2 = 0.785 \cdot in^2$

$spa := 3in$

Bolt Forces

Strength - $P_{u.str} := \frac{V_{u.v.st.1}}{2} + \frac{M_{u.v.st.1}}{spa} = 18.031 \cdot kip$ Shear and Tension

Slip - $P_{u.slip} := \frac{V_{u.v.se.1}}{2} + \frac{M_{u.v.se.1}}{spa} = 7.009 \cdot kip$

Bolt Shear Resistance

$N_s := 1$

$F_{ub} := 120ksi$

$R_{n.shear} := 0.38 \cdot A_b \cdot F_{ub} \cdot N_s = 35.814 \cdot kip$

$\phi_{bv} := 0.8$

$\phi R_{n.shear} := \phi_{bv} \cdot R_{n.shear} = 28.651 \cdot kip$

$check_8 := \begin{vmatrix} \text{"OK"} & \text{if } \phi R_{n.shear} \geq P_{u.str} \\ \text{"NG"} & \text{otherwise} \end{vmatrix} = \text{"OK"}$

Bolt Slip Resistance

$K_h := 1.00$ Standard holes

$K_s := 0.33$ Assume Class A surface

$P_t := 51kip$ For 1" diameter A325 bolts

$R_{n.slip} := K_h \cdot K_s \cdot N_s \cdot P_t = 16.83 \cdot kip$

$\phi_{bs} := 1.0$

$\phi R_{n.slip} := \phi_{bs} \cdot R_{n.slip} = 16.83 \cdot kip$

$check_9 := \begin{vmatrix} \text{"OK"} & \text{if } \phi R_{n.slip} \geq P_{u.slip} \\ \text{"NG"} & \text{otherwise} \end{vmatrix} = \text{"OK"}$

Bolt Bearing Resistance

$$L_{c.int} := spa - \left(\phi_{bolt} + \frac{1}{8}in\right) = 1.875 \cdot in$$

$$L_{c.end} := 2in - \left(\phi_{bolt} + \frac{1}{8}in\right) \cdot 0.5 = 1.438\ in$$

$$L_c := \min\left(L_{c.int}, L_{c.end}\right) = 1.438\ in$$

$$R_{n.bear} := \begin{cases} \left(2.4 \cdot \phi_{bolt} \cdot t_w \cdot F_u\right) & \text{if } L_c \geq 2 \cdot \phi_{bolt} \\ \left(1.2 \cdot L_c \cdot t_w \cdot F_u\right) & \text{otherwise} \end{cases} = 46.98 \cdot kip$$

$$\phi_{bb} := 0.80$$

$$\phi R_{n.bear} := \phi_{bb} \cdot R_{n.bear} = 37.584 \cdot kip$$

$$check_{10} := \begin{cases} \text{"OK"} & \text{if } \phi R_{n.bear} \geq P_{u.str} \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Bolt Tension Capacity

$$R_{n.ten} := 0.76 \cdot A_b \cdot F_{ub} = 71.628\ kip$$

$$\phi_{bt} := 0.80$$

$$\phi R_{n.ten} := \phi_{bb} \cdot R_{n.ten} = 57.303\ kip$$

$$check_{10.a} := \begin{cases} \text{"OK"} & \text{if } \phi R_{n.ten} \geq P_{u.str} \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

Combined Tension and Shear

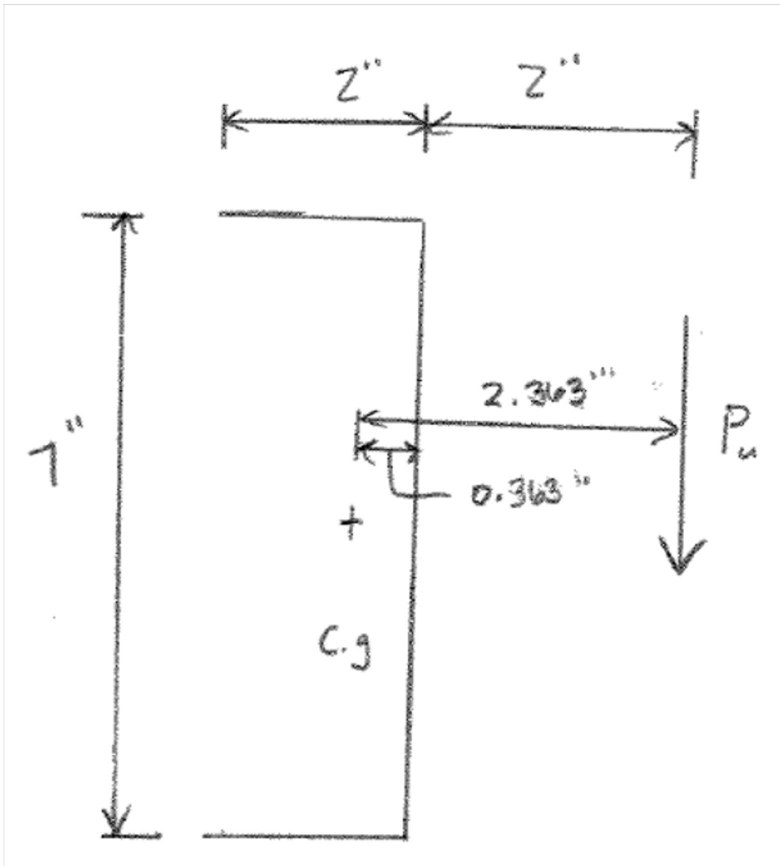
$$R_{n.ts} := \begin{cases} \left(0.76 \cdot A_b \cdot F_{ub}\right) & \text{if } \dfrac{P_{u.str}}{R_{n.shear}} \leq 0.33 \\ \left[0.76 \cdot A_b \cdot F_{ub} \cdot \sqrt{1 - \left(\dfrac{P_{u.str}}{\phi R_{n.shear}}\right)^2}\right] & \text{otherwise} \end{cases} = 55.666\ kip$$

$$\phi R_{n.ts} := \phi_{bt} \cdot R_{n.ts} = 44.533\ kip$$

$$check_{10.b} := \begin{cases} \text{"OK"} & \text{if } \phi R_{n.ts} \geq P_{u.str} \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

WELDED CONNECTION RESISTANCE

Use AISC Table 8-9 to determine capacity of weld group



$l_w := d = 7 \cdot in$

$k_w := \frac{2in}{l_w} = 0.286$

$e_x := 2.363in$

$a := \frac{e_x}{l_w} = 0.338$

Interpolation from Table 8-9

$k_{low} := 0.2 \quad k_{high} := 0.3 \quad a_{low} := 0.3 \quad a_{high} := 0.4$

At k_{low}

$C_{low.1} := 2.33 \quad C_{high.1} := 2.03$

$$C_{low} := C_{high.1} - \left(C_{high.1} - C_{low.1}\right)\cdot\frac{\left(a_{high} - a\right)}{\left(a_{high} - a_{low}\right)} = 2.217$$

At k_{high}

$C_{low.2} := 2.74 \quad C_{high.2} := 2.39$

$$C_{high} := C_{high.2} - \left(C_{high.2} - C_{low.2}\right)\cdot\frac{\left(a_{high} - a\right)}{\left(a_{high} - a_{low}\right)} = 2.609$$

$$C_{table} := \left[C_{high} - \frac{\left(C_{high} - C_{low}\right)\cdot\left(k_{high} - k_w\right)}{\left(k_{high} - k_{low}\right)}\right]\frac{kip}{in^2} = 2.553\cdot\frac{kip}{in^2}$$

$C_1 := 1.0$ For E70XX electrode

$D_{weld} := 4$ Use 1/4" weld

$R_{n.weld} := C_{table}\cdot C_1\cdot D\cdot l_w = 41.097\cdot kip$

$\phi_w := 0.75$

$\phi R_{weld} := \phi_w\cdot R_{n.weld} = 30.823\cdot kip$

$$P_{weld} := 1.05\cdot\left[1.25\cdot\left(P_{DL.pl} + P_{DL.lu} + P_{ICE.pl} + P_{ICE.lu}\right) + 1.4\cdot\left(P_{WS.pl} + P_{WS.lu}\right)\right] = 0.467\cdot kip$$

$$check_{11} := \begin{cases} \text{"OK"} & \text{if } \phi R_{weld} \ge P_{weld} \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

DEFLECTION CHECK

Limit deflection in the horizontal direction due to wind loads to l/240 to reduce vibrations

$$\Delta_{horiz} := \frac{0.3\left(P_{WS.pl} + P_{WS.lu}\right)\cdot l^3}{3\cdot E\cdot I_y} = 0.249\cdot in$$

$$limit := \frac{l}{240} = 0.319\cdot in$$

$$check_{12} := \begin{cases} \text{"OK"} & \text{if } \Delta_{horiz} \le limit \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$$

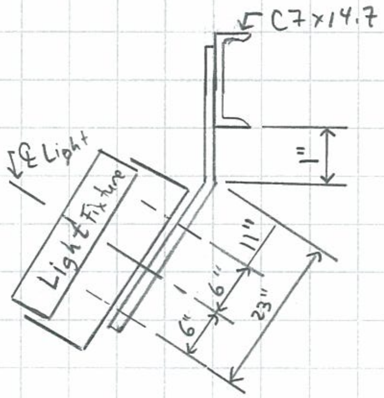
For	Cleveland Innerbelt	Job no.	49633	Sheet no.	
Made by	KDG	Checked by	LJD	Backchecked by	KDG
Date	3-12-12	Date	3/13/12	Date	3-15-12

HNTB

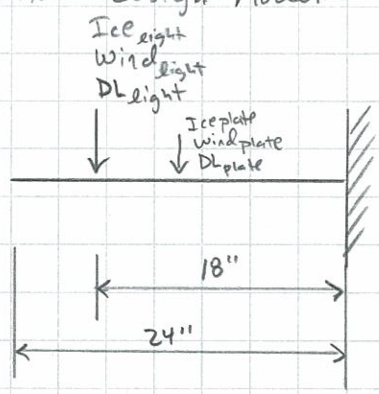
Light Bracket at the Bottom of the Delta has been changed to be supported below the Channel

Ice load = 3 psf.
use 50 psf for Wind load

Fixture EPA = $0.42\ m^2 = 4.52\ ft^2$



Simplified Design Model:



DL_{plate}: Assume PL ½×5

$$\left[\left(\frac{0.5}{12}\right)*\left(\frac{5}{12}\right)\times 2'\right]\left(490\ \frac{\#}{ft^3}\right) = 17.0\ \#$$

$DL_{light} = 75\ \#$

$Wind_{light} = 4.52\ ft^2\ (50) = 226\ \#$

$Wind_{plate} = (0.5')(50) = 25\ \#$

$Ice_{light} = (3)(4.52) = 13.6\ \#$

$Ice_{plate} = (3)(0.5')(2') = 3\ \#$

Group Load from AASHTO Standard Specifications for Highway Signs, Luminaires, and Traffic Signals

Group 1

V_{DL} =	17.0 + 75 =	92.0	#
M_{DL} =	1' x (17.0 #) + 1.5' x (75 #) =	129.5	#*ft

Group 2

V_{DL+W} =	(V_{DL} + 226 + 25) / 1.33 =	257.9	#
M_{DL+W} =	(M_{DL} +226# x1.5' + 25# x1') /1.33 =	371.1	#*ft

Group 3

$V_{DL+W/2+ice}$=	(V_{DL}+13.6+3+226/2+25/2)/1.33 =	176.0	#
$M_{DL+W/2+ice}$=	(M_{DL}+13.6x1.5+3x1+226/2x1.5+25/2 x1)/1.33 =	251.8	#*ft

Group 2 controls

$M_{G2} = 371.1\ \#ft = 4,453\ \#\cdot in$

$S = \frac{bh^2}{6} = \frac{5\,(0.5)^2}{6} = 0.208\ in^3$

$f_b = \frac{M}{S} = \frac{4453}{0.208} = 21,375\ psi$

Section 5-8

$F_b = 0.75\ F_y = 0.75(36) = 27\ ksi$

$F_y = 36\ ksi$

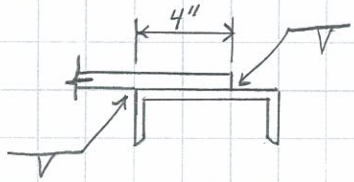
27 ksi > 21.4 ksi

ME101-1204

HNTB

For	Cleveland Innerbelt	Job no.	49633	Sheet no.	
Made by	KDG	Checked by	LJD	Backchecked by	KDG
Date	3-12-12	Date	3/13/12	Date	3-15-12

Design weld to Channel



Conserivituely design only for the weld on the ends ignore the weld on the sides.

On weld: $V = 0.258$ k
$M = 4.5$ k·in

Assume: 4" of weld on each end

$S_{weld} = bd = 4(4) = 16 \text{ in}^3$

Elastic Method

$r_p = \frac{V}{l} = \frac{0.258}{8} = 0.03$ k/in

$r_m = \frac{M}{S} = \frac{4.5}{16} = 0.28$ k/in

$r_u = \sqrt{0.03^2 + 0.28^2} = 0.28$ k/in

for E70 Electrode

$F_u = 70$ ksi

$F_{v\,weld} = 0.27(70) = 18.9$ ksi (stand. spec. eq. 10-12)

$R_{weld} = 18.9(0.707)(0.25) = 3.34$ k/in

$3.34 > 0.28$ OK