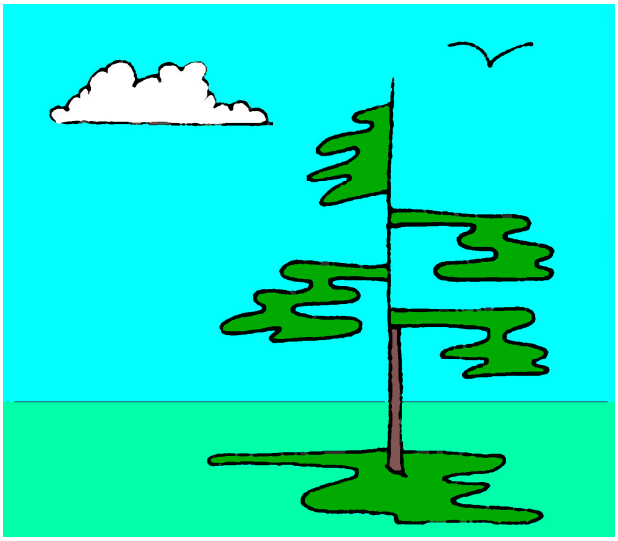
NorthWoods Software



Program Name: Conn-Moment_End_Plate_(2+4_Bolt)

Project Name: -

Project Number: -

Project Description: -

Project Designer: Dik

Last Revised (yy-mm-dd): 21.06.01

Reference: NBCC, CSA S16, AISC

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

$pci := \frac{lbf}{in^3}$ — 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"
```

$Check(2 = 3) = "...NG"$

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

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

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

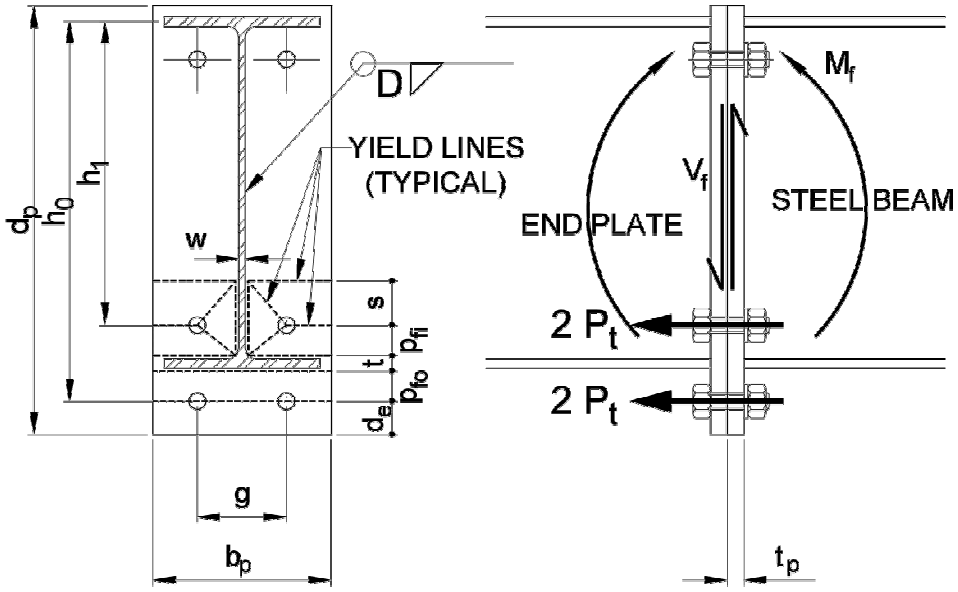
Input Data

Material Property Factors:

$\varphi_s := 0.90$
$\varphi_b := 0.8$
$\varphi_w := 0.67$
$\varphi_{br} := 0.8$

Load Factors:

$\alpha_L := 1.50$
$\alpha_D := 1.25$



Beam Properties:

$desI_b := "W24x76"$

$desM_b := "W610x113"$

$d := 23.92\ in$	$d = 23.92\ in$	$d = 607.6\ mm$	Depth
$b := 8.99\ in$	$b = 8.99\ in$	$b = 228.3\ mm$	Width
$t := 0.680\ in$	$t = 0.68\ in$	$t = 17.3\ mm$	Flange Thickness
$w := 0.440\ in$	$w = 0.44\ in$	$w = 11.2\ mm$	Web Thickness
$k := 1.4375\ in$	$k = 1.44\ in$	$k = 36.5\ mm$	'k' Factor
$k_1 := 0.9375\ in$	$k_1 = 0.94\ in$	$k_1 = 23.8\ mm$	'k1' Factor

End Plate Geometry:

$b_p := 9.5\ in$	$b_p = 9.50\ in$	$b_p = 241.3\ mm$	End Plate Width
$d_p := 28\ in$	$d_p = 28.00\ in$	$d_p = 711.2\ mm$	End Plate Width
$t_p := 0.5\ in$	$t_p = 0.50\ in$	$t_p = 12.7\ mm$	End Plate Thickness
$g := 3\ in$	$g = 3.00\ in$	$g = 76.2\ mm$	End Plate Gauge
$p_{fo} := 1.5\ in$	$p_{fo} = 1.50\ in$	$p_{fo} = 38.1\ mm$	See Diagram
$p_{fi} := 1.5\ in$	$p_{fi} = 1.50\ in$	$p_{fi} = 38.1\ mm$	See Diagram
$d_e := 1.5\ in$	$d_e = 1.50\ in$	$d_e = 38.1\ mm$	See Diagram
$h_1 := d - 1.5 \cdot t - p_{fi}$	$h_1 = 21.40\ in$	$h_1 = 543.6\ mm$	See Diagram
$h_0 := d - .5 \cdot t + p_{fo}$	$h_0 = 25.08\ in$	$h_0 = 637.0\ mm$	See Diagram

Design Forces

$M_f := 74\ K\_ft$	$M_f = 74.0\ K\_ft$	$M_f = 100.3\ kN\_m$	Factored Design Moment
$V_f := 22.6\ K$	$V_f = 22.6\ K$	$V_f = 100.5\ kN$	Factored Design Shear

Steel Properties:

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

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

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

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

End Plate: $st_{NDX} := 2$

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

Weld:

Electrodes: $we_{NDX} := 2$

$$we := \begin{bmatrix} \text{NDX} & \text{DesI} & \text{DesM} & \text{UTS} \\ 1 & \text{"E60xx"} & \text{"E43xx"} & 60\ \text{ksi} \\ 2 & \text{"E70xx"} & \text{"E49xx"} & 70\ \text{ksi} \\ 3 & \text{"E80xx"} & \text{"E55xx-x"} & 80\ \text{ksi} \\ 4 & \text{"E90xx"} & \text{"E62xx-x"} & 90\ \text{ksi} \end{bmatrix}$$

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

Sizes: $ws_{NDX} := 7$

$$ws := \begin{bmatrix} \text{NDX} & \text{desI} & \text{desM} & \text{D} \\ 1 & \text{""} & \text{"3mm"} & 0.11811\ \text{in} \\ 2 & \text{"1/8"} & \text{""} & 0.125\ \text{in} \\ 3 & \text{""} & \text{"4mm"} & 0.15748\ \text{in} \\ 4 & \text{"3/16"} & \text{""} & 0.1875\ \text{in} \\ 5 & \text{""} & \text{"5mm"} & 0.19685\ \text{in} \\ 6 & \text{""} & \text{"6mm"} & 0.23622\ \text{in} \\ 7 & \text{"1/4"} & \text{""} & 0.25\ \text{in} \\ 8 & \text{""} & \text{"7mm"} & 0.275591\ \text{in} \\ 9 & \text{"5/16"} & \text{""} & 0.3125\ \text{in} \\ 10 & \text{""} & \text{"8mm"} & 0.314961\ \text{in} \\ 11 & \text{""} & \text{"9mm"} & 0.354331\ \text{in} \\ 12 & \text{"3/8"} & \text{""} & 0.375\ \text{in} \\ 13 & \text{""} & \text{"10mm"} & 0.3937\ \text{in} \\ 14 & \text{""} & \text{"11mm"} & 0.4331\ \text{in} \\ 15 & \text{"7/16"} & \text{""} & 0.4375\ \text{in} \\ 16 & \text{""} & \text{"12mm"} & 0.4724\ \text{in} \\ 17 & \text{"1/2"} & \text{""} & 0.50\ \text{in} \end{bmatrix}$$

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

c b a

Bolt Properties:

$o := \frac{1}{16}\ in$ $\quad o = 0.06\ in$ $\quad o = 1.6\ mm$ Bolt Oversize Allowance

Total Quantity

$N_b := 6$ $\quad N_b = 6$ Number of Fasteners

$N_{ef} := 4$ $\quad N_{ef} = 4$ Number of Effective Fasteners

Bolt Grade $bg_{NDX} := 1$ **Add Data for 'Unknown'**

$$bg := \begin{bmatrix} \text{NDX} & \text{des} & \text{fy} & \text{Fu} \\ 1 & \text{"A325"} & 92\ Ksi & 120\ Ksi \\ 2 & \text{"A490"} & 130\ Ksi & 150\ Ksi \\ 3 & \text{"A307"} & 50\ Ksi & 60\ Ksi \\ 4 & \text{"Unknown"} & 50\ Ksi & 50\ Ksi \end{bmatrix}$$

$des_b := bg_{bg_{NDX},2}$ $\quad f_{yb} := bg_{bg_{NDX},3}$ $\quad F_{ub} := bg_{bg_{NDX},4}$

Threads $th_{NDX} := 1$

$$th := \begin{bmatrix} \text{NDX} & \text{des} \\ 1 & \text{"Included"} \\ 2 & \text{"Excluded"} \end{bmatrix}$$

$des_{th} := th_{th_{NDX},2}$

Bolt Diameter $bd_{NDX} := 3$

$$bd := \begin{bmatrix} \text{NDX} & \text{Dia} \\ 1 & 0.5\ in \\ 2 & 0.625\ in \\ 3 & 0.75\ in \\ 4 & 0.875\ in \\ 5 & 1.00\ in \end{bmatrix}$$

$\phi_b := bd_{bd_{NDX},2}$

$\phi_h := bd_{bd_{NDX},2} + o$

```
for i ∈ [1..rows(bd)]
    bd_{i,3} := (bd_{i,2})^2 · π / 4
```

$A_b := bd_{bd_{NDX},3}$

Bolt Shear Capacity

```
if des_th = "Included"
    V_rb := 0.70 · 0.6 · φ_b · A_b · F_ub
else
    V_rb := 0.6 · φ_b · A_b · F_ub
```

$V_{rb} = 17.8\ K$ $\quad V_{rb} = 79.2\ kN$ Single Bolt Shear Strength

Bolt Tension Capacity

$T_{rb} := 0.75 \cdot \varphi_b \cdot A_b \cdot F_{ub}$ $\quad T_{rb} = 31.81\ K$ $\quad T_{rb} = 141.49\ kN$ Single Bolt Tensile Strength

Bolt Bearing Capacity

$B_{rb} := 3 \cdot \varphi_{br} \cdot F_{u2} \cdot \phi_b \cdot t_p$ $\quad B_{rb} = 58.5\ K$ $\quad B_{rb} = 260.2\ kN$ Single Bolt Bearing Strength

End Plate:

Yield LIne Distance, s:

$s := \frac{1}{2} \cdot \sqrt{b_p \cdot g}$ $\quad s = 2.67\ in$ $\quad s = 67.8\ mm$ See Diagram

```
if p_fi > s
  p_fi = s
else
  p_fi = p_fi
```

$p_{fi} = 1.50$ in | $p_{fi} = 38.1$ mm | See Diagram

Yp Value:

$$Y_p := \frac{b_p}{2} \cdot \left(h_1 \cdot \left(\frac{1}{p_{fi}} + \frac{1}{s} \right) + h_0 \cdot \left(\frac{1}{p_{fo}} \right) - \frac{1}{2} \right) + \frac{2}{g} \cdot \left(h_1 \cdot \left(p_{fi} + s \right) \right)$$

$Y_p = 20.1979$ ft | $Y_p = 6.1563$ m | From AISC, Table 3.1

Moment Capacity of End Plate:

$M_{pl} := \varphi_s \cdot f_{y2} \cdot t_p^{\,2} \cdot Y_p$ | $M_{pl} = 200.0$ K_ft | $M_{pl} = 271.1$ kN_m

Moment Capacity of Bolts:

$P_t := T_{rb}$

$M_{rp} := \varphi_b \cdot 2 \cdot P_t \cdot \left(h_0 + h_1 \right)$ | $M_{rp} = 197.1$ K_ft | $M_{rp} = 267.3$ kN_m

Factored Load on Bolts from Moment

$T_f := \frac{M_f}{2 \cdot \left(h_0 + h_1 \right)}$ | $T_f = 9.55$ K | $T_f = 42.49$ kN | Bolt Load due to Mf (Pt)

Prying Action

$P_f := T_f$ | $P_f = 9.55$ K | $P_f = 42.49$ kN | Load per Bolt

$w_p := 3$ in | $w_p = 3.00$ in | $w_p = 76.2$ mm | Effective End Plate Width/Bolt

$\delta := 1 - \frac{\phi_h}{w_p}$ | $\delta = 0.73$ | $P_f = 42.5$ kN

$b := \frac{g}{2}$ | $b = 1.50$ in | $b = 38.1$ mm

$b' := \frac{g}{2} - \frac{\phi_h}{2}$ | $b' = 1.09$ in | $b' = 27.8$ mm

$a := \frac{b_p}{2} - b$ | $a = 3.25$ in | $a = 82.6$ mm

$a' := \frac{b_p}{2} - b'$ | $a' = 3.6562$ in | $a' = 92.9$ mm

$K := \frac{4 \cdot b' \cdot 10^{3}}{\varphi_s \cdot w_p \cdot f_{y2}}$ | $K = 36.83 \frac{1}{\text{Ksi}}$ | $K = 5.34 \frac{1}{\text{MPa}}$

$\alpha := \left(\frac{K \cdot P_f}{t_p^{\,2}} - 1 \right) \cdot \frac{1}{\delta}$ | $\alpha = 1928.43$

```
if α > 1          = 1
  α := 1
else
  if α < 0
    α := 0
  else
    dummy := 0
```

$\alpha = 1$

$$P'_f := P_f \cdot \left(1 + \frac{b'}{a'} \cdot \left(\frac{\delta \cdot \alpha}{1 + \delta \cdot \alpha} \right) \right)$$

$P'_f = 10.76$ K | $P'_f = 47.85$ kN | Bolt Force with Prying Action

Check Combined Stresses **Nef Bolt(s) Takes Shear**

$$cs := \left(\frac{P'_f}{T_{rb}}\right)^2 + \left(\frac{V_f}{N_{ef} \cdot V_{rb}}\right)^2 \qquad cs = 0.21$$

Shear Capacity of Nef Bolts:

$V_{r1} := V_{rb} \cdot N_{ef}$ $V_{r1} = 71.3$ K $V_{r1} = 316.9$ kN

Bearing Capacity of Nef Bolts :

$V_{r2} := B_{rb} \cdot N_{ef}$ $V_{r2} = 234.0$ K $V_{r2} = 1040.9$ kN

Weld Capacity:

	c	b	a
Base Metal			
$F_{wb} := \varphi_w \cdot f_{y2}$	$F_{wb} = 29.48$ Ksi	$F_{wb} = 203.26$ MPa	Base Metal Weld Strength
Weld Material			
$F_{ww} := \varphi_w \cdot \frac{X_u}{\sqrt{2}}$	$F_{ww} = 33.16$ Ksi	$F_{ww} = 228.65$ MPa	Weld Metal Weld Strength
Minimum Weld Strength			
$F_{rw} := \min\left(\left[\begin{array}{cc} F_{wb} & F_{ww} \end{array}\right]\right)$	$F_{rw} = 29.48$ Ksi	$F_{rw} = 203.26$ MPa	Minimum Strength of Weld

Moment Capacity of Welds (Flange Only):

$$M_{tf1} := \left(\left(b \cdot d\right) + \left(b - 2 \cdot k_1 - w\right) \cdot \left(d - 2 \cdot t\right)\right) \cdot F_{rw} \cdot D$$

$M_{tf1} = 10.7$ K_ft $M_{tf1} = 14.6$ kN_m

Moment Capacity of Welds (Web Only):

$M_{tf2} := 2 \cdot \frac{\left(d - 2 \cdot k\right)^2}{6} \cdot F_{rw} \cdot D$ $M_{tf2} = 90.7$ K_ft $M_{tf2} = 122.9$ kN_m

Total Moment Capacity of Welds:

$M_{tf} := M_{tf1} + M_{tf2}$ $M_{tf} = 101.4$ K_ft $M_{tf} = 137.5$ kN_m

Shear Capacity of Weld (Web Only):

$V_{r3} := 2 \cdot \left(d - 2 \cdot k\right) \cdot F_{rw} \cdot D$ $V_{r3} = 310.2$ K $V_{r3} = 1379.9$ kN

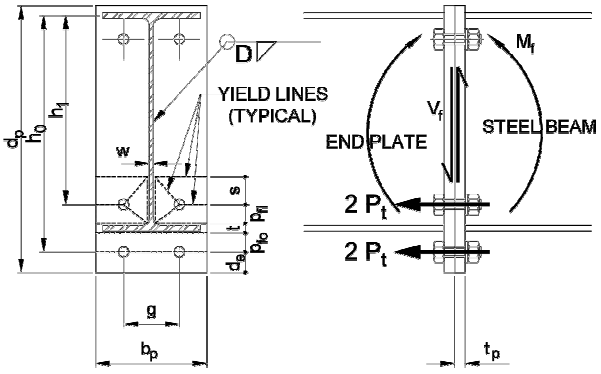
Minimum Moment Capacity of Connection:

$M_r := \min\left(\left[\begin{array}{ccc} M_{pl} & M_{rp} & M_{tf} \end{array}\right]\right)$ $M_r = 101.4$ K_ft $M_r = 137.5$ kN_m Minimum Moment Capacity

Minimum Shear Capacity of Connection:

$V_r := \min\left(\left[\begin{array}{ccc} V_{r1} & V_{r2} & V_{r3} \end{array}\right]\right)$ $V_r = 71.3$ K $V_r = 316.9$ kN Minimum Shear Capacity

Summary:



Material Property Factor		
Bolts Shear or Tension	$\varphi_b = 0.8$	
Rolled Steel	$\varphi_s = 0.9$	
Dead Load Factor	$\alpha_D = 1.25$	
Live Load Factor	$\alpha_L = 1.5$	
Steel		
Designation (Beam)	$desM_{st1} = \text{"G40.21-350W"}$	
Yield Strength (Beam)	$f_{y1} = 50\ \text{Ksi}$	$f_{y1} = 345\ \text{MPa}$
Ultimate Strength (Beam)	$F_{u1} = 65\ \text{Ksi}$	$F_{u1} = 448\ \text{MPa}$
Designation (End Plate)	$desM_{st2} = \text{"G40.21-300W"}$	
Yield Strength (End Plate)	$f_{y2} = 44\ \text{Ksi}$	$f_{y2} = 303\ \text{MPa}$
Ultimate Strength (End Plate)	$F_{u2} = 65\ \text{Ksi}$	$F_{u2} = 448\ \text{MPa}$
Young's Modulus	$E_s = 29000\ \text{Ksi}$	$E_s = 2.00 \cdot 10^5\ \text{MPa}$
Shear Modulus	$G_s = 11153.8462\ \text{Ksi}$	$G_s = 76903\ \text{MPa}$
Density	$\gamma_s = 489\ \text{pcf}$	$\gamma_s = 76.8\ \text{kNpcm}$
Beam Properties		
Beam Designation	$desI_b := \text{"W24x76"}$	$desM_b := \text{"W610x113"}$
Depth	$d = 23.92\ \text{in}$	$d = 607.6\ \text{mm}$
Width	$b = 1.50\ \text{in}$	$b = 38.1\ \text{mm}$
Flange Thickness	$t = 0.68\ \text{in}$	$t = 17.3\ \text{mm}$
Web Thickness	$w = 0.44\ \text{in}$	$w = 11.2\ \text{mm}$
'k' Factor	$k = 1.44\ \text{in}$	$k = 36.5\ \text{mm}$
'k1' Factor	$k_1 = 0.94\ \text{in}$	$k_1 = 23.8\ \text{mm}$
End Plate		
End Plate Width	$b_p = 9.50\ \text{in}$	$b_p = 241.3\ \text{mm}$
End Plate Width	$d_p = 28.00\ \text{in}$	$d_p = 711.2\ \text{mm}$
End Plate Thickness	$t_p = 0.50\ \text{in}$	$t_p = 12.7\ \text{mm}$
End Plate Gauge	$g = 3.00\ \text{in}$	$g = 76.2\ \text{mm}$
See Diagram	$p_{fo} = 1.50\ \text{in}$	$p_{fo} = 38.1\ \text{mm}$
See Diagram	$p_{fi} = 1.50\ \text{in}$	$p_{fi} = 38.1\ \text{mm}$
See Diagram	$d_e = 1.50\ \text{in}$	$d_e = 38.1\ \text{mm}$
Welds		
Designation (Welding Electrode)	$desI_w = \text{"E70xx"}$	$desM_w = \text{"E49xx"}$
Ultimate Strength (Welding Electrode)	$X_u = 70\ \text{Ksi}$	$X_u = 483\ \text{MPa}$
Designation (Fillet Weld Size)	$desI_D = \text{"1/4"}$	$desM_D = \text{""}$
Dimension (Fillet Weld Size)	$D = 0.25\ \text{in}$	$D = 6.35\ \text{mm}$

Bolts		
Designation	$des_b = \text{"A325"}$	
Yield Strength	$f_{yb} = 92\ \text{Ksi}$	$f_{yb} = 634\ \text{MPa}$
Ultimate Strength	$F_{ub} = 120\ \text{Ksi}$	$F_{ub} = 827\ \text{MPa}$
Threads Included/Excluded from Shear Plane	$des_{th} = \text{"Included"}$	
Diameter	$\phi_b = 0.75\ \text{in}$	$\phi_b = 19.1\ \text{mm}$
Hole Diameter (plus 'o')	$\phi_h = 0.8125\ \text{in}$	$\phi_h = 20.6\ \text{mm}$
Area	$A_b = 0.442\ \text{in}^2$	$A_b = 285\ \text{mm}^2$
Shear Resistance	$V_{rb} = 17.8\ \text{K}$	$V_{rb} = 79.2\ \text{kN}$
Tension Resistance	$T_{rb} = 31.8\ \text{K}$	$T_{rb} = 141.5\ \text{kN}$
Total Number of Bolts	$N_b = 6$	
Number of Effective Fasteners	$N_{ef} = 4$	
Connection Geometry		
End Plate Width	$b_p = 9.5\ \text{in}$	$b_p = 241.3\ \text{mm}$
Bolt Gauge	$g = 3\ \text{in}$	$g = 76.2\ \text{mm}$
Thickness of End Plate	$t_p = 0.5\ \text{in}$	$t_p = 12.7\ \text{mm}$
Bolt Moment Arm	$h_1 = 21.4\ \text{in}$	$h_1 = 543.56\ \text{mm}$
Bolt Moment Arm	$h_0 = 25.08\ \text{in}$	$h_0 = 637.032\ \text{mm}$
Bolt Spacing (see Diagram)	$d_e = 1.5\ \text{in}$	$d_e = 38.1\ \text{mm}$
Bolt Spacing (see Diagram)	$p_{fo} = 1.5\ \text{in}$	$p_{fo} = 38.1\ \text{mm}$
Bolt Spacing (see Diagram)	$p_{fi} = 1.5\ \text{in}$	$p_{fi} = 38.1\ \text{mm}$
Factored Loads		
Factored Moment	$M_f = 74\ \text{K\_ft}$	$M_f = 100.3\ \text{kN\_m}$
Factored Shear	$V_f = 22.6\ \text{K}$	$V_f = 100.5\ \text{kN}$
Moment Capacity of End Plate:	$M_{pl} = 200\ \text{K\_ft}$	$M_{pl} = 271.1\ \text{kN\_m}$
Moment Capacity of Bolts:	$M_{rp} = 197.1\ \text{K\_ft}$	$M_{rp} = 267.3\ \text{kN\_m}$
Total Moment Capacity of Welds:	$M_{tf} = 101.4\ \text{K\_ft}$	$M_{tf} = 137.5\ \text{kN\_m}$
Shear Capacity of Bolts (2 Bolts at Top Only):	$V_{r1} = 71.3\ \text{K}$	$V_{r1} = 316.9\ \text{kN}$
Bearing Capacity of Bolts (2 Bolts at Top Only):	$V_{r2} = 234\ \text{K}$	$V_{r2} = 1040.9\ \text{kN}$
Shear Capacity of Weld (Web Only):	$V_{r3} = 310.2\ \text{K}$	$V_{r3} = 1379.9\ \text{kN}$
Member Resistance		
Moment	$M_r = 101.4\ \text{K\_ft}$	$M_r = 137.5\ \text{kN\_m}$
Shear	$V_r = 71.3\ \text{K}$	$V_r = 316.9\ \text{kN}$

$Check\left(V_r \geq V_f\right) = \text{"...OK"}$

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