Given Properties

Area of Reinforcing Steel $Asprime := 0.4in^2$

Area of Strand $Ap := 3 \cdot 0.153in^2 = 0.459 \cdot in^2$

Compressive Strength of Concrete at 3 days $fc_3 := 5 \cdot ksi$

Compressive Strength of Concrete at 28 days $fc_{28} := 8ksi$

Modulus of Elasticity at 3 days $Ec_3 := 57\,ksi \sqrt{\frac{fc_3}{psi}} = 4030.509 \cdot ksi$

Modulus of Elasticity at 28 days $Ec_{28} := 57ksi \sqrt{\frac{fc_{28}}{psi}} = 5098.235 \cdot ksi$

Modulus of Elasticity of Steel $Es := 29000ksi$

Unit Weight of Concrete $\gamma c := 0.07 \frac{lbf}{in^3}$

Unit Weight of Steel $\gamma s := 490 \frac{lbf}{ft^3}$

Section Properties

$i := 1 .. 5$

Width: Height: Area: Moment of Inertia:

$b_1 := 8in$ $h_1 := 3in$ $A_1 := b_1 \cdot h_1 = 24 \cdot in^2$ $I_1 := b_1 \cdot \frac{(h_1)^3}{12} = 18 \cdot in^4$

$b_2 := 3in$ $h_2 := 10.5in$ $A_2 := b_2 h_2 = 31.5 \cdot in^2$ $I_2 := b_2 \cdot \frac{(h_2)^3}{12} = 289.406 \cdot in^4$

$b_3 := 8in$ $h_3 := 2.5in$ $A_3 := b_3 h_3 = 20 \cdot in^2$ $I_3 := b_3 \cdot \frac{(h_3)^3}{12} = 10.417 \cdot in^4$

$H := h_1 + h_2 + h_3 = 16 \cdot in$

$Agconcrete := (A_1 - Asprime) + A_2 + (A_3 - Ap) = 74.641 \cdot in^2$

Centroid:

$y_1 := h_3 + h_2 + \left(\frac{h_1}{2}\right) = 14.5 \cdot in$

$y_2 := h_3 + \frac{h_2}{2} = 7.75 \cdot in$

$y_3 := \frac{h_3}{2} = 1.25 \cdot in$

$y_4 := \frac{h_3}{2} = 1.25 \cdot in$

$y_5 := h_3 + h_2 + \frac{h_1}{2} = 14.5 \cdot in$

Transformed section at 3 days

$$n_3 := \frac{Es}{Ec_3} = 7.195$$

$$A_4 := \left(n_3 - 1\right)\cdot Asprime = 2.478\cdot in^2$$

$$A_5 := \left(n_3 - 1\right)\cdot Ap = 2.844\cdot in^2$$

$$Atr_3 := \sum_{i=1}^{5} A_i = 80.822\cdot in^2$$

$$ybar3 := \frac{\left[\sum_{i=1}^{5} \left(A_i \cdot y_i\right)\right]}{\left(\sum_{i=1}^{5} A_i\right)} = 8.184\cdot in$$

$$d_1 := ybar3 - y_1 = -6.316\cdot in$$

$$I_4 := 0 \qquad I_5 := 0$$

$$d_2 := ybar3 - y_2 = 0.434\cdot in$$

$$d_3 := ybar3 - y_3 = 6.934\cdot in$$

$$d_4 := ybar3 - y_4 = 6.934\cdot in$$

$$d_5 := ybar3 - y_5 = -6.316\cdot in$$

$$Itr_3 := \sum_{i=1}^{5} \left[I_i + A_i \cdot \left(d_i\right)^2\right] = 2475\cdot in^4$$

Transformed Section at 28 days

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

$$A_4 := \left(n_{28} - 1\right)\cdot Asprime = 1.875\cdot in^2$$

$$A_5 := \left(n_{28}\right)\cdot Ap = 2.611\cdot in^2$$

$$Atr_{28} := \sum_{i=1}^{5} A_i = 79.986\cdot in^2$$

$$ybar28 := \frac{\left[\sum_{i=1}^{5} \left(A_i\cdot y_i\right)\right]}{\left(\sum_{i=1}^{5} A_i\right)} = 8.218\cdot in$$

$$d_1 := ybar28 - y_1 = -6.282\cdot in$$

$$d_2 := ybar28 - y_2 = 0.468\cdot in$$

$$d_3 := ybar28 - y_3 = 6.968\cdot in$$

$$d_4 := ybar28 - y_4 = 6.968\cdot in$$

$$d_5 := ybar28 - y_5 = -6.282\cdot in$$

$$Itr_{28} := \sum_{i=1}^{5} \left[I_i + A_i\cdot\left(d_i\right)^2\right] = 2437\cdot in^4$$

Stresses at Release

Release: $fpi := 174ksi$ $\quad Fpi := fpi \cdot Ap = 79.866 \cdot kip$

Cracking: $fcr := 180ksi$ $\quad Fcr := fcr \cdot Ap = 82.62 \cdot kip$

Ultimate: $fu := 265ksi$ $\quad Fu := fu \cdot Ap = 121.635 \cdot kip$

$$H := \sum_{i=1}^{3} h_i = 16 \cdot in$$

$$e := ybar3 - y_3 = 6.934 \cdot in$$

axial stress $\quad \sigma a := \frac{Fpi}{Atr_3} = 988.176 \cdot psi$

flexural stress $\quad \sigma f := \frac{(Fpi \cdot e) \cdot ybar3}{Itr_3} = 1.831 \times 10^3 \cdot psi$

$\sigma t := \sigma a - \sigma f = -842.829 \cdot psi$ stress at top

$\sigma b := \sigma a + \sigma f = 2.819 \times 10^3 \cdot psi$ stress at bottom

Cracking Capacity

$$\omega sw := (Agconcrete \cdot \gamma c) + (\gamma s \cdot Ap) + (\gamma s \cdot Asprime) = 65.621 \cdot \frac{lbf}{ft}$$

$$L := 20ft$$

$$Msw := \frac{\omega sw \cdot L^2}{8} = 3.281 \cdot ft \cdot kip$$

$$\sigma sw := Msw \cdot \frac{ybar28}{Itr_{28}} = 132.773 \cdot psi$$

$$MLL := 1kip \cdot in$$

Given

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

$$-\sigma a + \sigma sw - \sigma f + \frac{MLL \cdot ybar28}{Itr_{28}} = fcr$$

$$MLL := Minerr(MLL)$$

$$Pcr := \frac{2 \cdot (MLL)}{8ft} = 20.741 \cdot kip$$

$$MLL = 82.964 \cdot kip \cdot ft$$

Ultimate Capacity

$d := y_1 = 14.5 \cdot in$

$dprime := y_4 = 1.25 \cdot in$

$\varepsilon := 0.003$

$fy := 60ksi$

$fp := 265ksi$

$$\beta := \begin{cases} 0.85 & \text{if } fc_{28} \le 4000psi \\ \left[0.85 - \left[0.05 \cdot \frac{(fc_{28} - 4000psi)}{1000psi}\right]\right] & \text{if } 4000psi < fc_{28} < 8000psi \\ 0.65 & \text{if } fc_{28} \ge 8000psi \end{cases}$$

$c := 1in$

Given

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

$c := Minerr(c)$

$c = 2.883 \cdot in$

$Cc := 0.85 \cdot fc_{28} \cdot \beta \cdot c \cdot b_1 = 101.926 \cdot kip$

$$Cs := Asprime \cdot Es \cdot \varepsilon \cdot \left[\frac{(c - y_4)}{c}\right] = 19.709 \cdot kip$$

$T := Ap \cdot fp = 121.635 \cdot kip$

$Mn := fp \cdot Ap \cdot [d - (\beta \cdot c \cdot 0.5)] + Cs \cdot (\beta \cdot c \cdot 0.5 - dprime) = 136.965 \cdot ft \cdot kip$

$$Pn := \frac{(Mn - Msw) \cdot 2}{8ft} = 33.421 \cdot kip$$

Shear Capacity

$x := 0.1in, 0.5in .. 90in$

Shear Properties

$Av := 0.04in^2$ $\quad bw := 3in$ $\quad \lambda := 0.75$ $\quad fym := 65ksi$

$H = 16 \cdot in$ $\quad ld := 4in$ $\quad S := 4in$

$dc := \max\left(y_5, 0.8H\right) = 14.5 \cdot in$

$$Vu(x) := \frac{Pn}{2} + \frac{\omega sw \cdot L}{2} - \omega sw \cdot (x) \qquad Vu(0) = 17.367 \cdot kip$$

Concrete Shear Capacity

$$fpc(x) := \begin{cases} \frac{fp}{ld} \cdot x & \text{if } 0 < x < ld \\ fp & \text{otherwise} \end{cases} \qquad Msw(x) := \frac{\omega sw \cdot L \cdot (x)}{2} - \frac{\omega sw \cdot \left(x^2\right)}{2}$$

$$fd(x) := \frac{(Msw(x) \cdot ybar28)}{Itr_{28}} \qquad Mmax(x) := \frac{Pn}{2} \cdot (x)$$

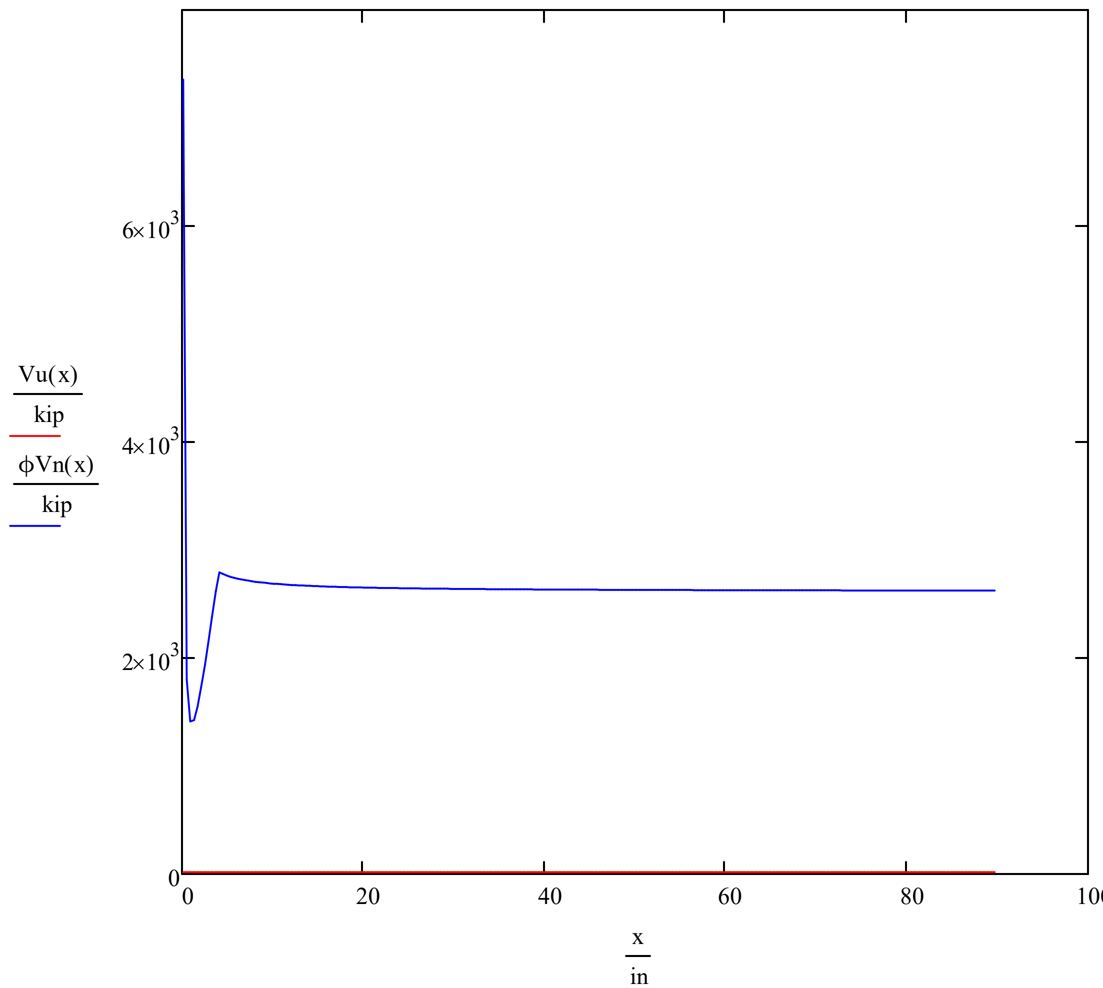
$$fpe := \frac{Fpi}{Atr_{28}} + \frac{(Fpi \cdot e \cdot ybar28)}{Itr_{28}} \qquad Mcre(x) := \left(\frac{Itr_{28}}{ybar28}\right) \cdot \left(6psi \cdot \lambda \cdot \sqrt{\frac{fc_{28}}{psi}} + fpe - fd(x)\right)$$

$$Vd(x) := \frac{\omega sw \cdot L}{2} - \omega sw \cdot (x) \qquad Vi(x) := Vu(x) - Vd(x)$$

$$Vci(x) := \max\left(0.6psi \cdot \lambda \cdot \sqrt{\frac{fc_{28}}{psi}} \cdot bw \cdot dc + Vd(x) + \frac{Vi(x) \cdot Mcre(x)}{Mmax(x)}, 1.7psi \cdot \lambda \cdot \sqrt{\frac{fc_{28}}{psi}} \cdot bw \cdot dc\right)$$

$$Vcw(x) := \left(3.5\lambda \cdot psi \cdot \sqrt{\frac{fc_{28}}{psi}} + 0.3 \cdot fpc(x)\right) \cdot bw \cdot d \qquad Vc(x) := Vci(x) + Vcw(x)$$

$$Vs(x) := \frac{2Av \cdot fym \cdot dc}{S} \qquad \phi Vn(x) := 0.75(Vc(x) + Vs(x))$$



6×10^3
4×10^3
2×10^3
0
Vu(x)
kip
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kip
0
20
40
60
80
100
x
in