# Beam Data

$mp := 10$

Beam length (ft) = $length := 77.0$

Composite slab strength (psi) = $fc := 4$

Concrete unit weitht (kcf) = $\gamma c := 0.150$

Initial strength of concrete (ksi) = $fci := 5.8$

Final Strength of concrete (ksi) = $fcf := 7.0$

Modulus of beam concrete based on final (ksi) = $Ec := 33000 \cdot \gamma c^{1.5} \cdot \sqrt{fcf}$ $Ec = 5072.241$

Modulus of slab concrete (ksi) = $Esl := 33000 \cdot \gamma c^{1.5} \cdot \sqrt{fc}$ $Esl = 3834.254$

Haunch thickness (in) = $ha := 0$

Effective compression slab width (in) = $ETFW := 110$

Slab thickness (in) = $ts := 8.5$

**Note:** 8.25 was used in slab calculations, the value of 8.5 use here is arbitrary.

Live Load distribution factor for moment = $LLDF := 0.852$

Non compostie DL (excluding beams)(k/ft) = $DLnc := 1.003$

Span Lengths (ft) = $span := \begin{pmatrix} 77 \\ 77 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$

Number of spans = $number := 2$ $ns := 0 .. number \cdot 10$ $sp_{ns} := 1 + \frac{ns}{10}$

Strength of reinforcing steel (ksi) = $fy := 60$

Factor for slabs = $\beta 1 := 0.85$

Size of bar to try = $size := 9$ As of one bar $Asone := 1.0$

Bar diameter (in) = $bd := 1.128$ clear cover (in) = $cover := 2.5$

## *Beam type to use*

$type := 3$

1 = AASHTO TYPE I
2 = AASHTO TYPE II
3 = AASHTO TYPE III
4 = AASHTO TYPE IV
5 = BT54
6 = BT63
7 = BT72

---

| | | | |
|---|---|---|---|
| Beam area (in^2) = | $Area := beam\_data_{type,1}$ | $Area = 560$ | |
| Dist from bottom to cg (in) = | $yb := beam\_data_{type,2}$ | $yb = 20.27$ | |
| Section inertia (in^2) = | $Inc := beam\_data_{type,3}$ | $Inc = 125390$ | $Ic := Inc$ |
| Beam weight (k/ft) = | $bwt := beam\_data_{type,4}$ | $bwt = 0.583$ | |
| Maximum span (ft) = | $max\_span := beam\_data_{type,5}$ | $max\_span = 80$ | |
| Total beam depth (in) = | $h := beam\_data_{type,6}$ | $h = 45$ | |
| Width of top flange (in) = | $fwt := beam\_data_{type,7}$ | $fwt = 16$ | |

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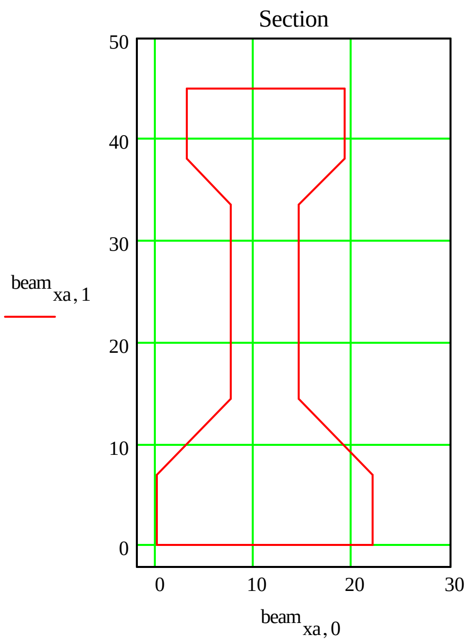


## Composite moment of Inertia

Haunch thickness (in) = $ha = 0$

Effective compression slab width (in) = $ETFW = 110$

Modular ratio = $\eta := \frac{\sqrt{fc}}{\sqrt{fcf}}$ $\eta = 0.756$

Transformed slab width (in) = $b1 := ETFW \cdot \eta$ $b1 = 83.152$

Slab thickness (in) = $ts = 8.5$

Composite distance from bottom to c.g. (in) = $ybc := \frac{b1 \cdot ts \cdot \left(h + ha + \frac{ts}{2}\right) + Area \cdot yb}{b1 \cdot ts + Area}$ $ybc = 36.439$

Composite N.A. to top beam (in) = $ytb := h - ybc$ $ytb = 8.561$

Composite N.A. to top slab (in) = $yts := h + ts - ybc$ $yts = 17.061$

Composite moment of inertia (in^t) = $Ic := Inc + \frac{b1 \cdot ts^3}{12} + Area \cdot (yb - ybc)^2 + b1 \cdot ts \cdot \left(yts - \frac{ts}{2}\right)^2$

$Ic = 392050.137$

## Composite Section Modulus

Section modulus bottom of beam (in^3) = $Sbc := \frac{Ic}{ybc}$ $Sbc = 10759.059$

Section modulus top beam (in^3) = $Stb := \frac{Ic}{ytb}$ $Stb = 45795.29$

Section modulus top concrete (in^3) = $Stc := \frac{Ic}{yts} \cdot \frac{1}{\eta}$ $Stc = 30398.91$

## Non-Composite Section Modulus

Section modulus bottom of beam (in^3) = $Sb := \frac{Inc}{yb}$ $Sb = 6185.989$

Section modulus top beam (in^3) = $St := \frac{Inc}{h - yb}$ $St = 5070.36$

# Non compostie Moments

Total load including beam weight (k/ft) = $DL := bwt + DLnc$ $DL = 1.586$

Define range (ft) = $x1_{ns} := \left| \begin{array}{l} j_{ns} \leftarrow ceil\left(\dfrac{ns + 0.001}{10} - 1\right) \\ j1_{ns} \leftarrow (sp_{ns} - j_{ns} - 1) \cdot span_{(j_{ns})} \end{array} \right.$

Indicate which span = $a1_{ns} := \left| \begin{array}{l} j_{ns} \leftarrow ceil\left(\dfrac{ns + 0.001}{10} - 1\right) \\ j1_{ns} \leftarrow span_{(j_{ns})} \end{array} \right.$

Calculate moment at tenth points from beam = $Mb_{ns} := \dfrac{bwt \cdot x1_{ns}}{2} \cdot (a1_{ns} - x1_{ns})$

Calculate moment at tenth points from other = $Mo_{ns} := \dfrac{DLnc \cdot x1_{ns}}{2} \cdot (a1_{ns} - x1_{ns})$

## Input the values straight from qcon here. This program was set up to use the loads generated by the program Qcon Bridge. The live load values input here shall not have had the LL dist factor applied, that will be done later.

The Live loads for Qcon are in lanes per beam. The LRFD dist factor is on lanes. So the get the service I LL moments, simply multiply the Qcon values by the LL distribution factor.

$$\begin{pmatrix} fullq \\ fp1 \\ fn1 \end{pmatrix} :=$$

| | | | | | | fp1 | fn1 |
|---|---|---|---|---|---|---|---|
| | DC LOADS (non-comp) | | DW Loads | LL + I | | FATIGUE TRUCk | |
| LOCATION | self wt | other (slab) | (comp) | M (+) | M (-) | M(+) | M(-) |
| 1.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.1 | 155.55 | 267.61 | 111.00 | 692.00 | -91.00 | 392.00 | -50.00 |
| 1.2 | 276.53 | 475.74 | 188.00 | 1169.00 | -181.00 | 641.00 | -100.00 |
| 1.3 | 362.94 | 624.41 | 231.00 | 1443.00 | -271.00 | 794.00 | -149.00 |
| 1.4 | 414.79 | 713.61 | 239.00 | 1565.00 | -362.00 | 836.00 | -199.00 |
| 1.5 | 432.08 | 743.35 | 213.00 | 1534.00 | -453.00 | 793.00 | -248.00 |
| 1.6 | 414.79 | 713.61 | 154.00 | 1375.00 | -454.00 | 747.00 | -298.00 |
| 1.7 | 362.94 | 624.41 | 60.00 | 1062.00 | -635.00 | 591.00 | -347.00 |
| 1.8 | 276.53 | 475.74 | -69.00 | 628.00 | -725.00 | 344.00 | -397.00 |
| 1.9 | 155.55 | 267.61 | -230.00 | 237.00 | -1002.00 | 149.00 | -447.00 |
| 2.0 | 0.00 | 0.00 | -427.00 | 0.00 | -1602.00 | 0.00 | -496.00 |
| 2.1 | 155.55 | 267.61 | -231.00 | 237.00 | -1002.00 | 149.00 | -447.00 |
| 2.2 | 276.53 | 475.74 | -69.00 | 628.00 | -725.00 | 344.00 | -397.00 |
| 2.3 | 362.94 | 624.41 | 60.00 | 1062.00 | -635.00 | 591.00 | -347.00 |
| 2.4 | 414.79 | 713.61 | 154.00 | 1375.00 | -454.00 | 747.00 | -298.00 |
| 2.5 | 432.08 | 743.35 | 213.00 | 1534.00 | -453.00 | 793.00 | -248.00 |
| 2.6 | 414.79 | 713.61 | 239.00 | 1565.00 | -362.00 | 836.00 | -199.00 |
| 2.7 | 362.94 | 624.41 | 231.00 | 1443.00 | -271.00 | 794.00 | -149.00 |
| 2.8 | 276.53 | 475.74 | 188.00 | 1169.00 | -181.00 | 641.00 | -100.00 |
| 2.9 | 155.55 | 267.61 | 111.00 | 692.00 | -91.00 | 392.00 | -50.00 |
| 3.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

(Mb Mo)

# Service I loads (moment)

Live load distribution factor has been applied to the Live Loads shown here.

$$\begin{pmatrix} \mathrm{full} \\ \mathrm{SI1} \\ \mathrm{SI2} \\ \mathrm{SI3} \\ \mathrm{SI4} \\ \mathrm{SI5} \\ \mathrm{SI6} \\ \mathrm{SI7} \end{pmatrix} :=$$

| | SI1 | SI2 | SI3 | SI4 | SI5 | SI5 | SI7 |
|---|---|---|---|---|---|---|---|
| 0.0 | DC LOADS | 0 | DW Loads | LL + I | 0 | TOTAL LOADS | |
| LOCATION | self wt | other (slab) | (comp) | M (+) | M (-) | M (+) | M (-) |
| 1.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.1 | 155.55 | 267.61 | 111.00 | 692.00 | -91.00 | 1226.15 | 443.15 |
| 1.2 | 276.53 | 475.74 | 188.00 | 1169.00 | -181.00 | 2109.27 | 759.27 |
| 1.3 | 362.94 | 624.41 | 231.00 | 1443.00 | -271.00 | 2661.36 | 947.36 |
| 1.4 | 414.79 | 713.61 | 239.00 | 1565.00 | -362.00 | 2932.41 | 1005.41 |
| 1.5 | 432.08 | 743.35 | 213.00 | 1534.00 | -453.00 | 2922.42 | 935.42 |
| 1.6 | 414.79 | 713.61 | 154.00 | 1375.00 | -454.00 | 2657.41 | 828.41 |
| 1.7 | 362.94 | 624.41 | 60.00 | 1062.00 | -635.00 | 2109.36 | 412.36 |
| 1.8 | 276.53 | 475.74 | -69.00 | 628.00 | -725.00 | 1311.27 | -41.73 |
| 1.9 | 155.55 | 267.61 | -230.00 | 237.00 | -1002.00 | 430.15 | -808.85 |
| 2.0 | 0.00 | 0.00 | -427.00 | 0.00 | -1602.00 | -427.00 | -2029.00 |
| 2.1 | 155.55 | 267.61 | -231.00 | 237.00 | -1002.00 | 429.15 | -809.85 |
| 2.2 | 276.53 | 475.74 | -69.00 | 628.00 | -725.00 | 1311.27 | -41.73 |
| 2.3 | 362.94 | 624.41 | 60.00 | 1062.00 | -635.00 | 2109.36 | 412.36 |
| 2.4 | 414.79 | 713.61 | 154.00 | 1375.00 | -454.00 | 2657.41 | 828.41 |
| 2.5 | 432.08 | 743.35 | 213.00 | 1534.00 | -453.00 | 2922.42 | 935.42 |
| 2.6 | 414.79 | 713.61 | 239.00 | 1565.00 | -362.00 | 2932.41 | 1005.41 |
| 2.7 | 362.94 | 624.41 | 231.00 | 1443.00 | -271.00 | 2661.36 | 947.36 |
| 2.8 | 276.53 | 475.74 | 188.00 | 1169.00 | -181.00 | 2109.27 | 759.27 |
| 2.9 | 155.55 | 267.61 | 111.00 | 692.00 | -91.00 | 1226.15 | 443.15 |
| 3.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

fullq

# Service III loads (moment)

$\begin{pmatrix} SIII1 \\ SIII2 \\ SIII3 \\ SIII4 \\ SIII5 \\ SIII6 \\ SIII7 \end{pmatrix} :=$

| | SIII1 | SIII2 | SIII3 | SIII4 | SIII5 | SIII5 | SIII7 | |
|---|---|---|---|---|---|---|---|---|
| | DC LOADS (non-comp) | | DW Loads | LL + I | | TOTAL LOADS | | |
| LOCATION | self wt | other (slab) | (comp) | M (+) | M (-) | M (+) | M (-) | |
| 1.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | |
| 1.1 | 155.55 | 267.61 | 111.00 | 553.60 | -72.80 | 1087.75 | 461.35 | |
| 1.2 | 276.53 | 475.74 | 188.00 | 935.20 | -144.80 | 1875.47 | 795.47 | |
| 1.3 | 362.94 | 624.41 | 231.00 | 1154.40 | -216.80 | 2372.76 | 1001.56 | |
| 1.4 | 414.79 | 713.61 | 239.00 | 1252.00 | -289.60 | 2619.41 | 1077.81 | |
| 1.5 | 432.08 | 743.35 | 213.00 | 1227.20 | -362.40 | 2615.62 | 1026.02 | |
| 1.6 | 414.79 | 713.61 | 154.00 | 1100.00 | -363.20 | 2382.41 | 919.21 | |
| 1.7 | 362.94 | 624.41 | 60.00 | 849.60 | -508.00 | 1896.96 | 539.36 | |
| 1.8 | 276.53 | 475.74 | -69.00 | 502.40 | -580.00 | 1185.67 | 103.27 | |
| 1.9 | 155.55 | 267.61 | -230.00 | 189.60 | -801.60 | 382.75 | -608.45 | |
| 2.0 | 0.00 | 0.00 | -427.00 | 0.00 | -1281.60 | -427.00 | -1708.60 | |
| 2.1 | 155.55 | 267.61 | -231.00 | 189.60 | -801.60 | 381.75 | -609.45 | |
| 2.2 | 276.53 | 475.74 | -69.00 | 502.40 | -580.00 | 1185.67 | 103.27 | |
| 2.3 | 362.94 | 624.41 | 60.00 | 849.60 | -508.00 | 1896.96 | 539.36 | |
| 2.4 | 414.79 | 713.61 | 154.00 | 1100.00 | -363.20 | 2382.41 | 919.21 | |
| 2.5 | 432.08 | 743.35 | 213.00 | 1227.20 | -362.40 | 2615.62 | 1026.02 | |
| 2.6 | 414.79 | 713.61 | 239.00 | 1252.00 | -289.60 | 2619.41 | 1077.81 | |
| 2.7 | 362.94 | 624.41 | 231.00 | 1154.40 | -216.80 | 2372.76 | 1001.56 | |
| 2.8 | 276.53 | 475.74 | 188.00 | 935.20 | -144.80 | 1875.47 | 795.47 | |
| 2.9 | 155.55 | 267.61 | 111.00 | 553.60 | -72.80 | 1087.75 | 461.35 | |
| 3.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | |

full

# Strength I loads (moment)

Maximum 1.25*DW + 1.5*DW + 1.75*(LL + IM)
Minimum 0.9*DC + 0.65*DW + 1.75*(LL + IM)

The loads shown in the DL columns reflect the values from Service I. The appropriate load combination (max or min) is shown in the total loads columns. The minimum load factors for dead load are used when dead load and future wearing survace stresses are of opposite sign to that of the live load.

$$\begin{pmatrix} STI1 \\ STI2 \\ STI3 \\ STI4 \\ STI5 \\ STI6 \\ STI7 \end{pmatrix} :=$$

| | STI1 | STI2 | STI3 | STI4 | STI5 | STI6 | STI7 |
|---|---|---|---|---|---|---|---|
| | DC LOADS (non-comp) | | DW Loads | LL + I | | TOTAL LOADS | |
| LOCATION | self wt | other (slab) | (comp) | M (+) | M (-) | M (+) | M (-) |
| 1.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.1 | 155.55 | 267.61 | 111.00 | 692.00 | -91.00 | 1906.44 | 293.74 |
| 1.2 | 276.53 | 475.74 | 188.00 | 1169.00 | -181.00 | 3268.09 | 482.49 |
| 1.3 | 362.94 | 624.41 | 231.00 | 1443.00 | -271.00 | 4105.95 | 564.52 |
| 1.4 | 414.79 | 713.61 | 239.00 | 1565.00 | -362.00 | 4507.76 | 537.42 |
| 1.5 | 432.08 | 743.35 | 213.00 | 1534.00 | -453.00 | 4473.28 | 403.58 |
| 1.6 | 414.79 | 713.61 | 154.00 | 1375.00 | -454.00 | 4047.76 | 321.17 |
| 1.7 | 362.94 | 624.41 | 60.00 | 1062.00 | -635.00 | 3182.70 | -183.63 |
| 1.8 | 276.53 | 475.74 | -69.00 | 628.00 | -725.00 | 1994.49 | -695.21 |
| 1.9 | 155.55 | 267.61 | -230.00 | 237.00 | -1002.00 | 794.19 | -1717.66 |
| 2.0 | 0.00 | 0.00 | -427.00 | 0.00 | -1602.00 | 0.00 | -3444.00 |
| 2.1 | 155.55 | 267.61 | -231.00 | 237.00 | -1002.00 | 793.54 | -1719.16 |
| 2.2 | 276.53 | 475.74 | -69.00 | 628.00 | -725.00 | 1994.49 | -695.21 |
| 2.3 | 362.94 | 624.41 | 60.00 | 1062.00 | -635.00 | 3182.70 | -183.63 |
| 2.4 | 414.79 | 713.61 | 154.00 | 1375.00 | -454.00 | 4047.76 | 321.17 |
| 2.5 | 432.08 | 743.35 | 213.00 | 1534.00 | -453.00 | 4473.28 | 403.58 |
| 2.6 | 414.79 | 713.61 | 239.00 | 1565.00 | -362.00 | 4507.76 | 537.42 |
| 2.7 | 362.94 | 624.41 | 231.00 | 1443.00 | -271.00 | 4105.95 | 564.52 |
| 2.8 | 276.53 | 475.74 | 188.00 | 1169.00 | -181.00 | 3268.09 | 482.49 |
| 2.9 | 155.55 | 267.61 | 111.00 | 692.00 | -91.00 | 1906.44 | 293.74 |
| 3.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

full

# LRFD 5.7.3.3.2 minimum reinforcement

Unless otherwise specified, at any section of a flexural component, the amount of prestressed and nonprestressed tensile reinforcement shall be adequate to develop a factored flexural resistance, Mr, at least equal to the lesser of

1.2* the cracking strength
1.33 times the factored moment required by Strength I

What I shall do is calculate required steel based on the cracking moment. Then I shall calculate the required steel based on strength. If any of the required are less than 1.2*Mcr I shall increase the required by 4/3.

LRFD 5.4.2.6 the modulus of rupture (ksi) = $fr := 0.24 \cdot \sqrt{fc}$ $fr = 0.48$

Cracking moment (k*ft) = $Mcr := \frac{fr \cdot Stc}{12}$ $Mcr = 1215.956$

Effective section depth (in) = $d := h + \frac{ts}{2}$ $d = 49.25$ assume steel in center of slab

$Acr := 0$ $As := 0$ $Ar := 0$ $Art := 0$

Required steel based on 1.2*Mcr (in^2) = $Acr := root\left[\left|12 \cdot Mcr\right| - 0.9 \cdot Acr \cdot fy \cdot \left(d - \frac{Acr \cdot fy}{1.7 \cdot fc \cdot b}\right), Acr\right]$

$Acr = 5.756$

**CALCULATIONS BASED ON RECTANGULAR SECTION**

Required steel (pure strength)(in^2) =

$$Ar_{ns} := \left| \begin{array}{l} j_{ns} \leftarrow root\left[\left|12 \cdot STI7_{ns}\right| - 0.9 \cdot Ar \cdot fy \cdot \left(d - \frac{Ar \cdot fy}{1.7 \cdot fc \cdot b}\right), Ar\right] \\ 0 \ \text{ if } \left(STI7_{ns} \geq 0\right) \\ j_{ns} \ \text{ otherwise} \end{array} \right.$$

$Ar_{mp} = 18.253$

Required Steed (in^2) =

$$As1_{ns} := \left| \begin{array}{l} 0 \ \text{ if } \ STI7_{ns} \geq 0 \\ \text{otherwise} \\ \quad \left| \begin{array}{l} \frac{4}{3} \cdot Ar_{ns} \ \text{ if } \ Ar_{ns} < Acr \\ Ar_{ns} \ \text{ otherwise} \end{array} \right. \end{array} \right.$$

$As1_{mp} = 18.253$

Distance between the N.A. and the compression flange (in) = $c1_{ns} := \frac{As1_{ns} \cdot fy}{0.85 \cdot fc \cdot \beta 1 \cdot b}$ $c1_{mp} = 17.225$

## CALCULATIONS BASED ON "T" SECTION

$hf := tbf$

### Required steel for "T" section

$$Art_{ns} := root\left[\left|12 \cdot STI7_{ns}\right| - 0.9 \cdot Art \cdot fy \cdot \left[d - \frac{Art \cdot fy - \beta 1 \cdot fc \cdot (b - bw) \cdot hf}{1.7 \cdot fc \cdot b}\right] - 0.85 \cdot fc \cdot (b - bw) \cdot \beta 1 \cdot hf \cdot \left[\frac{Art \cdot fy - \beta 1 \cdot fc \cdot (b - bw) \cdot hf}{1.7 \cdot fc \cdot b} - \frac{hf}{2}\right], Art\right]$$

Apply the requirements of 1.2*Mcr to "T" section behavior

Required Steed (in^2) =

$$As2_{ns} := \begin{cases} 0 & \text{if } STI7_{ns} \geq 0 \\ \text{otherwise} & \\ \quad \begin{cases} \frac{4}{3} \cdot Art_{ns} & \text{if } Art_{ns} < Acr \\ Art_{ns} & \text{otherwise} \end{cases} \end{cases}$$

$As2_{mp} = 16.955$

## Check rectangular section behavior

Thickness of bottom flange (compression flange) (in) = $tbf = 7$

Check

$$ck1_{ns} := \begin{cases} \text{"R"} & \text{if } tbf > c1_{ns} \\ \text{"T"} & \text{otherwise} \end{cases}$$

Actual steel to use (in^2) =

$$As_{ns} := \begin{cases} As1_{ns} & \text{if } ck1_{ns} = \text{"R"} \\ As2_{ns} & \text{otherwise} \end{cases}$$

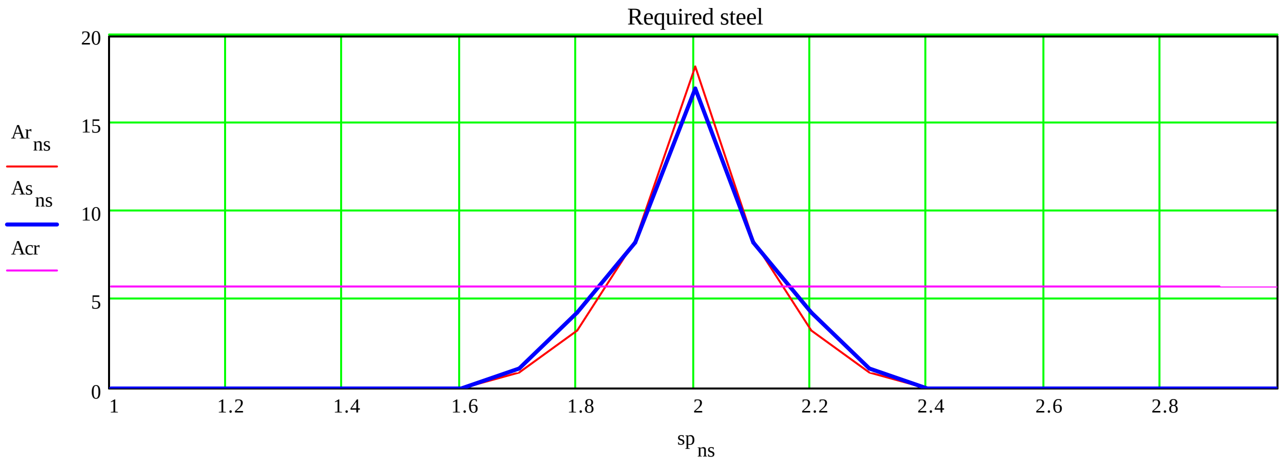
$disp_{ns,0} := sp_{ns}$ $disp_{ns,1} := x1_{ns}$ $disp_{ns,2} := STI7_{ns}$ $disp_{ns,3} := Ar_{ns}$ $disp_{ns,4} := As1_{ns}$

$disp_{ns,5} := c1_{ns}$ $disp_{ns,6} := ck1_{ns}$ $disp_{ns,7} := Art_{ns}$ $disp_{ns,8} := As2_{ns}$ $disp_{ns,9} := As_{ns}$

column 0 = span point
column 1 = range
column 2 = Strength I Negative moment
column 3 = required steel for negative moment based on rectangular section
column 4 = Required steel using 1.2*Mcr
column 5 = "c" value based on rectangular section
column 6 = check rectangular section "R" denotes rectangular "T" denotes "T" section
column 7 = required steel based on "T" section non considering 1.2*Mcr
column 8 = required steel based on "T" section and using 1.2*Mcr
column 9 = actual steel to use

disp =

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 0 | 0 | 0 | 0 | 0 | "R" | 0.617 | 0 | 0 |
| 1 | 1.1 | 7.7 | 293.737 | 0 | 0 | 0 | "R" | 1.851 | 0 | 0 |
| 2 | 1.2 | 15.4 | 482.494 | 0 | 0 | 0 | "R" | 2.656 | 0 | 0 |
| 3 | 1.3 | 23.1 | 564.521 | 0 | 0 | 0 | "R" | 3.009 | 0 | 0 |
| 4 | 1.4 | 30.8 | 537.417 | 0 | 0 | 0 | "R" | 2.892 | 0 | 0 |
| 5 | 1.5 | 38.5 | 403.582 | 0 | 0 | 0 | "R" | 2.318 | 0 | 0 |
| 6 | 1.6 | 46.2 | 321.167 | 0 | 0 | 0 | "R" | 1.967 | 0 | 0 |
| 7 | 1.7 | 53.9 | -183.629 | 0.834 | 1.112 | 1.05 | "R" | 1.385 | 1.847 | 1.112 |
| 8 | 1.8 | 61.6 | -695.206 | 3.221 | 4.295 | 4.053 | "R" | 3.576 | 4.768 | 4.295 |
| 9 | 1.9 | 69.3 | -1717.663 | 8.313 | 8.313 | 7.845 | "T" | 8.197 | 8.197 | 8.197 |
| 10 | 2 | 0 | -3444 | 18.253 | 18.253 | 17.225 | "T" | 16.955 | 16.955 | 16.955 |
| 11 | 2.1 | 7.7 | -1719.163 | 8.321 | 8.321 | 7.852 | "T" | 8.204 | 8.204 | 8.204 |
| 12 | 2.2 | 15.4 | -695.206 | 3.221 | 4.295 | 4.053 | "R" | 3.576 | 4.768 | 4.295 |
| 13 | 2.3 | 23.1 | -183.629 | 0.834 | 1.112 | 1.05 | "R" | 1.385 | 1.847 | 1.112 |
| 14 | 2.4 | 30.8 | 321.167 | 0 | 0 | 0 | "R" | 1.967 | 0 | 0 |
| 15 | 2.5 | 38.5 | 403.582 | 0 | 0 | 0 | "R" | 2.318 | 0 | 0 |
| 16 | 2.6 | 46.2 | 537.417 | 0 | 0 | 0 | "R" | 2.892 | 0 | 0 |
| 17 | 2.7 | 53.9 | 564.521 | 0 | 0 | 0 | "R" | 3.009 | 0 | 0 |
| 18 | 2.8 | 61.6 | 482.494 | 0 | 0 | 0 | "R" | 2.656 | 0 | 0 |
| 19 | 2.9 | 69.3 | 293.737 | 0 | 0 | 0 | "R" | 1.851 | 0 | 0 |
| 20 | 3 | 0 | 0 | 0 | 0 | 0 | "R" | 0.617 | 0 | 0 |



## *LRFD 5.7.3.4 CONTROL OF CRACKING BY DISTRIBUTION OF REINFORCEMENT*

The provisions specified herein shall apply to the reinforcement of all concrete components, except that of deck slabs designed in accordance with Article 9.7.2, in which tension in the cross-section exceeds 80 percent of the modulus of rupture, specified in article 5.4.2.6, at applicable service limit state load combination specified in Table 3.4.1-1.

Since this is the main negative moment reinforcement parallel to traffic I shall apply the provisions of this article.

Components shall be so proportioned that the tensile stress in the mild steel reinforcement at the service limit state, fsa does not exceed:

$$fsa = \frac{Z}{(dc \cdot A)^{\frac{1}{3}}} \le 0.6 \cdot fy \qquad \text{5.7.3.4-1}$$

dc = depth of concrete measured from extreme tension fiber to center of bar or wire located closest thereto; for calculation purposes, the thickness of clear coner used to compute dc shall not be taken to be greater than 2 in.

A = area fo concrete having the same centroid as the principal tensile reinforcement and bounded by the surfaces of hte cross-section and a straight line parallel to the neutral axis, divided by the number of bars or wires; for calculation purposes the thickness of clear concrete cover used to compute A shall not be taken to be greater than 2.0 in.

Z = crack width parameter - use 170 k/in for moderate exposure.

Max Required number of bars using input bar size =
(formula will chose an even number of bars)

$$nmax := \left| \begin{array}{l} j \leftarrow ceil\left(\frac{max\left(As^{\langle 0 \rangle}\right)}{Asone}\right) \\ j \ \text{ if } \ ceil\left(\frac{j}{2}\right) = \frac{j}{2} \\ j + 1 \ \text{ otherwise} \end{array} \right. \qquad nmax = 18$$

Maximim steel (in^2) =

$$Asmax := nmax \cdot Asone \qquad Asmax = 18$$

Minimum number of bars (after cutoff) =

$$nmin := \frac{nmax}{2} \qquad nmin = 9$$

Minimum steel (in^2) =

$$Asmin := nmin \cdot Asone \qquad Asmin = 9$$

SL moment to be used (use 0 if the moment is positive)

$$M1_{ns} := \begin{cases} |SI7_{ns}| & \text{if } SI7_{ns} < 0 \\ 0 & \text{otherwise} \end{cases}$$

$M1_{mp} = 2029$

$F := 0$

**Stress in steel for rectangular section**

SL Stress in max steel (psi) =

$$fsmax1_{ns} := \mathrm{root}\left[12\cdot M1_{ns} - Asmax\cdot F\cdot\left(d - \frac{Asmax\cdot F}{1.7\cdot fc\cdot b}\right), F\right]$$

$fsmax1_{mp} = 29.607$

SL Stress in min steel (psi) =

$$fsmin1_{ns} := \mathrm{root}\left[12\cdot M1_{ns} - Asmin\cdot F\cdot\left(d - \frac{Asmin\cdot F}{1.7\cdot fc\cdot b}\right), F\right]$$

$fsmin1_{mp} = 59.214$

**Stress in steel for "T" section**

$$fsmax2_{ns} := \mathrm{root}\left[\left|12\cdot M1_{ns}\right| - 0.9\cdot Asmax\cdot F\cdot\left[d - \frac{Asmax\cdot F - \beta1\cdot fc\cdot(b - bw)\cdot hf}{1.7\cdot fc\cdot b}\right] - 0.85\cdot fc\cdot(b - bw)\cdot\beta1\cdot hf\cdot\left[\frac{Asmax\cdot F - \beta1\cdot fc\cdot(b - bw)\cdot hf}{1.7\cdot fc\cdot b} - \frac{hf}{2}\right], F\right]$$

$fsmax2_{mp} = 32.259$

$$fsmin2_{ns} := \mathrm{root}\left[\left|12\cdot M1_{ns}\right| - 0.9\cdot Asmin\cdot F\cdot\left[d - \frac{Asmin\cdot F - \beta1\cdot fc\cdot(b - bw)\cdot hf}{1.7\cdot fc\cdot b}\right] - 0.85\cdot fc\cdot(b - bw)\cdot\beta1\cdot hf\cdot\left[\frac{Asmin\cdot F - \beta1\cdot fc\cdot(b - bw)\cdot hf}{1.7\cdot fc\cdot b} - \frac{hf}{2}\right], F\right]$$

$fsmin2_{mp} = 64.518$

**Chose values of stress to use (rectangular or "T" stress)**

Max stress (ksi) =

$$fsmax_{ns} := \begin{cases} 0 & \text{if } M1_{ns} = 0 \\ \text{otherwise} & \begin{cases} fsmax1_{ns} & \text{if } ck1_{ns} = \text{"R"} \\ fsmax2_{ns} & \text{otherwise} \end{cases} \end{cases}$$

$fsmax_{mp} = 32.259$

Minimum stress (ksi) =

$$fsmin_{ns} := \begin{cases} 0 & \text{if } M1_{ns} = 0 \\ \text{otherwise} & \begin{cases} fsmin2_{ns} & \text{if } ck1_{ns} = \text{"R"} \\ fsmin2_{ns} & \text{otherwise} \end{cases} \end{cases}$$

$fsmin_{mp} = 64.518$

## Allowable Stress

Cracking factor = $z := 170$

Total Section Height (in) = $height := h + ts$ $height = 53.5$

Distance from extreme tension fiber to CL. reinforcing $dc := \min\left(\left(\frac{cover}{2}\right)\right) + 0.75 + \frac{bd}{2}$ $dc = 3.314$

Effective tension flange area $Amax := \frac{2 \cdot dc \cdot ETFW}{nmax}$ $Amax = 40.504$

$Amin := \frac{2 \cdot dc \cdot ETFW}{nmin}$ $Amin = 81.009$

Allowable Stress $fsamax_{ns} := \min\left[\left[\begin{matrix} \frac{z}{(dc \cdot Amax)^{\frac{1}{3}}} \\ 0.6 \cdot fy \end{matrix}\right]\right]$ $fsamax_{mp} = 33.202$

$fsamin_{ns} := \min\left[\left[\begin{matrix} \frac{z}{(dc \cdot Amin)^{\frac{1}{3}}} \\ 0.6 \cdot fy \end{matrix}\right]\right]$ $fsamin_{mp} = 26.352$

Check max steel for cracking moment $ckmax_{ns} := \left| \begin{matrix} \text{"fail max"} & \text{if } fsamax_{ns} < fsmax_{ns} \\ \text{"pass"} & \text{otherwise} \end{matrix} \right.$ $ckmax_{mp} = \text{"pass"}$

Check min steel for cracking moment $ckmin_{ns} := \left| \begin{matrix} \text{"fail min"} & \text{if } fsamin_{ns} < fsmin_{ns} \\ \text{"pass"} & \text{otherwise} \end{matrix} \right.$ $ckmax_{mp} = \text{"pass"}$

Prepare output display $disp := 0$

$disp_{ns,0} := sp_{ns}$ $disp_{ns,1} := fsmax_{ns}$ $disp_{ns,4} := fsmin_{ns}$

$disp_{ns,2} := fsamax_{ns}$ $disp_{ns,5} := fsamin_{ns}$

$disp_{ns,3} := ckmax_{ns}$ $disp_{ns,6} := ckmin_{ns}$

disp =

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| 0 | 1 | 0 | 33.202 | "pass" | 0 | 26.352 | "pass" |
| 1 | 1.1 | 0 | 33.202 | "pass" | 0 | 26.352 | "pass" |
| 2 | 1.2 | 0 | 33.202 | "pass" | 0 | 26.352 | "pass" |
| 3 | 1.3 | 0 | 33.202 | "pass" | 0 | 26.352 | "pass" |
| 4 | 1.4 | 0 | 33.202 | "pass" | 0 | 26.352 | "pass" |
| 5 | 1.5 | 0 | 33.202 | "pass" | 0 | 26.352 | "pass" |
| 6 | 1.6 | 0 | 33.202 | "pass" | 0 | 26.352 | "pass" |
| 7 | 1.7 | 0 | 33.202 | "pass" | 0 | 26.352 | "pass" |
| 8 | 1.8 | 0.566 | 33.202 | "pass" | 5.27 | 26.352 | "pass" |
| 9 | 1.9 | 13.575 | 33.202 | "pass" | 27.151 | 26.352 | "fail min" |
| 10 | 2 | 32.259 | 33.202 | "pass" | 64.518 | 26.352 | "fail min" |
| 11 | 2.1 | 13.59 | 33.202 | "pass" | 27.18 | 26.352 | "fail min" |
| 12 | 2.2 | 0.566 | 33.202 | "pass" | 5.27 | 26.352 | "pass" |
| 13 | 2.3 | 0 | 33.202 | "pass" | 0 | 26.352 | "pass" |
| 14 | 2.4 | 0 | 33.202 | "pass" | 0 | 26.352 | "pass" |
| 15 | 2.5 | 0 | 33.202 | "pass" | 0 | 26.352 | "pass" |
| 16 | 2.6 | 0 | 33.202 | "pass" | 0 | 26.352 | "pass" |
| 17 | 2.7 | 0 | 33.202 | "pass" | 0 | 26.352 | "pass" |
| 18 | 2.8 | 0 | 33.202 | "pass" | 0 | 26.352 | "pass" |
| 19 | 2.9 | 0 | 33.202 | "pass" | 0 | 26.352 | "pass" |
| 20 | 3 | 0 | 33.202 | "pass" | 0 | 26.352 | "pass" |
| 21 | | | | | | | |

column 0 = span point
column 1 = stress on max
column 2 = allowable on max
column 3 = pass/fail for max
column 4 = stress on min
column 5 = allowable on min
column 6 = pass/fail for min

column 0 = span point
column 1 = stress on max
column 2 = allowable on max
column 3 = pass/fail for max
column 4 = stress on min
column 5 = allowable on min
column 6 = pass/fail for min

# LRFD 5.5.3.2 Fatigue

The stress range in straight reinforcement resulting from the fatigue load combination, specified in Table 3.4.1-1 shall not exceed:

$$ff = 21 - 0.33 \cdot fmin + 8 \cdot \frac{r}{h}$$

ff = stress range (ksi)
fmin = the minimum live load stress resulting from the fatigue load combination specified in Table 3.4.1-1
r/h = ratio f base radius to height of rolled-on trasnverse deformations; if the actual value is not known, 0.3 may be used

Apply LLDF to the fatigue truck = $fp_{ns} := fp1_{ns} \cdot LLDF$ $\quad fp_{mp} = 0$

$fn_{ns} := fn1_{ns} \cdot LLDF$ $\quad fn_{mp} = -422.592$

**Using maximum steel**

Determine if section is rectangular or "T" section for max and min amounts of steel used. The previouse determination was done based on the required steel of a rectangular section. This calculation will be based on the actual steel used (max and min).

"c" value for "T" section $ct := \frac{Asmax \cdot fy - 0.85 \cdot \beta 1 \cdot fc \cdot (b - bw) \cdot hf}{0.85 \cdot fc \cdot \beta 1 \cdot bw}$ $\quad ct = 38.386$

"c" value for rectangular $cr := \frac{Asmax \cdot fy}{0.85 \cdot fc \cdot \beta 1 \cdot b}$ $\quad cr = 16.986$

determine rectantular or "T" $ck2 := \begin{cases} \text{"R"} & \text{if } cr \le tbf \\ \text{"T"} & \text{otherwise} \end{cases}$ $\quad ck2 = \text{"T"}$

jd for rectangular section $jdrmax := d - \frac{Asmax \cdot fy}{0.85 \cdot fc \cdot b}$ $\quad jdrmax = 34.811$

jd for "T" section $jdtmax := d - \frac{\beta 1 \cdot ct}{2}$ $\quad jdtmax = 32.936$

Pick value of jd for rectangular or "T" section $jdmax := \begin{cases} jdrmax & \text{if } ck2 = \text{"R"} \\ jdtmax & \text{otherwise} \end{cases}$ $\quad jdmax = 32.936$

## Stress in steel for fatigue limit state

$$fmaxp_{ns} := \begin{cases} \dfrac{-fp_{ns} \cdot 12}{Asmax \cdot jdmax} & \text{if } fp_{ns} < 0 \\ \dfrac{-fp_{ns} \cdot [yts - (height - d)] \cdot 2 \cdot \eta \cdot 12}{Ic} & \text{otherwise} \end{cases}$$

$fmaxp_{mp} = 0$

$$fmaxn_{ns} := \begin{cases} \dfrac{-fn_{ns} \cdot 12}{Asmax \cdot jdmax} & \text{if } fn_{ns} < 0 \\ \dfrac{-fn_{ns} \cdot [yts - (height - d)] \cdot 2 \cdot \eta \cdot 12}{Ic} & \text{otherwise} \end{cases}$$

$fmaxn_{mp} = 8.554$

Stress range for max steel $ffmax_{ns} := \left| fmaxp_{ns} - fmaxn_{ns} \right|$ $ffmax_{mp} = 8.554$

Min stress for Max steel $fm1_{ns} := \min\left(\left(\begin{matrix} fmaxp_{ns} \\ fmaxn_{ns} \end{matrix}\right)\right)$ $fm1_{mp} = 0$

Allowable stress range $fmax_{ns} := 21 - 0.33 \cdot fm1_{ns} + 8 \cdot 0.3$ $fmax_{mp} = 23.4$

Check stress range $frmax_{ns} := \begin{cases} \text{"fail"} & \text{if } ffmax_{ns} > fmax_{ns} \\ \text{"pass"} & \text{otherwise} \end{cases}$ $frmax_{mp} = \text{"pass"}$

$disp := 0$

$disp_{ns,0} := sp_{ns}$ $disp_{ns,1} := ck2$ $disp_{ns,2} := jdmax$ $disp_{ns,3} := fmaxp_{ns}$ $disp_{ns,4} := fmaxn_{ns}$

$disp_{ns,5} := ffmax_{ns}$ $disp_{ns,6} := fmax_{ns}$ $disp_{ns,7} := frmax_{ns}$

disp =

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| 0 | 1 | "T" | 32.936 | 0 | 0 | 0 | 23.4 | "pass" |
| 1 | 1.1 | "T" | 32.936 | -0.198 | 0.862 | 1.06 | 23.465 | "pass" |
| 2 | 1.2 | "T" | 32.936 | -0.324 | 1.725 | 2.048 | 23.507 | "pass" |
| 3 | 1.3 | "T" | 32.936 | -0.401 | 2.57 | 2.971 | 23.532 | "pass" |
| 4 | 1.4 | "T" | 32.936 | -0.422 | 3.432 | 3.854 | 23.539 | "pass" |
| 5 | 1.5 | "T" | 32.936 | -0.401 | 4.277 | 4.677 | 23.532 | "pass" |
| 6 | 1.6 | "T" | 32.936 | -0.377 | 5.139 | 5.516 | 23.525 | "pass" |
| 7 | 1.7 | "T" | 32.936 | -0.299 | 5.984 | 6.283 | 23.499 | "pass" |
| 8 | 1.8 | "T" | 32.936 | -0.174 | 6.847 | 7.02 | 23.457 | "pass" |
| 9 | 1.9 | "T" | 32.936 | -0.075 | 7.709 | 7.784 | 23.425 | "pass" |
| 10 | 2 | "T" | 32.936 | 0 | 8.554 | 8.554 | 23.4 | "pass" |
| 11 | 2.1 | "T" | 32.936 | -0.075 | 7.709 | 7.784 | 23.425 | "pass" |
| 12 | 2.2 | "T" | 32.936 | -0.174 | 6.847 | 7.02 | 23.457 | "pass" |
| 13 | 2.3 | "T" | 32.936 | -0.299 | 5.984 | 6.283 | 23.499 | "pass" |
| 14 | 2.4 | "T" | 32.936 | -0.377 | 5.139 | 5.516 | 23.525 | "pass" |
| 15 | 2.5 | "T" | 32.936 | -0.401 | 4.277 | 4.677 | 23.532 | "pass" |
| 16 | 2.6 | "T" | 32.936 | -0.422 | 3.432 | 3.854 | 23.539 | "pass" |
| 17 | 2.7 | "T" | 32.936 | -0.401 | 2.57 | 2.971 | 23.532 | "pass" |
| 18 | 2.8 | "T" | 32.936 | -0.324 | 1.725 | 2.048 | 23.507 | "pass" |
| 19 | 2.9 | "T" | 32.936 | -0.198 | 0.862 | 1.06 | 23.465 | "pass" |
| 20 | 3 | "T" | 32.936 | 0 | 0 | 0 | 23.4 | "pass" |
| 21 | | | | | | | | |

0 = span point
1 = section type
2 = "jd" value
3 = stress for positive moment
4 = stress for negative moment
5 = stress range
6 = allowable stress range
7 = pass/fail

## Using minimum steel

Determine if section is rectangular or "T" section for max and min amounts of steel used. The previouse determination was done based on the required steel of a rectangular section. This calculation will be based on the actual steel used (max and min).

"c" value for "T" section $ct := \frac{Asmin \cdot fy - 0.85 \cdot \beta 1 \cdot fc \cdot (b - bw) \cdot hf}{0.85 \cdot fc \cdot \beta 1 \cdot bw}$ $ct = 11.693$

"c" value for rectangular $cr := \frac{Asmin \cdot fy}{0.85 \cdot fc \cdot \beta 1 \cdot b}$ $cr = 8.493$

determine rectantular or "T" $ck2 := \begin{cases} \text{"R"} & \text{if } cr \le tbf \\ \text{"T"} & \text{otherwise} \end{cases}$ $ck2 = \text{"T"}$

jd for rectangular section $jdrmin := d - \frac{Asmax \cdot fy}{0.85 \cdot fc \cdot b}$ $jdrmin = 34.811$

jd for "T" section $jdtmin := d - \frac{\beta 1 \cdot ct}{2}$ $jdtmin = 44.28$

Pick value of jd for rectangular or "T" section $jdmin := \begin{cases} jdrmin & \text{if } ck2 = \text{"R"} \\ jdtmin & \text{otherwise} \end{cases}$ $jdmin = 44.28$

## Stress in steel for fatigue limit state

$$fminp_{ns} := \begin{cases} \dfrac{-fp_{ns} \cdot 12}{Amin \cdot jdmin} & \text{if } fp_{ns} < 0 \\ \dfrac{-fp_{ns} \cdot [yts - (height - d)] \cdot 2 \cdot \eta \cdot 12}{Ic} & \text{otherwise} \end{cases}$$

$fminp_{mp} = 0$

$$fminn_{ns} := \begin{cases} \dfrac{-fn_{ns} \cdot 12}{Asmin \cdot jdmin} & \text{if } fn_{ns} < 0 \\ \dfrac{-fn_{ns} \cdot [yts - (height - d)] \cdot 2 \cdot \eta \cdot 12}{Ic} & \text{otherwise} \end{cases}$$

$fminn_{mp} = 12.725$

Stress range for min steel $ffmin_{ns} := \left| fminp_{ns} - fminn_{ns} \right|$ $ffmin_{mp} = 12.725$

Min stress for Min steel $fm2_{ns} := \min\left(\begin{pmatrix} fminp_{ns} \\ fminn_{ns} \end{pmatrix}\right)$ $fm2_{mp} = 0$

Allowable stress range $fmin_{ns} := 21 - 0.33 \cdot fm1_{ns} + 8 \cdot 0.3$ $fmin_{mp} = 23.4$

Check stress range $frmin_{ns} := \begin{cases} \text{"fail"} & \text{if } ffmin_{ns} > fmin_{ns} \\ \text{"pass"} & \text{otherwise} \end{cases}$ $frmin_{mp} = \text{"pass"}$

$disp := 0$

$disp_{ns,0} := sp_{ns}$ $disp_{ns,1} := ck2$ $disp_{ns,2} := jdmin$ $disp_{ns,3} := fminp_{ns}$ $disp_{ns,4} := fminn_{ns}$

$disp_{ns,5} := ffmin_{ns}$ $disp_{ns,6} := fmin_{ns}$ $disp_{ns,7} := frmin_{ns}$

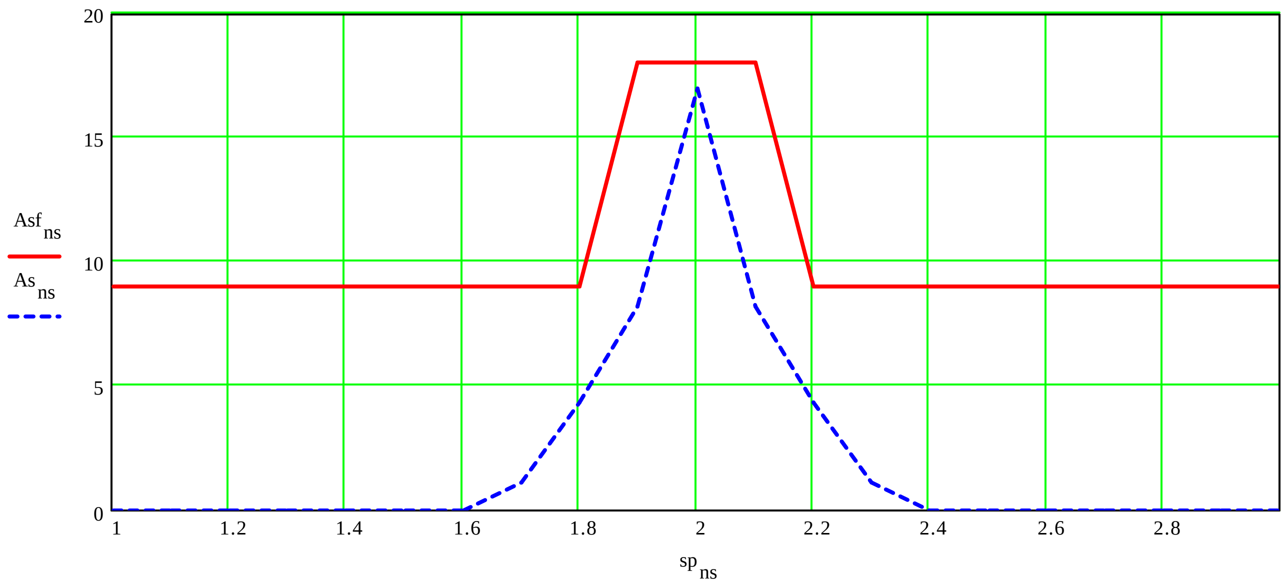
disp =

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| 0 | 1 | "T" | 44.28 | 0 | 0 | 0 | 23.4 | "pass" |
| 1 | 1.1 | "T" | 44.28 | -0.198 | 1.283 | 1.481 | 23.465 | "pass" |
| 2 | 1.2 | "T" | 44.28 | -0.324 | 2.565 | 2.889 | 23.507 | "pass" |
| 3 | 1.3 | "T" | 44.28 | -0.401 | 3.823 | 4.224 | 23.532 | "pass" |
| 4 | 1.4 | "T" | 44.28 | -0.422 | 5.105 | 5.528 | 23.539 | "pass" |
| 5 | 1.5 | "T" | 44.28 | -0.401 | 6.362 | 6.763 | 23.532 | "pass" |
| 6 | 1.6 | "T" | 44.28 | -0.377 | 7.645 | 8.022 | 23.525 | "pass" |
| 7 | 1.7 | "T" | 44.28 | -0.299 | 8.902 | 9.201 | 23.499 | "pass" |
| 8 | 1.8 | "T" | 44.28 | -0.174 | 10.185 | 10.359 | 23.457 | "pass" |
| 9 | 1.9 | "T" | 44.28 | -0.075 | 11.468 | 11.543 | 23.425 | "pass" |
| 10 | 2 | "T" | 44.28 | 0 | 12.725 | 12.725 | 23.4 | "pass" |
| 11 | 2.1 | "T" | 44.28 | -0.075 | 11.468 | 11.543 | 23.425 | "pass" |
| 12 | 2.2 | "T" | 44.28 | -0.174 | 10.185 | 10.359 | 23.457 | "pass" |
| 13 | 2.3 | "T" | 44.28 | -0.299 | 8.902 | 9.201 | 23.499 | "pass" |
| 14 | 2.4 | "T" | 44.28 | -0.377 | 7.645 | 8.022 | 23.525 | "pass" |
| 15 | 2.5 | "T" | 44.28 | -0.401 | 6.362 | 6.763 | 23.532 | "pass" |
| 16 | 2.6 | "T" | 44.28 | -0.422 | 5.105 | 5.528 | 23.539 | "pass" |
| 17 | 2.7 | "T" | 44.28 | -0.401 | 3.823 | 4.224 | 23.532 | "pass" |
| 18 | 2.8 | "T" | 44.28 | -0.324 | 2.565 | 2.889 | 23.507 | "pass" |
| 19 | 2.9 | "T" | 44.28 | -0.198 | 1.283 | 1.481 | 23.465 | "pass" |
| 20 | 3 | "T" | 44.28 | 0 | 0 | 0 | 23.4 | "pass" |
| 21 | | | | | | | | |

0 = span point
1 = section type
2 = "jd" value
3 = stress for positive moment
4 = stress for negative moment
5 = stress range
6 = allowable stress range
7 = pass/fail

# *Final steel selection*

$$Asf_{ns} := \begin{cases} Asmin & \text{if } (Asmin > As_{ns}) \cdot (ckmin_{ns} = \text{"pass"}) \cdot (frmin_{ns} = \text{"pass"}) \\ \text{otherwise} & \begin{cases} Asmax & \text{if } (Asmax > As_{ns}) \cdot (ckmax_{ns} = \text{"pass"}) \cdot (frmax_{ns} = \text{"pass"}) \\ \text{"fail"} & \text{otherwise} \end{cases} \end{cases}$$

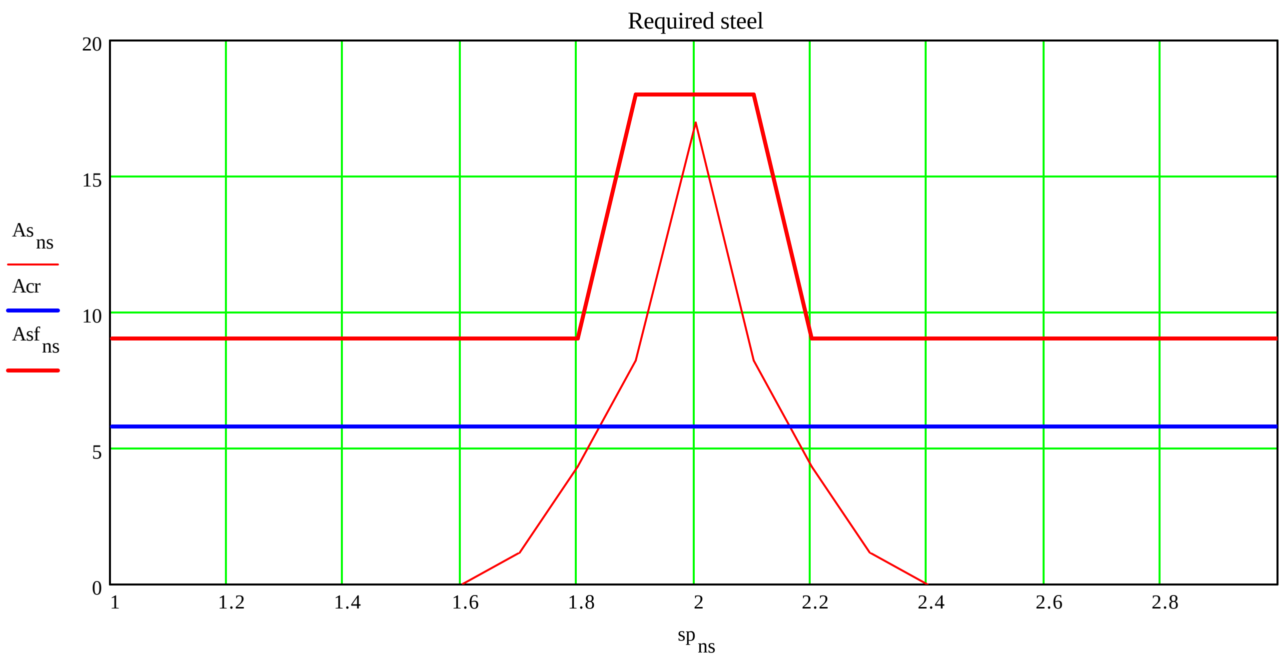



**Embedment length (in)**

$$embed := \max\left(\begin{pmatrix} 15 \cdot bd \\ d \\ \frac{span_0}{12} \cdot 12 \end{pmatrix}\right)$$

$embed = 77$

# *Final bar output data*




Size of bar used = size = 9

disp =

| | 0 | 1 | 2 |
|---|---|---|---|
| 0 | 1 | 0 | 9 |
| 1 | 1.1 | 0 | 9 |
| 2 | 1.2 | 0 | 9 |
| 3 | 1.3 | 0 | 9 |
| 4 | 1.4 | 0 | 9 |
| 5 | 1.5 | 0 | 9 |
| 6 | 1.6 | 0 | 9 |
| 7 | 1.7 | 1.112 | 9 |
| 8 | 1.8 | 4.295 | 9 |
| 9 | 1.9 | 8.197 | 18 |
| 10 | 2 | 16.955 | 18 |
| 11 | 2.1 | 8.204 | 18 |
| 12 | 2.2 | 4.295 | 9 |
| 13 | 2.3 | 1.112 | 9 |
| 14 | 2.4 | 0 | 9 |
| 15 | 2.5 | 0 | 9 |
| 16 | 2.6 | 0 | 9 |
| 17 | 2.7 | 0 | 9 |
| 18 | 2.8 | 0 | 9 |
| 19 | 2.9 | 0 | 9 |
| 20 | 3 | 0 | 9 |
| 21 | | | |

column 0 = span point
column 1 = Total area of steel required
column 2 = Number of bars per beam