FORM DQP 2.01-1
LEVEL 1 CHECK PRINT SIGN-OFF SHEET

Client Name:	**Ohio Department of Transportation**
Job Title:	**Cleveland Innerbelt Design-Build Contract**
Job Number:	**CUY-90-14.90**
Document Title:	KNEE BRACE STIFFENER AT FLANGE BENDS

Check Level (Mark One):

- [X] 1A 100% Document Check
- [ ] 1B 100% Input Check

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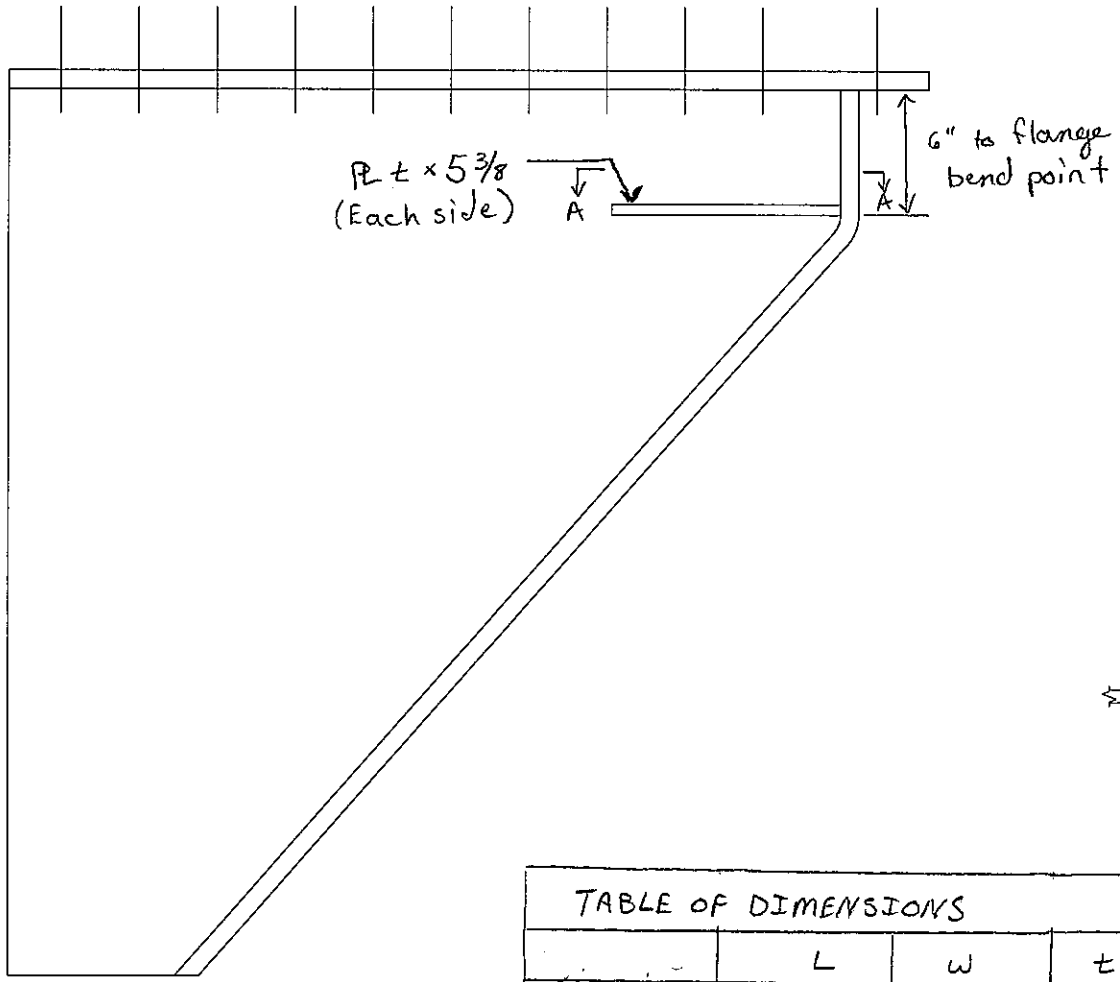
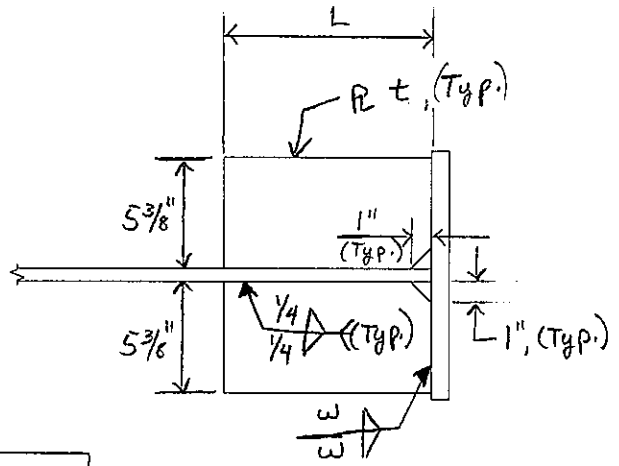
49633

SJL 10-5-11
✓DJG 10/6/11

FLOOR BEAM TYPES A, B, C
Stiffeners at Flange Bend Points





SECTION A-A

TABLE OF DIMENSIONS			
	L	w	t
Type A, C	9"	1/2"	1/2"
Type B	11"	5/8"	1/2"

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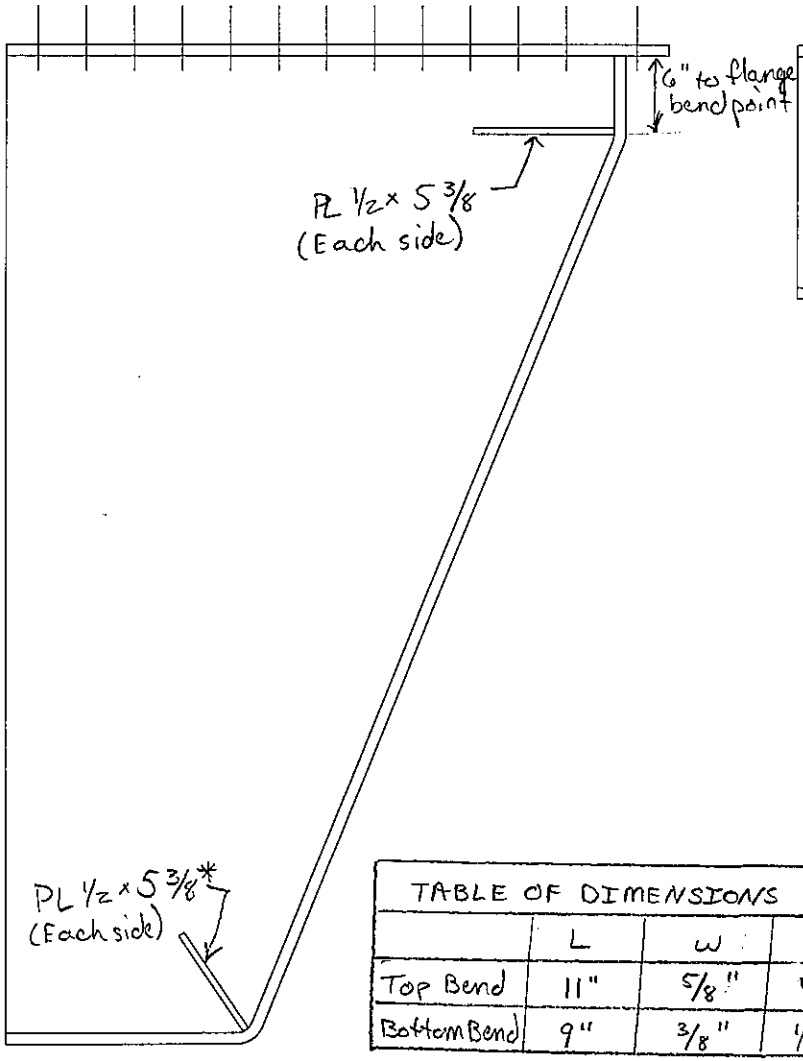
SIL 10-5-11
VDJG 10/6/11

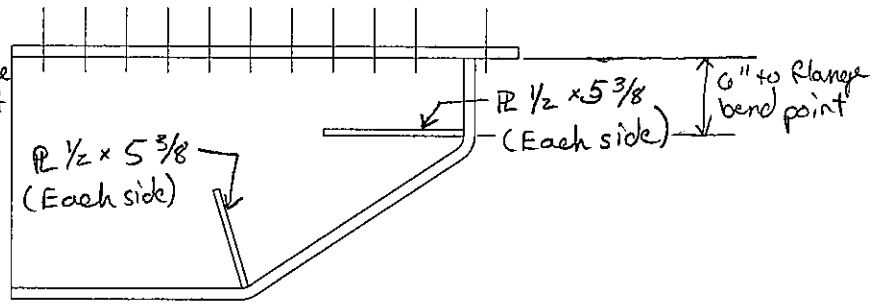
FLOORBEAM TYPES D, E, F
Stiffeners at Flange Bend Points

Note:-Intermediate Knee Brace sizes not shown. Stiffeners at flange bend points are similar.

* Bottom Bend stiffener is placed radially in flange bend.

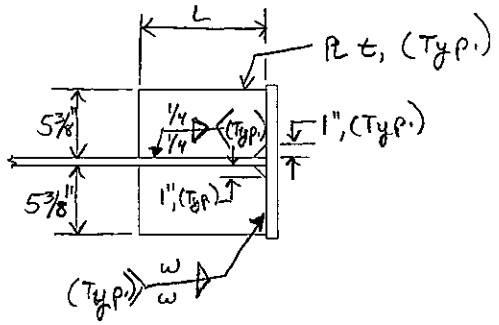


6'-6" Deep
Knee Brace



1'-7 3/4" Deep
Knee Brace

TABLE OF DIMENSIONS			
	L	w	t
Top Bend	11"	5/8"	½"
Bottom Bend	9"	3/8"	½"



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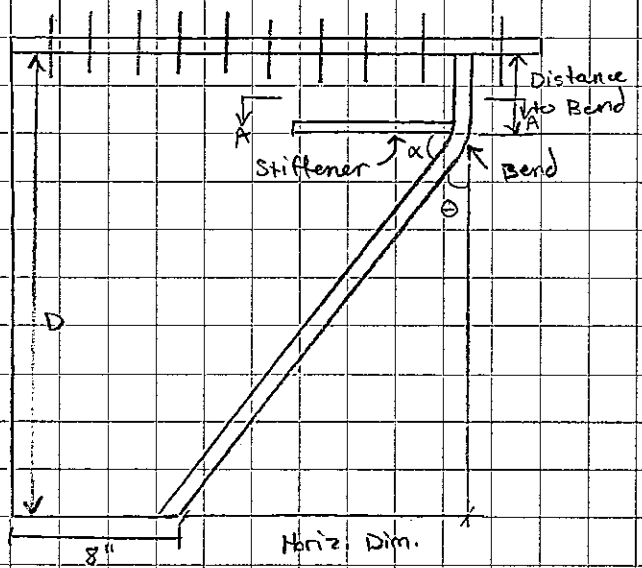
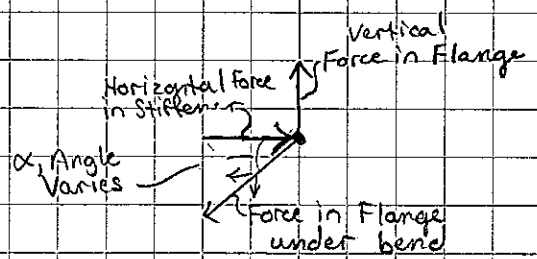
UNIT 2 - DIAPHRAGMS

KNEE BRACE

→ Per RFI, change knee brace flange to have a bend to allow for a fillet weld between knee brace top and side flanges. Add stiffener at flange bend.



→ Determine component of horizontal force to be resisted by stiffener:



$\Sigma F_y = 0 = +(\text{Vert. Flange F}) - (\text{Flange under Bend F})(\sin\alpha)$

$\Sigma F_x = 0 = +(\text{Horiz. Stiff. F}) - (\text{Flange under Bend F})(\cos\alpha)$

Weld Capacity:

$\text{Capacity} = \phi_{c2}(0.6)(F_{exx})\,l \pm (0.707)$

$\phi_{c2} = 0.80$

$F_{exx} = 70\ \text{ksi}$

ME101-1204

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UNIT 2 - DIAPHRAGMS

KNEE BRACE

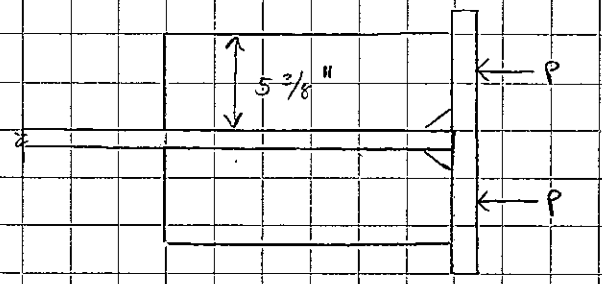
→ Distance to Bend for Bolt clearance

Bolt Length:

$L = 7/8" + 1.5" + 0.177" + 1\,3/4" + 39/64"$ (39/64" = bolt head)

$L = 4.91"$

→ Use 6" between bend point



SECTION A-A

→ Design stiffener as a Non-slender member (AASHTO 6.9.4.2)

If member satisfies b/t ratio for non-slender members, yielding will control over local buckling (AASHTO C.6.9.4.2.1)

$\frac{b}{t} \leq k\sqrt{\frac{E}{F_y}}$ $\quad k = 0.45$

$\Rightarrow t \geq \frac{b}{k\sqrt{\frac{E}{F_y}}} = \frac{(5.375")}{(0.45)\sqrt{\frac{(29000ksi)}{(50\,ksi)}}}$

$t \geq 0.5"$

→ Check Yielding

$\phi P_n = \phi F_y A_g = (0.9)(50ksi)(5.375")(1/2")$

$\phi P_n = 121k$

Max Force to both stiffeners = 225k

→ Force to 1 stiffener = $\frac{225k}{2} = 113k = P_u$

$\phi P_n = 121k > 113k = P_u \Rightarrow OK$

ME101-1204

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UNIT 2 - DIAPHRAGMS

KNEE BRACE

→ Check for Flexure: (AASHTO 6.12.2.2.7)

$$\frac{L_b d}{t^2} \leq \frac{0.08E}{F_y}$$

$$\frac{(5.375")(8")}{(1/2")^2} \leq \frac{(0.08)(29000\,ksi)}{(50\,ksi)}$$

$$172 \leq 46.4$$

→ Flexural yielding is N/A

Lateral Torsional Buckling

$$\frac{0.08E}{F_y} \leq \frac{L_b d}{t^2} \leq \frac{1.9E}{F_y}$$

$$46.4 \leq 172 \leq 1102$$

$$m_n = C_b\left[1.52 - 0.274\left(\frac{L_b d}{t^2}\right)\frac{F_y}{E}\right] m_y \leq m_p$$

$$m_n = (1)\left[1.52 - (0.274)\left(\frac{(5.375")(8")}{(1/2")^2}\right)\frac{(50ksi)}{(29000ksi)}\right] \times (50ksi)(1/6)(1/2")(8")^2 \leq m_p$$

$$m_n = 383.7\ k\cdot in \leq m_p.$$

$$m_p = (50ksi)(1/4)(1/2")(8")^2$$

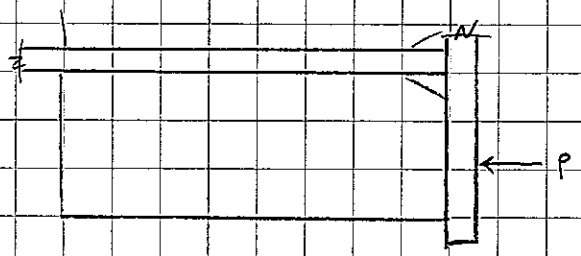
$$m_p = 400\ k\cdot in.$$

$\phi = 1.0$ $\quad \phi m_n = 383\ k\cdot in.$

$$m_u = PL = (113k)(2.6875") = 304\ k\cdot in.$$

Assume P is centered at half of flange

$$L = \frac{12"/2}{2} - (5/8"/2) = 2.6875"$$



$\phi m_n = 383\ k\cdot in > 304\ k\cdot in = m_u$

$\Rightarrow$ OK

→ Check Shear: (AASHTO 6.10.9.2)

$V_r = \phi V_n \qquad V_n = C V_p$

$k = 5.0$

$$\frac{D}{t_w} \leq 1.12\sqrt{\frac{Ek}{F_y}}$$

$$\frac{8"}{1/2"} \leq (1.12)\sqrt{\frac{(29000ksi)(5)}{(50\,ksi)}}$$

$$16 \leq 60.3$$

$\Rightarrow C = 1.0$

$$V_p = 0.58 F_y D t_w = (0.58)(50ksi)(8")(1/2")$$

$V_p = 116\ k$

$V_r = (1)(1)(116k)$

$V_r = 116k > P_u = 113k \Rightarrow$ OK

→ Use a 5.375" x 1/2" stiffener at Knee Brace flange bend points

ME101-1204

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N:\49633\Bridges\Design\Final Design\Unit 2\Excel\Diaphragms\final forces\LateralBracingRevision\RFI calcs\[Diaphragm_connections.xlsx]KB bend stiffener

Knee Brace Stiffener at Flange Bend

$Rr = \Phi * 0.6 * F_{exx} =$ 33.6 ksi

	Flange Stress (ksi)	Flange Area (in^2)	Knee Brace Web Depth (in)	Distance to Bend Point (in)	Horiz. Flange Dimension (in)	Vertical Force in Flange (k)	Angle θ (deg.)	Angle α (deg.)	Force in Flange Under Bend (k)	Horiz. Force to Stiffeners (k)	Weld length for Stiff. to side Flange (in)	Req'd Weld Size, Stiff. to side Flange (in)	Weld length for Stiff. to KB web (in)	Req'd Weld Size, Stiff. to KB web (in)
Type A														
A-S Min M	-18.4	10.5	42.625	6	32	-193.2	41.1	48.9	-256.6	-168.8	7.75	0.458	8	0.222
A-S Max M	19.5	10.5	42.625	6	32	204.8	41.1	48.9	271.9	178.9	7.75	0.486	8	0.235
A-T Min M	-20.8	10.5	71.125	6	32	-218.4	26.2	63.8	-243.3	-107.3	7.75	0.291	8	0.141
A-T Max M	22.2	10.5	71.125	6	32	233.1	26.2	63.8	259.7	114.5	7.75	0.311	8	0.151
Type B														
B-S Min M	-15.8	10.5	35.125	6	39.5	-165.9	53.6	36.4	-279.5	-225.0	7.75	0.611	10	0.237
B-S Max M	11.4	10.5	35.125	6	39.5	119.7	53.6	36.4	201.7	162.3	7.75	0.441	10	0.171
B-T Min M	-29.3	10.5	77.125	6	39.5	-307.7	29.0	61.0	-351.9	-170.9	7.75	0.464	10	0.180
B-T Max M	22.5	10.5	77.125	6	39.5	236.3	29.0	61.0	270.2	131.2	7.75	0.356	10	0.138
Type C														
C-S Min M	-15.1	10.5	34.125	6	26.25	-158.6	43.0	47.0	-216.9	-148.0	7.75	0.402	8	0.195
C-S Max M	18.2	10.5	34.125	6	26.25	191.1	43.0	47.0	261.4	178.4	7.75	0.484	8	0.235
C-T Min M	-20.6	10.5	47.125	6	26.25	-216.3	32.6	57.4	-256.6	-138.1	7.75	0.375	8	0.182
C-T Max M	24.6	10.5	47.125	6	26.25	258.3	32.6	57.4	306.4	164.9	7.75	0.448	8	0.217
Type D, E, F														
D Bot Min M	-14.7	10.5	18	6	17.5	-154.4	55.6	34.4	-272.9	-225.1	7.75	0.611	10	0.237
D Bot Max M	10.3	10.5	18	6	17.5	108.2	55.6	34.4	191.2	157.7	7.75	0.428	10	0.166
D Top Min M	13	10.5	18	6	17.5	136.5	55.6	34.4	241.4	199.1	7.75	0.541	10	0.209
D Top Max M	-11.3	10.5	18	6	17.5	-118.7	55.6	34.4	-209.8	-173.0	7.75	0.470	10	0.182
D-M Min M	-24.6	10.5	27.75	6	17.5	-258.3	38.8	51.2	-331.5	-207.8	7.75	0.564	10	0.219
D-M Max M	17.8	10.5	27.75	6	17.5	186.9	38.8	51.2	239.9	150.4	7.75	0.408	10	0.158
D-T Min M	-30.2	10.5	76.25	6	29.5	-317.1	22.8	67.2	-343.9	-133.2	7.75	0.362	10	0.140
D-T Max M	23.7	10.5	76.25	6	29.5	248.9	22.8	67.2	269.9	104.5	7.75	0.284	10	0.110

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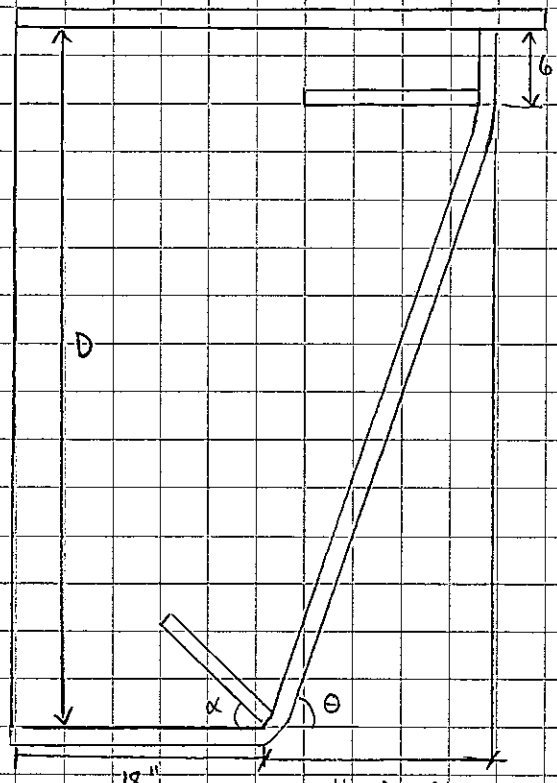
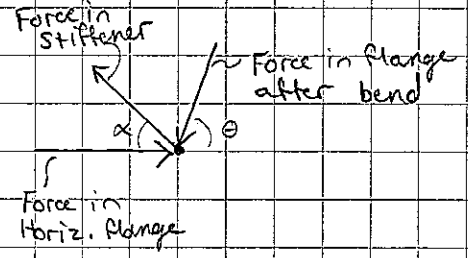
UNIT 2 - DIAPHRAGMS

KNEE BRACE

→ Determine Force in Type D, E, F bottom bend stiffener





$$\Sigma F_x = +(F_{Horiz.f.}) - (F_{a.b.})(\cos\theta) - (F_{stiff})(\cos\alpha) = 0$$

$$(F_{Horiz.f.}) = +\left[\frac{(F_{stiff})(\sin\alpha)}{(\sin\theta)}\right](\cos\theta) + (F_{stiff})(\cos\alpha)$$

$$(F_{Horiz.f}) = (F_{stiff})\left[\frac{(\sin\alpha)(\cos\theta)}{(\sin\theta)} + (\cos\alpha)\right]$$

$$\Sigma F_y = 0 = -(F_{a.b.})(\sin\theta) + (F_{stiff})(\sin\alpha)$$

$$F_{a.b.} = \frac{(F_{stiff})(\sin\alpha)}{(\sin\theta)}$$

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N:\49633\Bridges\Design\Final Design\Unit 2\Excel\Diaphragms\final forces\LateralBracingRevision\RFI calcs\[Diaphragm_connections.xlsx]KB bend stiffener

	Flange Stress (ksi)	Flange Area (in^2)	Knee Brace Web Depth (in)	Distance to Bend Point (in)	Horiz. Flange Dimension (in)	Horiz. Force in Flange (k)	Angle θ (deg.)	Angle α (deg.)	Force in Flange after Bend (k)	Force to Stiffeners (k)	Weld length for Stiff. to side Flange (in)	Req'd Weld Size, Stiff. to side Flange (in)	Weld length for Stiff. to KB web (in)	Req'd Weld Size, Stiff. to KB web (in)
Type D, Bottom Bend														
D Bot Min M	-15.4	10.5	18	6	17.5	-161.7	34.4	72.8	161.7	95.7	7.75	0.260	8	0.126
D Bot Max M	10.5	10.5	18	6	17.5	110.3	34.4	72.8	110.3	65.3	7.75	0.177	8	0.086
D Top Min M	13	10.5	18	6	17.5	136.5	34.4	72.8	136.5	80.8	7.75	0.219	8	0.106
D Top Max M	-11.9	10.5	18	6	17.5	-125.0	34.4	72.8	125.0	74.0	7.75	0.201	8	0.097
D-M Min M	-13.1	10.5	27.75	6	17.5	-137.6	51.2	64.4	137.6	118.8	7.75	0.323	8	0.156
D-M Max M	8.7	10.5	27.75	6	17.5	91.4	51.2	64.4	91.4	78.9	7.75	0.214	8	0.104
D-T Min M	-4.8	10.5	76.25	6	29.25	-50.4	67.4	56.3	50.4	55.9	7.75	0.152	8	0.074
D-T Max M	1.6	10.5	76.25	6	29.25	16.8	67.4	56.3	16.8	18.6	7.75	0.051	8	0.025