Given Properties:

Area of Reinforcing Steel	$Asprime := 3 \cdot 0.2in^2 = 0.6 \cdot in^2$
Tensile Strength of Steel Reinforcement	$fy := 60ksi$
No. of Strands	$N := 3$
Area of Strand	$Ap := 2 \cdot 0.153in^2 = 0.306 \cdot in^2$
Tensile Stress of Strand at Release	$fpi := 174ksi$
Tensile Stress of Strand at Cracking	$fcr := 180ksi$
Tensile Stress of Strand at Ultimate	$fu := 265$
Compressive Strength of Concrete at 3 days	$fc_3 := 5ksi$
Compressive Strength of Concrete at 28 days	$fc_{28} := 8ksi$
Modulus of Elasticy at 3 days	$Ec_3 := 57ksi \cdot \sqrt{\frac{fc_3}{psi}} = 4.031 \times 10^3 \cdot ksi$
Modulus of Elasticy at 28 days	$Ec_{28} := 57ksi \cdot \sqrt{\frac{fc_{28}}{psi}} = 5.098 \times 10^3 \cdot ksi$
Modulus of Elasticity of Steel	$Es := 29000ksi$
Modulus of Elasticty of Strand	$Ep := 28500ksi$
Unit Weight of Reinforced Concrete	$\gamma c := 121 \frac{lbf}{ft^3}$
Unit Weight of Steel	$\gamma s := 490 \frac{lbf}{ft^3}$

Section Properties:

$i := 1..7$

Width: Height: Area: Moment of Inertia:

$b_1 := 23in$ $h_1 := 3in$ $A_1 := b_1 \cdot h_1 = 69 \cdot in^2$ $I_1 := b_1 \cdot \frac{(h_1)^3}{12} = 51.75 \cdot in^4$

$b_2 := 5in$ $h_2 := 16in$ $A_2 := b_2 \cdot h_2 = 80 \cdot in^2$ $I_2 := b_2 \cdot \frac{(h_2)^3}{12} = 1.707 \times 10^3 \cdot in^4$

$b_3 := 15in$ $h_3 := 5in$ $A_3 := b_3 \cdot h_3 = 75 \cdot in^2$ $I_3 := b_3 \cdot \frac{(h_3)^3}{12} = 156.25 \cdot in^4$

$b_4 := 9in$ $h_4 := .5in$ $A_4 := \frac{(b_4 \cdot h_4)}{2} = 2.25 \cdot in^2$ $I_4 := b_4 \cdot \frac{(h_4)^3}{12} = 0.094 \cdot in^4$

$b_5 := 5in$ $h_5 := .5in$ $A_5 := \frac{(b_5 \cdot h_5)}{2} = 1.25 \cdot in^2$ $I_5 := b_5 \cdot \frac{(h_5)^3}{12} = 0.052 \cdot in^4$

$H := h_1 + h_2 + h_3 = 24 \cdot in$

$$Agconcrete := \sum_{i=1}^{5} A_i = 227.5 \cdot in^2$$

Centroid:

$$y_1 := h_3 + h_2 + \left(\frac{h_1}{2}\right) = 22.5 \cdot in$$

$$y_2 := h_3 + \left(\frac{h_2}{2}\right) = 13 \cdot in$$

$$y_3 := \frac{h_3}{2} = 2.5 \cdot in$$

$$y_4 := h_3 + h_2 - \frac{h_4}{2} = 20.75 \cdot in$$

$$y_5 := h_3 + \frac{h_5}{2} = 5.25 \cdot in$$

$$y_6 := \frac{h_3}{2} = 2.5 \cdot in$$

$$y_7 := h_3 + h_2 + \left(\frac{h_1}{2}\right) = 22.5 \cdot in$$

$$\sum_{i=1}^{7} y_i = 89 \cdot in$$

Transformed Section at 3 Days:

$$n_{3s} := \frac{Es}{Ec_3} = 7.195$$

$$n_{3p} := \frac{Ep}{Ec_3} = 7.071$$

$$A_6 := (n_{3s} - 1)\cdot Asprime = 3.717\cdot in^2$$

$$A_7 := (n_{3p} - 1)\cdot Ap = 1.858\cdot in^2$$

$$Atr_3 := \sum_{i=1}^{7} A_i = 233.075\cdot in^2$$

$$I_6 := 0$$

$$I_7 := 0$$

$$ybar3 := \frac{\left[\sum_{i=1}^{7} (A_i\cdot y_i)\right]}{\left(\sum_{i=1}^{7} A_i\right)} = 12.375\cdot in \qquad \sum_{i=1}^{7} I_i = 1.915\times 10^3\cdot in^4$$

$$d_1 := ybar3 - y_1 = -10.125\cdot in$$

$$d_2 := ybar3 - y_2 = -0.625\cdot in$$

$$d_3 := ybar3 - y_3 = 9.875\cdot in$$

$$d_4 := ybar3 - y_4 = -8.375\cdot in$$

$$d_5 := ybar3 - y_5 = 7.125\cdot in$$

$$d_6 := ybar3 - y_6 = 9.875\cdot in$$

$$d_7 := ybar3 - y_7 = -10.125\cdot in$$

$$\sum_{i=1}^{7} d_i = -2.374\cdot in$$

$$Itr_3 := \sum_{i=1}^{7} \left[I_i + A_i\cdot(d_i)^2\right] = 1.711\times 10^4\cdot in^4$$

Transformed Section at 28 Days:

$$n_{28s} := \frac{Es}{Ec_{28}} = 5.688$$

$$n_{28p} := \frac{Ep}{Ec_{28}} = 5.59$$

$$A_6 := \left(n_{28s} - 1\right)\cdot Asprime = 2.813\cdot in^2$$

$$A_7 := \left(n_{28p} - 1\right)\cdot Ap = 1.405\cdot in^2$$

$$Atr_{28} := \sum_{i=1}^{7} A_i = 231.718\cdot in^2$$

$$ybar28 := \frac{\left[\sum_{i=1}^{7} \left(A_i\cdot y_i\right)\right]}{\left(\sum_{i=1}^{7} A_i\right)} = 12.394\cdot in \qquad \sum_{i=1}^{7} I_i = 1.915\times 10^3\cdot in^4$$

$$d_1 := ybar28 - y_1 = -10.106\cdot in$$

$$d_2 := ybar28 - y_2 = -0.606\cdot in$$

$$d_3 := ybar28 - y_3 = 9.894\cdot in$$

$$d_4 := ybar28 - y_4 = -8.356\cdot in$$

$$d_5 := ybar28 - y_5 = 7.144\cdot in$$

$$d_6 := ybar28 - y_6 = 9.894\cdot in$$

$$d_7 := ybar28 - y_7 = -10.106\cdot in$$

$$\sum_{i=1}^{7} d_i = -2.243\cdot in$$

$$Itr_{28} := \sum_{i=1}^{7} \left[I_i + A_i\cdot\left(d_i\right)^2\right] = 1.697\times 10^4\cdot in^4$$

Beam Stress at Release:

$fpi := 174ksi \quad Fpi := fpi \cdot Ap = 53.244 \times 10^{0} \cdot kip$

$fcr := 180ksi$

$fu := 265ksi$

Strand Force Eccentricity $\quad e := ybar3 - y_3 = 9.875 \cdot in \quad ybar3 = 12.375 \cdot in$

Axial Stress $\quad \sigma a := \frac{-Fpi}{Atr_3} = -228.442 \cdot psi$

Flexural Stress at the Bottom $\quad bot \;\; \sigma f := \frac{[(Fpi \cdot e) \cdot ybar3]}{Itr_3} = 380.347 \cdot psi$

Flexural Stress at the Top $\quad top \;\; \sigma ft := \frac{[(Fpi \cdot e) \cdot (H - ybar3)]}{Itr_3} = 357.285 \cdot psi$

Stress at the Bottom $\quad \sigma a - \sigma f = -0.609 \cdot ksi$

Stress at Top $\quad \sigma a + \sigma ft = 128.844 \cdot psi$

Allowable Compressive Stress $\quad .7 \cdot fc_3 = 3.5 \cdot ksi$

Allowable Tensile Stress $\quad 6 \cdot \left[\sqrt{(fc_3 \cdot psi)}\right] = 0.424 \cdot ksi$

$$Check1 := \begin{cases} \text{"Okay"} & \text{if } .7 \cdot fc_3 \geq |\sigma a - \sigma f| \\ \text{"No Good"} & \text{if } .7 \cdot fc_3 < |\sigma a - \sigma f| \end{cases}$$

Check1 = "Okay"

$$Check2 := \begin{cases} \text{"Okay"} & \text{if } .6\left[\sqrt{(fc_3 \cdot psi)}\right] \geq |\sigma a - \sigma ft| \\ \text{"Provide Crack Control Reinforcement"} & \text{if } .6 \cdot \left[\sqrt{(fc_3 \cdot psi)}\right] < |\sigma a + \sigma ft| \end{cases}$$

Check2 = "Provide Crack Control Reinforcement"

Cracking Capacity:

$\omega sw := (Agconcrete \cdot \gamma c) = 191.163 \cdot \frac{lbf}{ft}$

$L := 20ft$

$Msw := \frac{\left(\omega sw \cdot L^2\right)}{8} = 9.558 \cdot ft \cdot kip$

$\sigma sw := Msw \cdot \frac{ybar28}{Itr_{28}} = 83.755 \cdot psi$

$fcr := 7.5psi \sqrt{\frac{fc_{28}}{psi}} = 670.82 \cdot psi$

$MLL := 1kip \cdot in$

Given

$fcr = \left[-\sigma a + \sigma sw - \sigma f + \frac{(MLL \cdot ybar28)}{Itr_{28}} \right]$

$MLL := Minerr(MLL)$

$Pcr := \frac{2 \cdot (MLL)}{8ft} = 21.083 \cdot kip$

$MLL = 84.332 \cdot kip \cdot ft$

Ultimate Capacity

$d := y_1 = 22.5 \cdot in$

$dprime := y_6 = 2.5 \cdot in$

$$\beta := \begin{cases} 0.85 \text{ if } (fc_{28} \le 4000psi) \\ \left[0.85 - \left[0.5 \cdot \left(\frac{fc_{28} - 4000psi}{1000psi}\right)\right]\right] \text{ if } 4000psi < fc_{28} < 8000psi \\ 0.65 \text{ if } fc_{28} \ge 8000psi \end{cases} = 0.65$$

Initial Guess: $c := 1in$ Strain in Concrete at Failure: $\varepsilon := .003$

Given

$$\left(0.85 \cdot fc_{28} \cdot \beta \cdot c \cdot b_1\right) + \min\left[Asprime \cdot \varepsilon \cdot \left[\frac{(c - dprime)}{c}\right] \cdot Es, fy \cdot Asprime\right] - Ap \cdot fu = 0$$

$c := Minerr(c) = 1.284 \cdot in$ $h_3 = 5 \cdot in$

Check in $Flange := \begin{cases} \text{"Okay" if } c \le h_3 \\ \text{"Incorrect Assumption" if } c > h_3 \end{cases}$

Check in $Flange = \text{"Okay"}$

$Cc := 0.85fc_{28} \beta \cdot c \cdot b_1 = 130.528 \cdot kip$ $\varepsilon = 3 \times 10^{-3}$

$$Cs := Asprime \cdot Es \cdot \varepsilon \cdot \left[\frac{(c - y_6)}{c}\right] = -49.438 \cdot kip$$

$T := Ap \cdot fu = 81.09 \cdot kip$

$Mn := fu \cdot Ap \cdot [d - (\beta \cdot c \cdot 0.5)] + Cs \cdot (\beta \cdot c \cdot 0.5 - dprime) = 157.804 \cdot ft \cdot kip$

$$Pn := \frac{[(Mn - Msw) \cdot 2]}{8ft} = 37.062 \cdot kip$$