

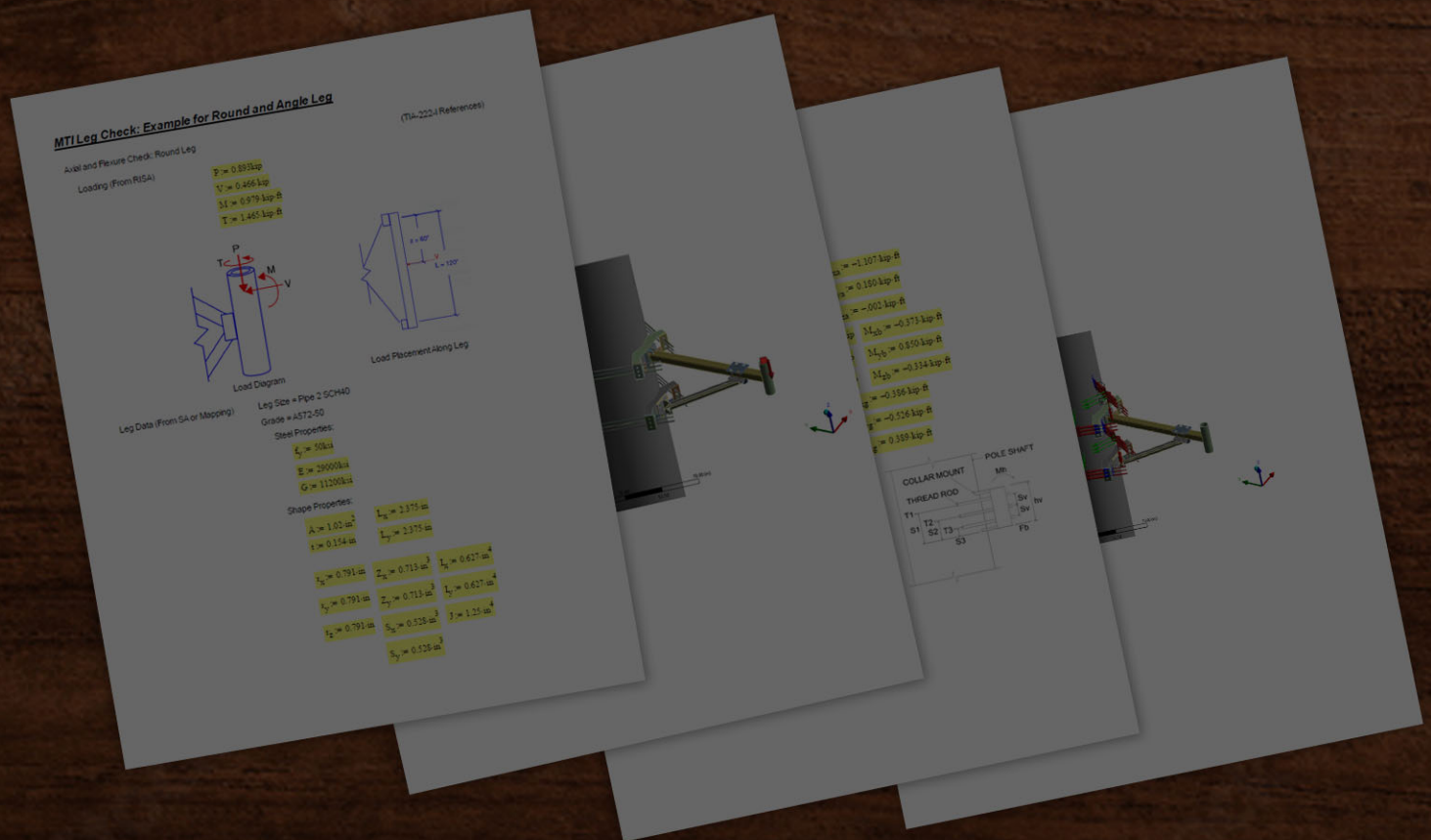


TIF

TELECOMMUNICATIONS
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Illustrative Examples

Mount to Tower Interaction Calculations and Finite Element Analysis Models



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Exhibit 1

Example calculation of an angle-leg
tower analyzed for mount reactions
from a sector frame

MTI Leg Check: Example for Round and Angle Leg

Axial and Flexure Check: Round Leg

(TIA-222-I References)

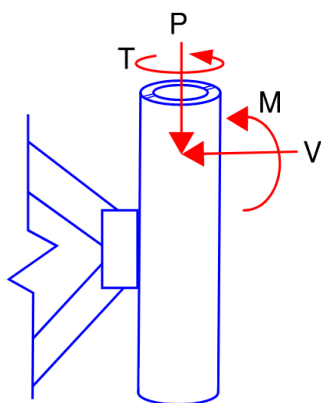
Loading (From RISA)

$$P := 0.893 \text{ kip}$$

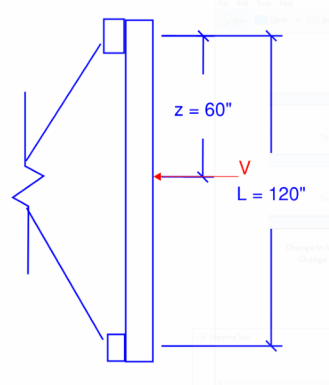
$$V := 0.466 \cdot \text{kip}$$

$$M := 0.979 \cdot \text{kip} \cdot \text{ft}$$

$$T := 1.465 \cdot \text{kip} \cdot \text{ft}$$



Load Diagram



Load Placement Along Leg

Leg Data (From SA or Mapping)

Leg Size = Pipe 2 SCH40

Grade = A572-50

Steel Properties:

$$f_y := 50 \text{ ksi}$$

$$E := 29000 \text{ ksi}$$

$$G := 11200 \text{ ksi}$$

Shape Properties:

$$A := 1.02 \cdot \text{in}^2$$

$$L_x := 2.375 \cdot \text{in}$$

$$t := 0.154 \cdot \text{in}$$

$$L_y := 2.375 \cdot \text{in}$$

$$r_x := 0.791 \cdot \text{in}$$

$$Z_x := 0.713 \cdot \text{in}^3$$

$$I_x := 0.627 \cdot \text{in}^4$$

$$r_y := 0.791 \cdot \text{in}$$

$$Z_y := 0.713 \cdot \text{in}^3$$

$$I_y := 0.627 \cdot \text{in}^4$$

$$r_z := 0.791 \cdot \text{in}$$

$$S_x := 0.528 \cdot \text{in}^3$$

$$J := 1.25 \cdot \text{in}^4$$

$$S_y := 0.528 \cdot \text{in}^3$$

$$K := 1$$

$$L := 120 \cdot \text{in}$$

$$\phi := 0.9$$

$$z := 60 \cdot \text{in}$$

Leg Capacities (Calculated)

$$f_e := \frac{\pi^2 \cdot E}{\left(\frac{K \cdot L}{r_z} \right)^2} = 12.436 \cdot \text{ksi} \quad (4.5.4.2)$$

$$f_{cr} := 0.877 \cdot f_e = 10.907 \cdot \text{ksi} \quad (4.5.4.2)$$

$$P_n := f_{cr} \cdot A = 11.125 \cdot \text{kip} \quad (4.5.4.2)$$

$$M_n := (Z_x \cdot f_y) = 2.971 \cdot \text{kip} \cdot \text{ft} \quad (4.7.2)$$

$$P_e := \frac{\pi^2 \cdot E \cdot I_x}{(K \cdot L)^2} = 12.462 \cdot \text{kip} \quad (4.8.1)$$

$$\beta := \frac{1}{\left(1 - \frac{P}{P_e} \right)} = 1.077 \quad (4.8.1)$$

Utilization Calculations:

Compression Utilization:

$$C_u := \frac{P}{\phi \cdot P_n} = 0.089$$

Flexure Utilization:

$$B_u := \frac{M + 0.7 \left[\frac{2 \cdot V \cdot [(L - z)^2] \cdot z^2}{L^3} \right]}{\phi \cdot M_n} = 0.519$$

Interaction Utilization:

$$T_u := \frac{C_u}{2} + (\beta \cdot B_u) = 0.603 \quad (4.8.1.1)$$

Capacity Check:

$$\text{Check} := \begin{cases} \text{"OK"} & \text{if } T_u < 1 \\ \text{"No Good"} & \text{otherwise} \end{cases}$$

Check = "OK"

Torsion and Shear Check: Angle Leg

Loading (From RISA)

$$P := 0.893 \text{ kip}$$

$$V := 0.466 \cdot \text{kip}$$

$$M := 0.979 \cdot \text{kip} \cdot \text{ft}$$

$$T := 1.465 \cdot \text{kip} \cdot \text{in}$$

Leg Data (From SA)

Leg Size = 60 Degree 4"x4"x1/4"

Grade = A572-50

Steel Properties:

$$f_y := 50 \text{ ksi}$$

$$K := 1$$

$$E := 29000 \text{ ksi}$$

$$G := 11200 \text{ ksi}$$

$$L := 120 \text{ in}$$

$$z := 12 \cdot \text{in}$$

$$t := 0.25 \cdot \text{in}$$

$$A := 1.9375 \cdot \text{in}^2$$

$$J := 0.0404 \cdot \text{in}^4$$

$$C_w := 0.0701 \cdot \text{in}^6$$

$$\alpha := \frac{z}{L} = 0.1$$

$$a := \left[\frac{(E \cdot C_w)}{G \cdot J} \right]^{\frac{1}{2}} = 0.177 \text{ ft}$$

(16.5.1-Torsional Stiffness 1)

$$\theta_L := \left(\frac{T \cdot L}{G \cdot J} \right) \cdot (1 - \alpha) \cdot \left(\frac{z}{L} \right) + \frac{a}{L} \cdot \left(\frac{\sinh\left(\alpha \cdot \frac{L}{a}\right)}{\tanh\left(\frac{L}{a}\right)} - \cosh\left(\alpha \cdot \frac{L}{a}\right) \right) \cdot \sinh\left(\frac{z}{a}\right) = 0.026 \cdot \text{rad}$$

$$\theta_{PL} := \left(\frac{T \cdot L}{G \cdot J} \right) \cdot \left[\left(\frac{1 - \alpha}{L} \right) + \frac{\alpha}{L} \left(\frac{\sinh\left(\alpha \cdot \frac{L}{a}\right)}{\tanh\left(\frac{L}{a}\right)} \cdot \cosh\left(\frac{z}{a}\right) - \cosh\left(\frac{\alpha \cdot L}{a}\right) \cdot \cosh\left(\frac{z}{a}\right) \right) \right] = 2.752 \times 10^{-3} \cdot \frac{\text{rad}}{\text{in}}$$

$$V_{ut} := 1.2 \cdot A \cdot G \cdot t \cdot \theta_{PL} = 17.916 \cdot \text{kip}$$

(16.5.1-Torsional Stiffness 2)

$$V_u := V_{ut} + V = 18.382 \cdot \text{kip}$$

(16.5.1-Torsional Stiffness 3)

$$V_n := 0.6 \cdot f_y \cdot \left(\frac{A}{2} \right) = 29.063 \cdot \text{kip}$$

(16.5.1-Torsional Stiffness 4)

$$\phi := 0.9$$

$$\text{Capacity} := \frac{V_u}{\phi \cdot V_n} = 0.703$$

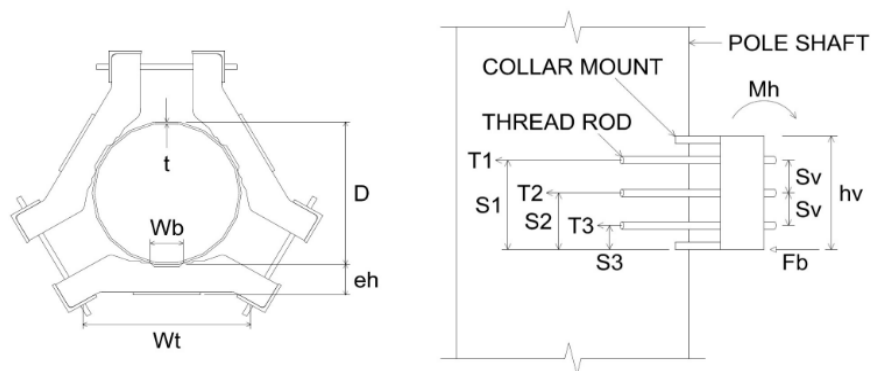
$$\text{Check} := \begin{cases} \text{"OK"} & \text{if } \frac{V_u}{\phi \cdot V_n} < 1 \\ \text{"No Good"} & \text{otherwise} \end{cases}$$

Check = "OK"

MTI Collar Check

Loading (From RISA)

Alpha	$F_{xa} := -0.06318 \text{ kip}$	$M_{xa} := -1.107 \cdot \text{kip} \cdot \text{ft}$
$\theta_a := 180^\circ$	$F_{ya} := -2.67071 \text{ kip}$	$M_{ya} := 0.180 \cdot \text{kip} \cdot \text{ft}$
	$F_{za} := 6.42122 \text{ kip}$	$M_{za} := -0.002 \cdot \text{kip} \cdot \text{ft}$
Beta	$F_{xb} := -1.25025 \text{ kip}$	$M_{xb} := -0.373 \cdot \text{kip} \cdot \text{ft}$
$\theta_b := 60^\circ$	$F_{yb} := 1.08555 \text{ kip}$	$M_{yb} := 0.850 \cdot \text{kip} \cdot \text{ft}$
	$F_{zb} := 1.53866 \text{ kip}$	$M_{zb} := -0.334 \cdot \text{kip} \cdot \text{ft}$
Gamma	$F_{xg} := 1.36633 \text{ kip}$	$M_{xg} := -0.386 \cdot \text{kip} \cdot \text{ft}$
$\theta_g := 300^\circ$	$F_{yg} := 1.20414 \text{ kip}$	$M_{yg} := -0.526 \cdot \text{kip} \cdot \text{ft}$
	$F_{zg} := 1.50055 \text{ kip}$	$M_{zg} := 0.389 \cdot \text{kip} \cdot \text{ft}$



Collar Data:

Threaded Rod Qty:	$Q_{tr} := 2$
Collar Height:	$h_v := 11.5 \text{ in}$
Threaded Rod Vertical Spacing:	$s_v := 9.5 \text{ in}$

Threaded Rod Width: $W_t := 23\text{in}$

Threaded Rod Considered: 1/2" A307

Diameter: $d_{tr} := 0.5\text{in}$

Yield Strength: $f_{ytr} := 36\text{ksi}$ $f_{utr} := 60\text{ksi}$

Threaded Rod Vertical Height: $s_{v1} := 10.5\text{in}$ $s_{v2} := 1\text{in}$

Bearing Width: $W_b := 7.5\text{in}$

$$R2 := \frac{s_{v2}}{s_{v1}} = 0.095$$

(16.5.1 - Tension Collar 1.i.i)

Pole Data: Pole Offset: $e_h := 6\text{in}$

Pole Diameter: $D := 17.3\text{in}$

Pole Thickness: $t := 0.1875\text{in}$

Pole Strength: $f_{yp} := 65\text{ksi}$

Max Reactions (Calculated): $M_{ma} := 2.560\text{kip}\cdot\text{ft}$

$$M_{mb} := -0.442\text{kip}\cdot\text{ft}$$

$$M_{mg} := -0.458\text{kip}\cdot\text{ft}$$

Max Moment: $M_h := \frac{2.560}{12}\text{in}\cdot\text{kip}$

Capacity Calculations:

$$\delta := \frac{6 \cdot M_h}{\left(\cos\left(\frac{\pi}{6}\right) \right) \left[s_{v2} \cdot (R2 - 1) + \frac{[(5 - R2) \cdot (R2 \cdot s_{v2} + s_{v1})]}{1 + R2} \right]} = 0.032\text{kip}$$

(16.5.1 - Tension Collar 1.i.ii)

$$T1 := \delta \frac{5 - R2}{1 + R2} = 0.142\text{kip}$$

(16.5.1 - Tension Collar 1.i.iii)

$$T2 := R2 \cdot (T1 + \delta) - \delta = -0.015\text{kip}$$

(16.5.1 - Tension Collar 1.i.iv)

$$\phi := 0.65 \quad (16.5.4.iii.ii)$$

$$\phi_p := 0.9 \quad (16.5.1 - \text{Tension Collar 1.iv.ii})$$

Threaded Rod Capacity:

$$R_n := \phi \cdot f_{utr} \cdot \frac{\pi}{4} \cdot \left(d_{tr} - \frac{0.9743 \text{ in}}{13} \right)^2 = 5.534 \cdot \text{kip}$$

Utilization Calculations:

Threaded Rod Utilization:

$$U_{tr} := \frac{T_1}{R_n} = 0.026$$

$$\text{Check} := \begin{cases} \text{"OK"} & \text{if } U_{tr} < 1 \\ \text{"No Good"} & \text{otherwise} \end{cases}$$

Check = "OK"

Pole Utilization:

$$B_p := 2 \cdot \cos\left(\frac{\pi}{6}\right) \cdot (T_1 + T_2) = 0.22 \cdot \text{kip}$$

$$R_{np} := \left[\phi_p \cdot f_{yp} \cdot t^2 \cdot \frac{5.5}{\left(1 - \frac{0.81 \cdot W_b}{D}\right)} \right] = 17.433 \cdot \text{kip} \quad (16.5.1 - \text{Tension Collar 1.i.iv})$$

$$U_p := \frac{B_p}{R_{np}} = 0.013$$

$$\text{Check} := \begin{cases} \text{"OK"} & \text{if } U_p < 1 \\ \text{"No Good"} & \text{otherwise} \end{cases}$$

Check = "OK"

$$\frac{\alpha \cdot L}{a} = 5.661$$

$$\frac{T \cdot L}{G \cdot J} = 0.389$$

$$\frac{1 - \alpha}{L} = 0.09 \frac{1}{\text{ft}}$$

$$\frac{a}{L} = 0.018$$

$$\frac{\sinh\left(\alpha \cdot \frac{L}{a}\right)}{\tanh\left(\frac{L}{a}\right)} \cdot \cosh\left(\frac{z}{a}\right) = 2.067 \times 10^4$$

$$\cosh\left(\frac{z}{a}\right) = 143.776$$

$$T \cdot L = 3.928 \times 10^4 \frac{\text{ft}^3 \cdot \text{lb}}{\text{s}^2}$$

$$\cosh\left(\frac{\alpha \cdot L}{a}\right) = 143.776$$

$$T \cdot \frac{L}{G \cdot J} = 0.389$$

$$G \cdot J = 1.011 \times 10^5 \frac{\text{ft}^3 \cdot \text{lb}}{\text{s}^2}$$

$$\frac{(6 \cdot 2.442)}{0.866 \cdot \left[(0.095 - 1) + \left[(5 - 0.095) \cdot \frac{(0.095 + 10.5)}{1.095} \right] \right]} = 0.363$$

$$\begin{aligned} 6 \cdot M_h &= 0.107 \cdot \text{ft} \cdot \text{kip} \\ \left(\cos \left(\frac{\pi}{6} \right) \right) &= 0.866 \\ s_{v2} \cdot (R2 - 1) &= -0.075 \text{ ft} \\ 5 - R2 &= 4.905 \\ R2 \cdot s_{v2} + s_{v1} &= 0.883 \text{ ft} \\ 1 + R2 &= 1.095 \end{aligned}$$

$$\theta_{\text{PrimeL}} := \left[\left(\frac{1 - \alpha}{L} \right) + \left(\frac{\sinh\left(\alpha \cdot \frac{L}{a}\right)}{\tanh\left(\frac{L}{a}\right)} \cdot \cosh\left(\frac{z}{a}\right) - \cosh\left(\frac{\alpha \cdot L}{a}\right) \cdot \cosh\left(\frac{z}{a}\right) \right) \right] = \blacksquare$$

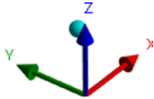
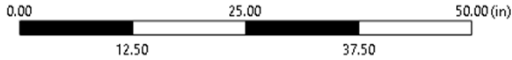
Exhibit 2

Finite element analysis results showing the reduction of stress in a monopole when a kicker kit is added

4800 pretension. 2200 lbs vertical. Dual
Collar

D: 2k Pretension 2200 lbs Vertical
Fixed Support
Time: 2. s

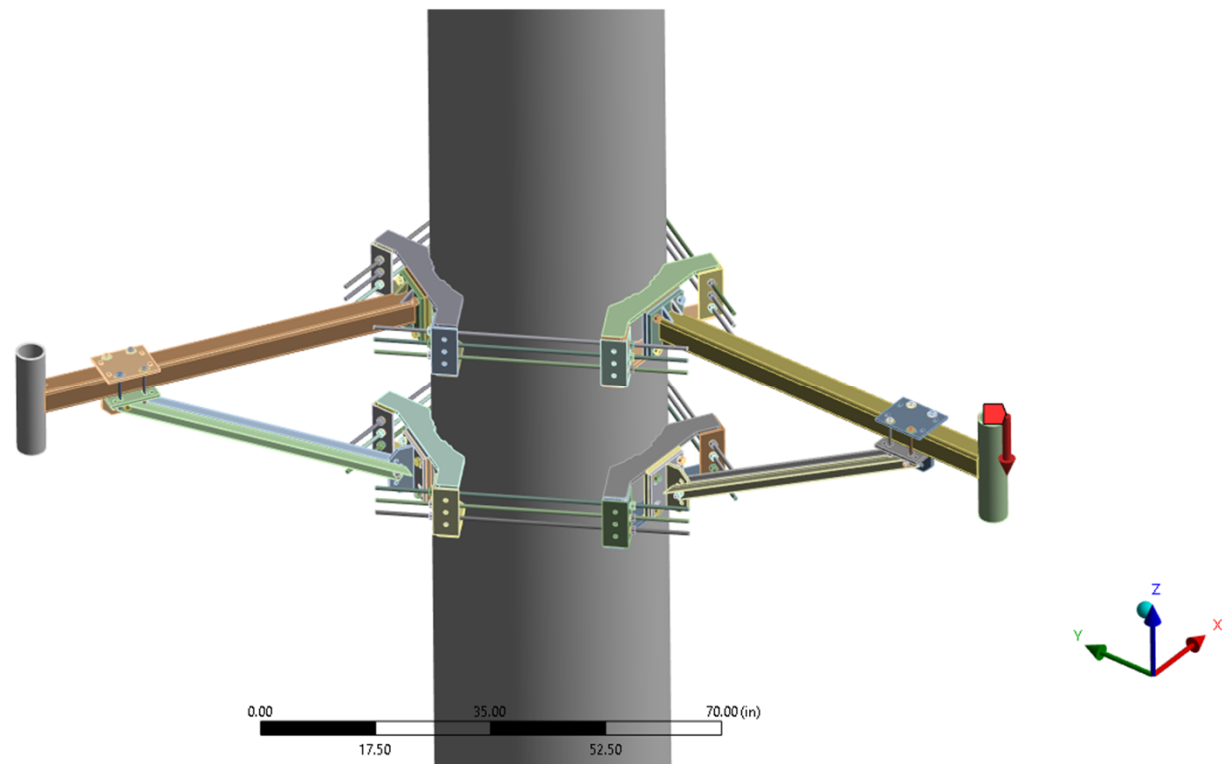
Fixed Support



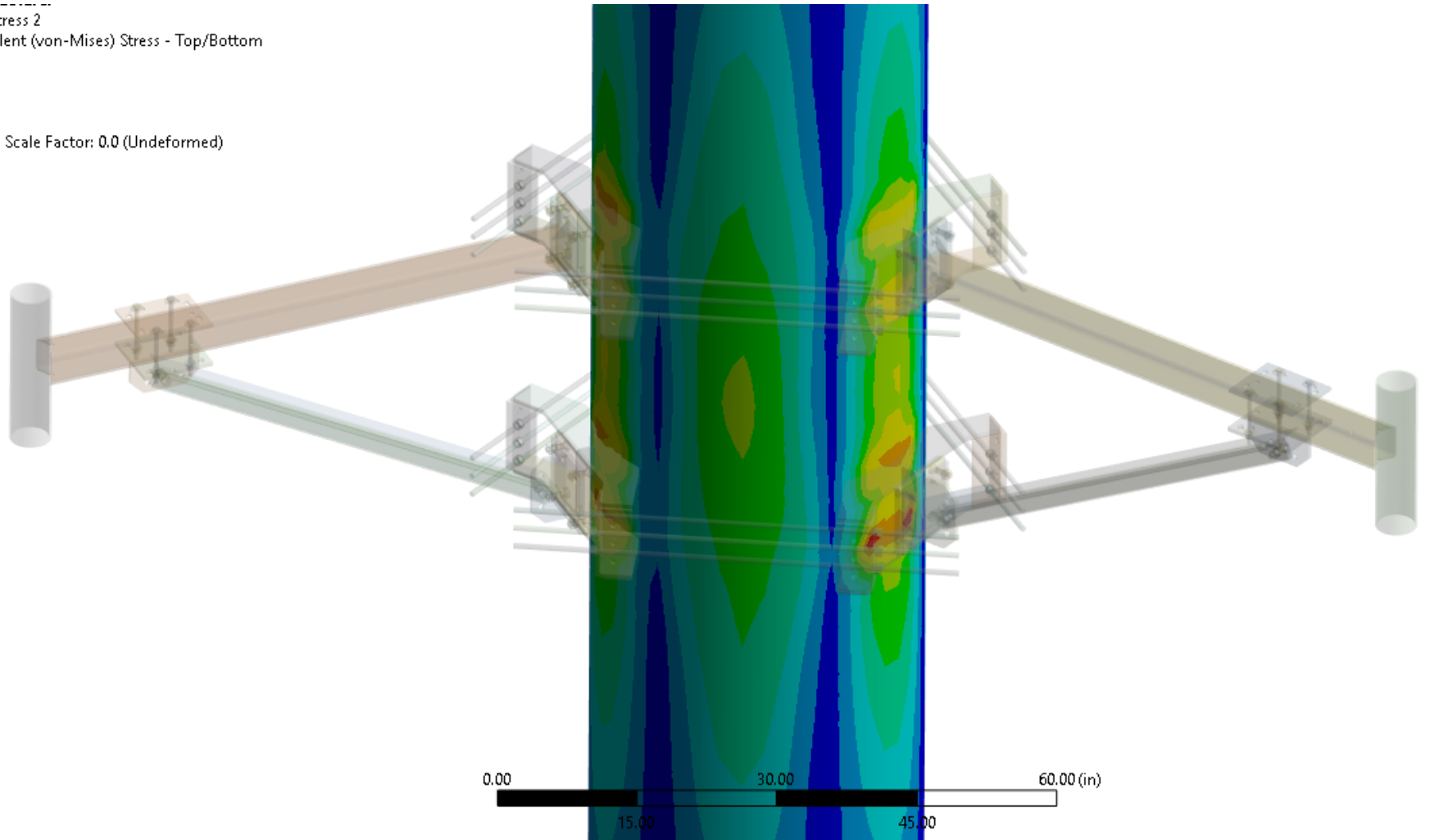
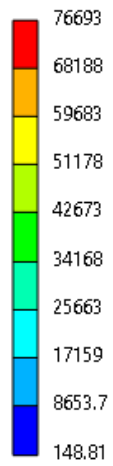
5.Ft standoff arm 2200 lb vertical

D: 2k Pretension 2200 lbs Vertical
Force
Time: 2. s

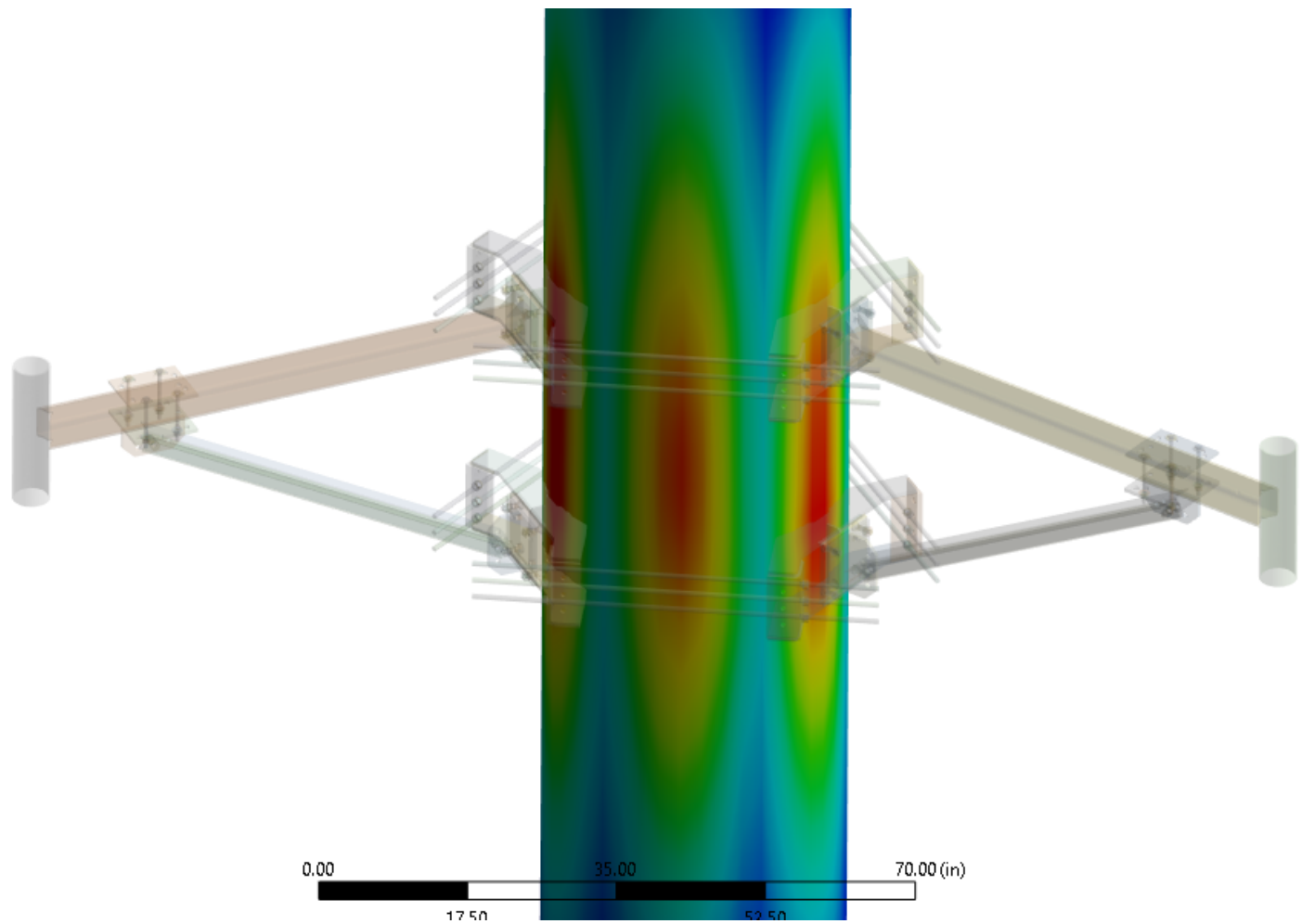
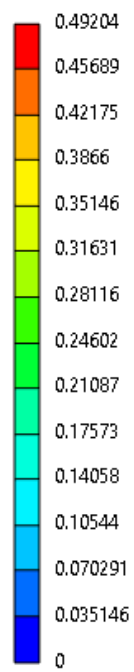
Force: 2200. lbf
Components: 0, 0, -2200.



Equivalent Stress 2
Type: Equivalent (von-Mises) Stress - Top/Bottom
Unit: psi
Time: 2 s
Max: 76693
Min: 148.81
Deformation Scale Factor: 0.0 (Undeformed)

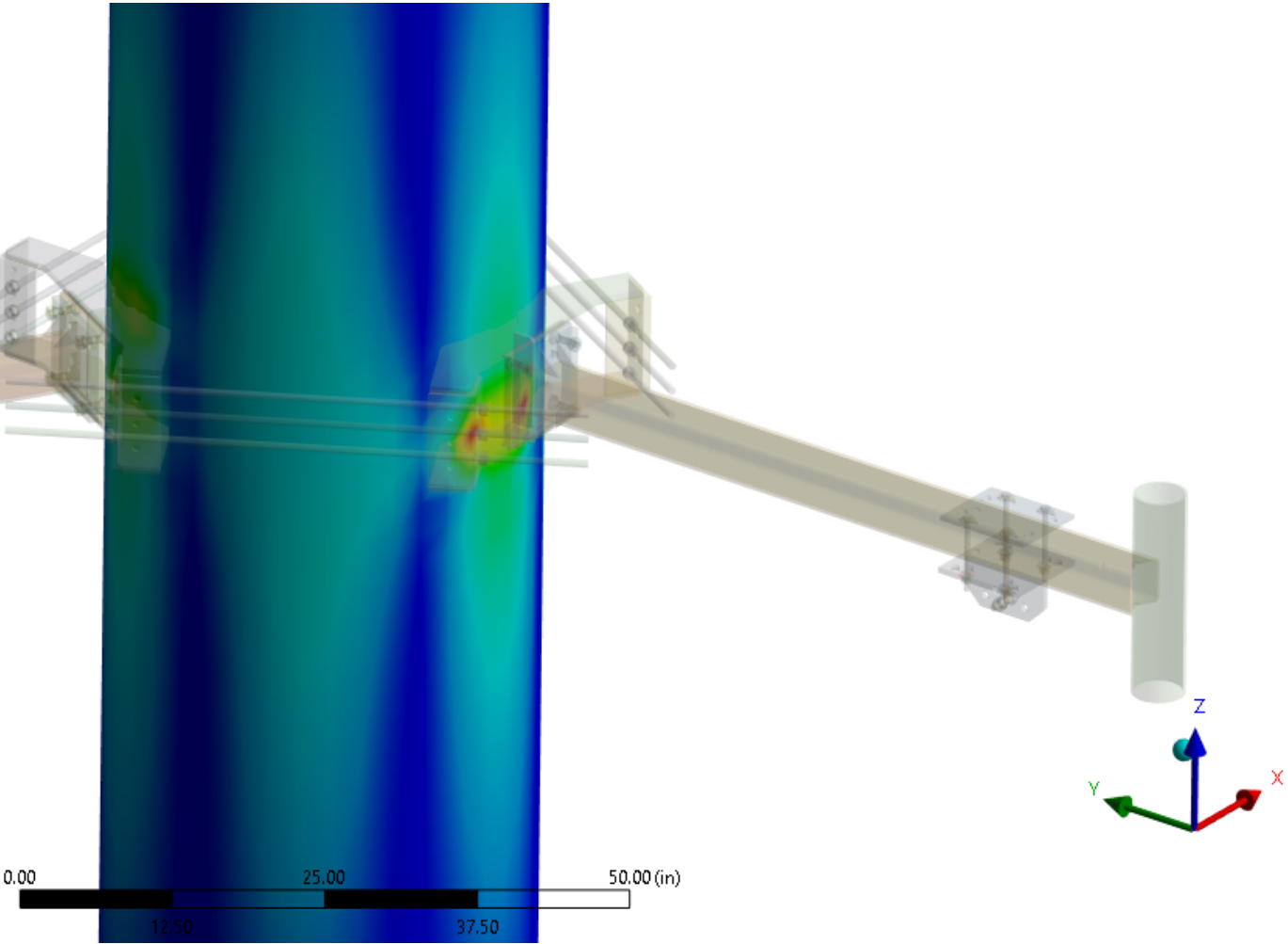
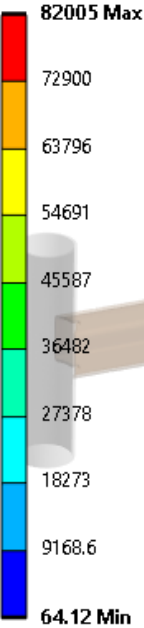


total Deformation z
Type: Total Deformation
Unit: in
Time: 2 s
Custom
Max: 0.49204
Min: 0
Deformation Scale Factor: 0.0 (Undeformed)

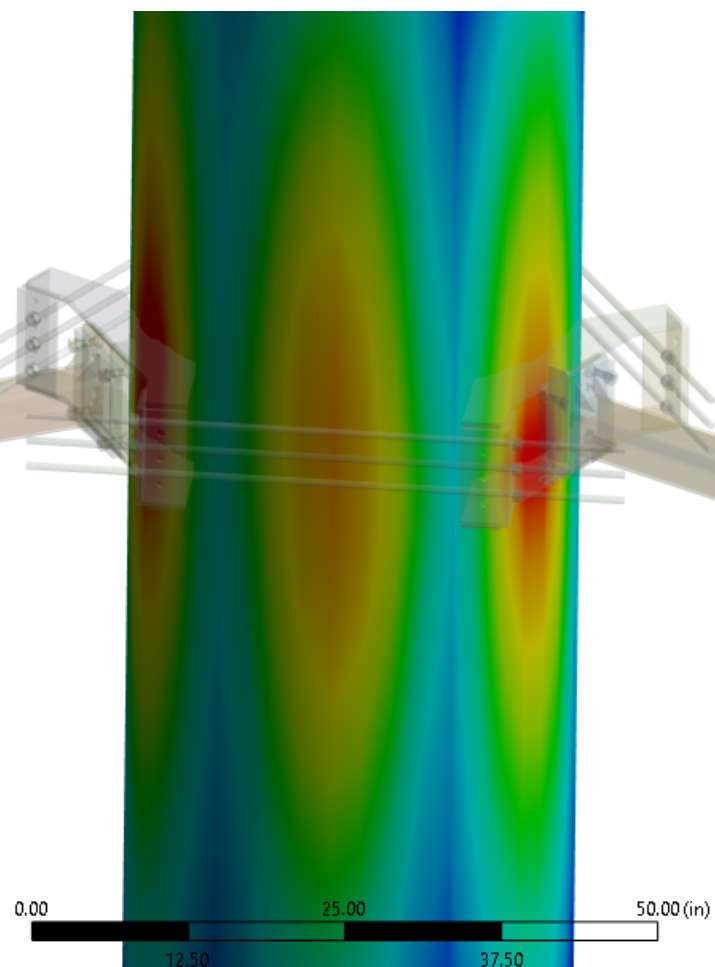
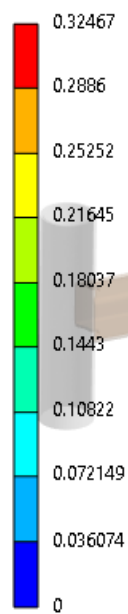


4800 pretension. 2200 lbs vertical. Single collar

equivalent stress σ
Type: Equivalent (von-Mises) Stress - Top/Bottom
Unit: psi
Time: 2 s
Custom
Deformation Scale Factor: 0.0 (Undeformed)



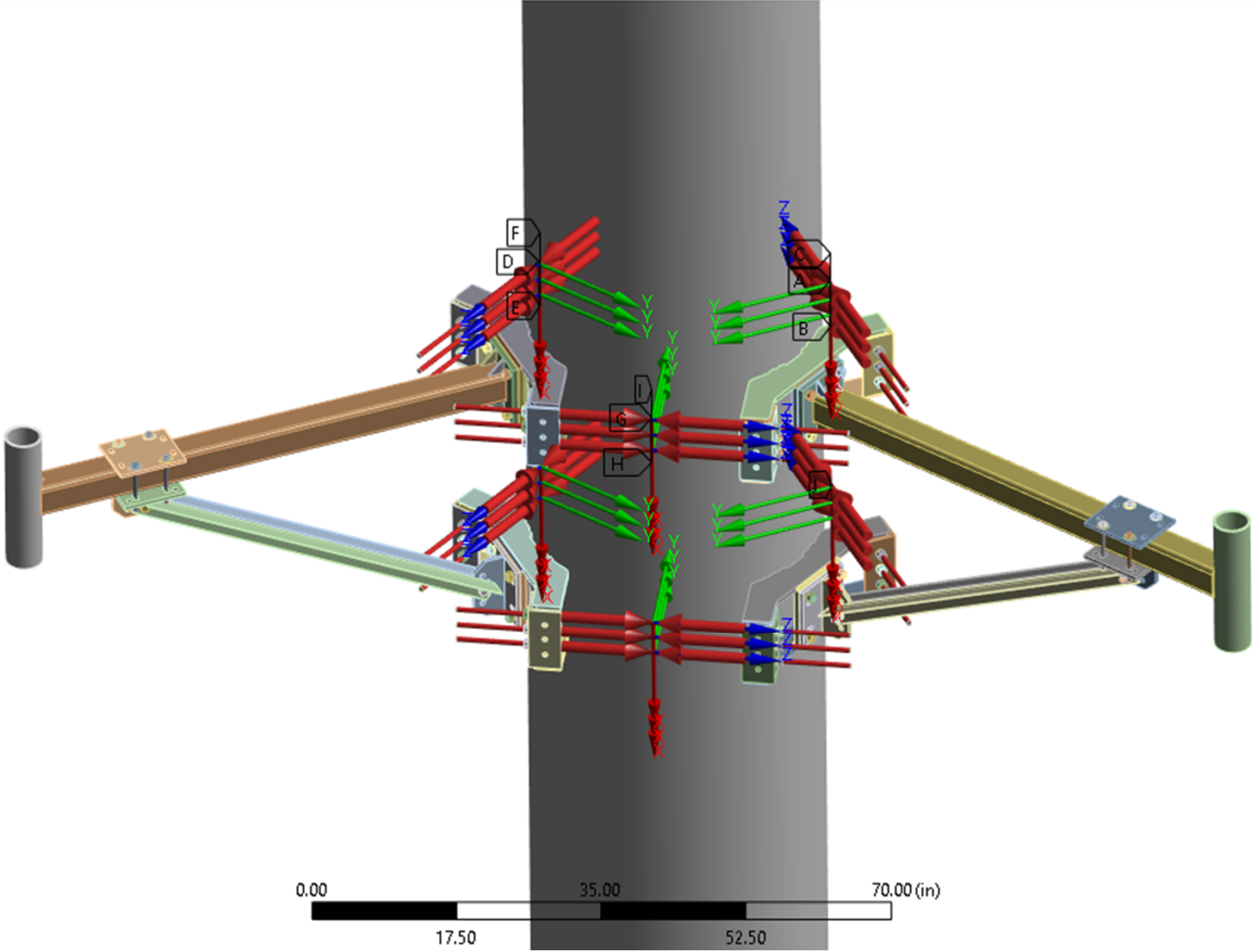
Total Deformation ϵ
Type: Total Deformation
Unit: in
Time: 2 s
Custom
Max: 0.32467
Min: 0
Deformation Scale Factor: 0.0 (Undeformed)



2000 pretension. 2200 lbs vertical. Dual collar

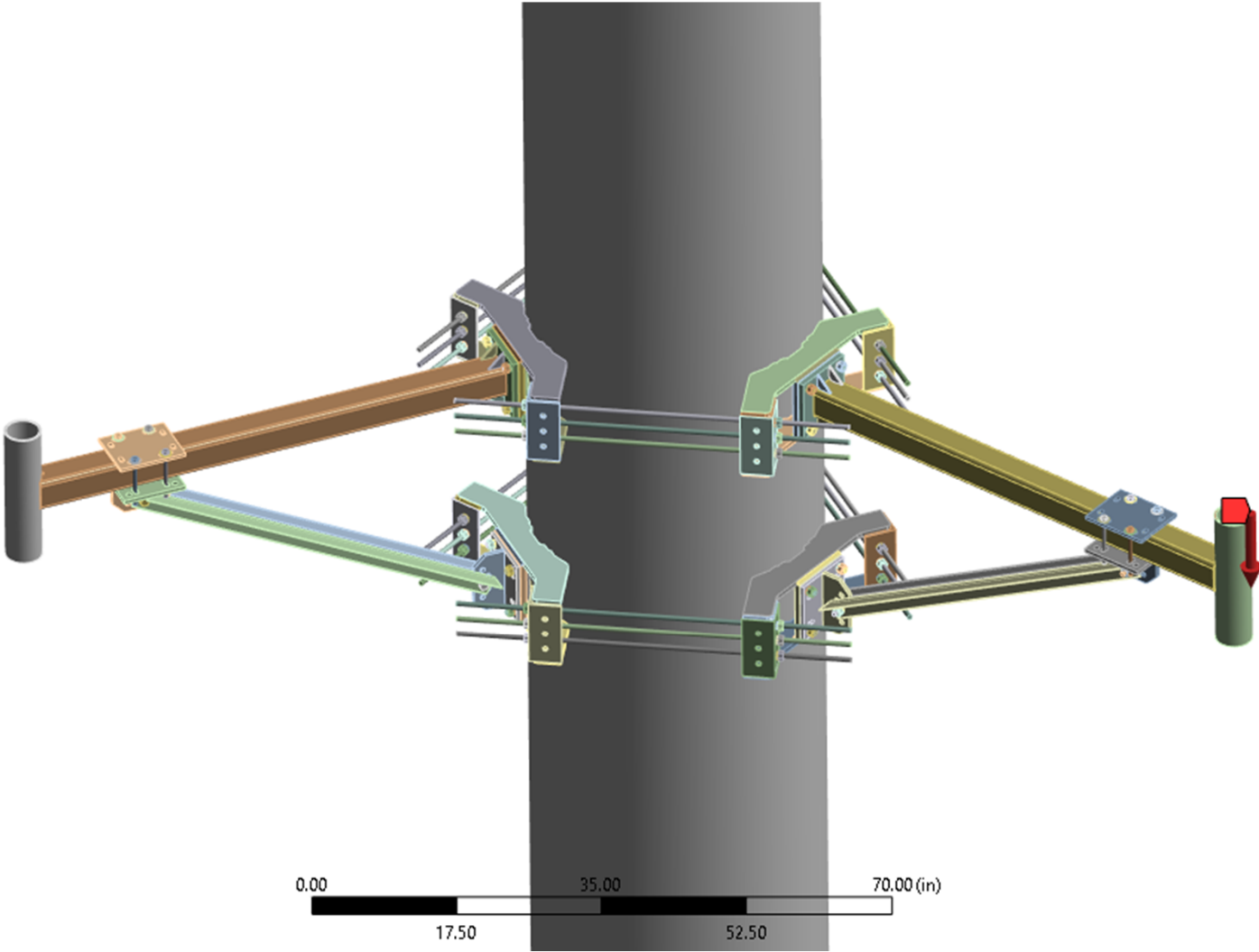
D: 2k Pretension 2200 lbs Vertical
Bolt Pretension 18
Step: 1
Items: 10 of 18 indicated

- A** Bolt Pretension: 2000. lbf
- B** Bolt Pretension 2: 2000. lbf
- C** Bolt Pretension 3: 2000. lbf
- D** Bolt Pretension 4: 2000. lbf
- E** Bolt Pretension 5: 2000. lbf
- F** Bolt Pretension 6: 2000. lbf
- G** Bolt Pretension 7: 2000. lbf
- H** Bolt Pretension 8: 2000. lbf
- I** Bolt Pretension 9: 2000. lbf
- J** Bolt Pretension 10: 2000. lbf

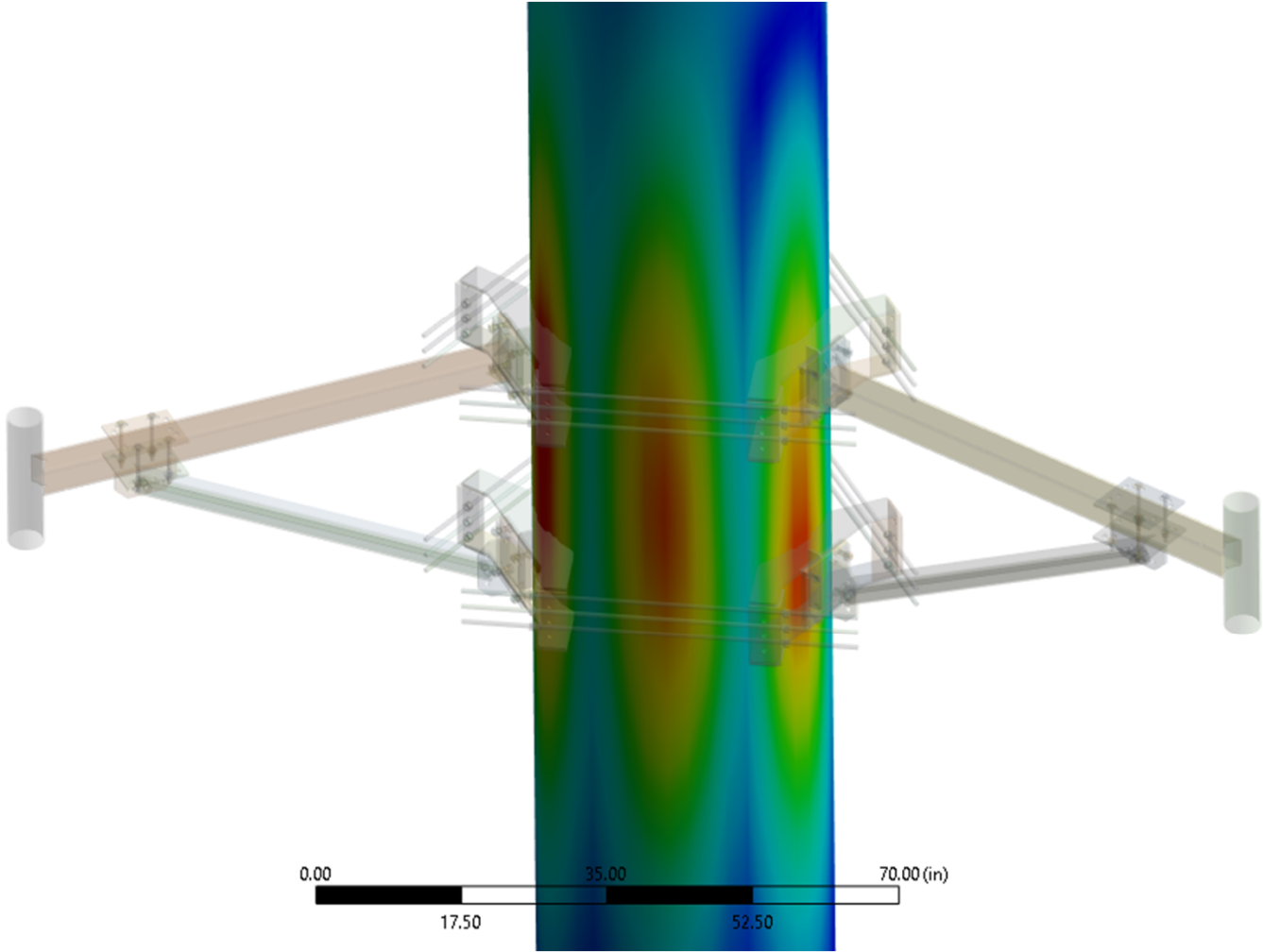


D: 2k Pretension 2200 lbs Vertical
Force
Time: 2. s

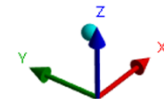
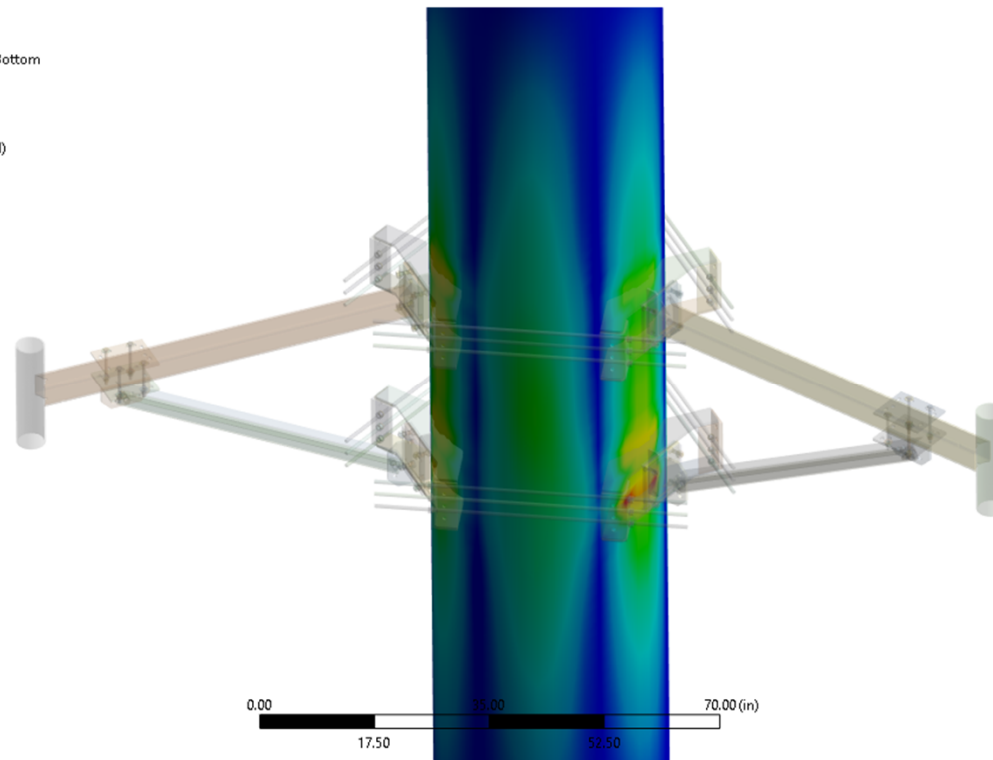
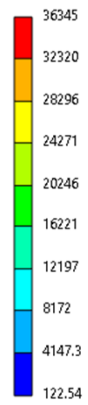
Force: 2200. lbf
Components: 0,0,-2200.



D: 2k Pretension 2200 lbs Vertical
Total Deformation 2
Type: Total Deformation
Unit: in
Time: 2 s
Custom
Max: 0.21217
Min: 0
Deformation Scale Factor: 0.0 (Undeformed)

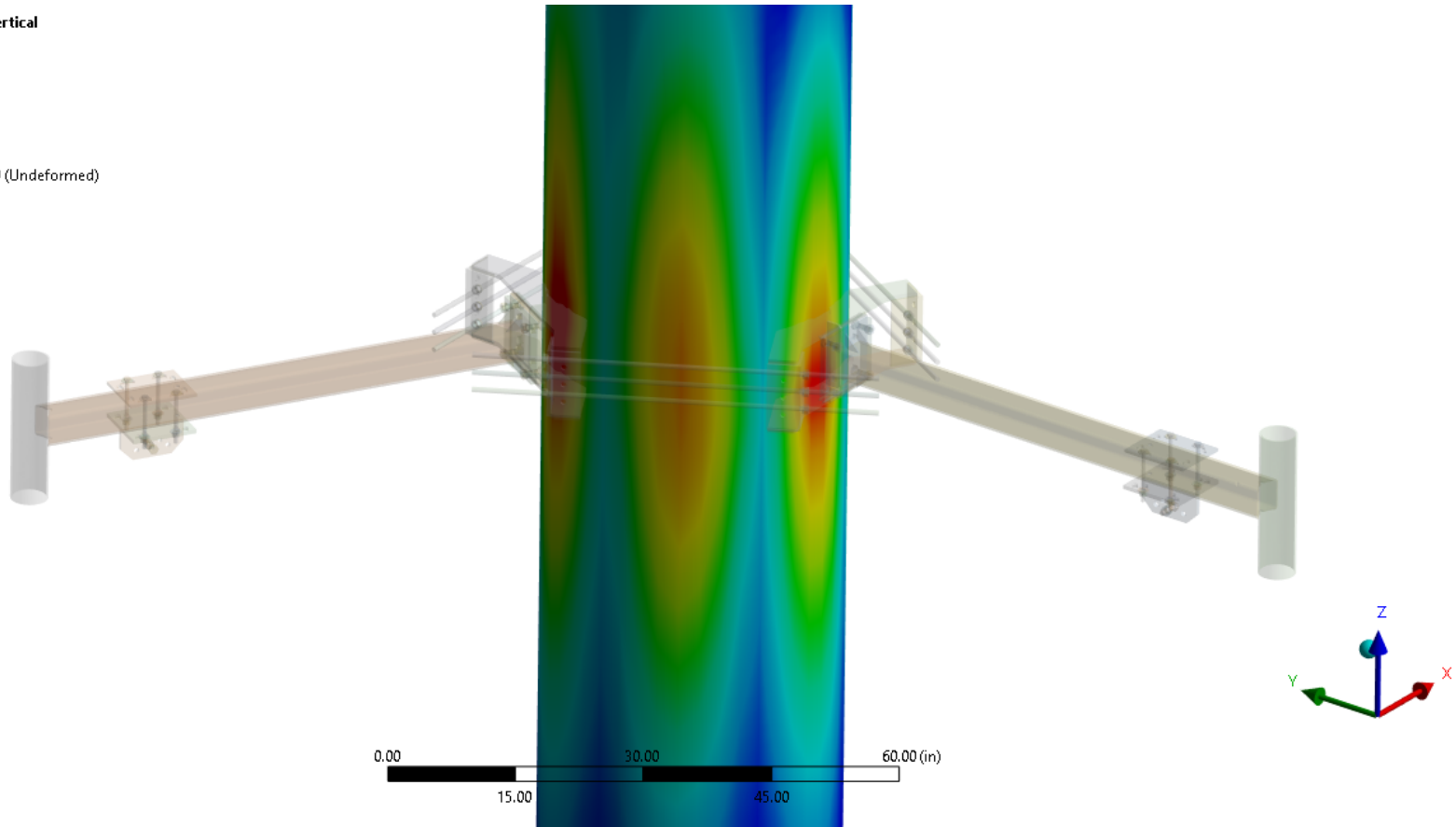
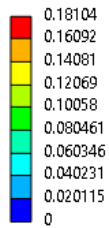


D: 2k Pretension 2200 lbs Vertical
Equivalent Stress 2
Type: Equivalent (von-Mises) Stress - Top/Bottom
Unit: psi
Time: 2 s
Max: 36345
Min: 122.54
Deformation Scale Factor: 0.0 (Undeformed)



2000 pretension. 2200 lbs vertical. Single Collar

E: 2k Pretension 2200 lbs Vertical
Total Deformation 2
Type: Total Deformation
Unit: in
Time: 1.7 s
Custom
Max: 0.18104
Min: 0
Deformation Scale Factor: 0.0 (Undeformed)



E: 2k Pretension 2200 lbs Vertical

Equivalent Stress 2

Type: Equivalent (von-Mises) Stress - Top/Bottom

Unit: psi

Time: 1.7 s

Custom

Max: 45897

Min: 29.475

Deformation Scale Factor: 0.0 (Undeformed)

