Attachment K. Supplemental Shear Test Information

Computer Program

Due to the iterative nature of shear design following the General Procedure in Article 5.8.3.4.2 of the AASHTO LRFD Bridge Specifications a computer program was developed in order to help speed up the calculation process. The program was created through the use of the software, Mathcad, v. 14.0, copyrighted by Parametric Technology Corporation. The main program appears in Figure K-1, with the supplemental subroutines shown in Figure K-2. There was a third program, also developed using Mathcad, that helped to interpolate the tabularized values for β and θ found in Appendix B5 of the AASHTO LRFD Bridge Specifications. This program is not presented here due to the size of the program rendering the program impractical to display. Although the equations used in Article 5.8.3.4.2 are certainly easier than interpolating the tabularized values, the initial research started prior to having access to the latest design code. Furthermore, the results using the β and θ equations proved to be even more conservative than the original LRFD method.

Although not nearly as iterative in nature, a computer program was also developed for calculating the shear strength following the Simplified Procedure for Prestressed and Nonprestressed Sections in Article 5.8.4.3.3 of the AASHTO LRFD Bridge Specifications. That program is given in

```
calc = | ShearStrengthCheckFinal ← "NG"
       | iterations ← 0
       | iterations_θ.tot ← 0
       | for  i ∈ 1.. rows(P_assume)
       |   θ_i ← 28
       | while  ShearStrengthCheckFinal = "NG"
       |   | iterations ← iterations + 1
       |   | for  i ∈ 1.. 1
       |   |   | x_dist ← x_θ(x_critical.assume)_1
       |   |   | if  rows(x_dist) ≠ rows(P_assume)
       |   |   |   | for  i ∈ 1.. rows(x_dist)          if  rows(x_dist) < rows(P_assume)
       |   |   |   |   | P_assume.old_i ← P_assume_i
       |   |   |   |   | θold_i ← θ_i
       |   |   |   | for  i ∈ 1.. rows(x_dist) − rows(P_assume)          if  rows(x_dist) > rows(P_assume)
       |   |   |   |   | P_assume.old ← P_assume
       |   |   |   |   | P_assume.old_i+rows(P_assume) ← P_assume_rows(P_assume)
       |   |   |   |   | θ_old ← θ
       |   |   |   |   | θold_i+rows(P_assume) ← θ_rows(P_assume)
       |   |   |   | P_assume ← P_assume.old
       |   |   |   | θ ← θ_old
       |   |   | LiveLoad ← Load_Live(x_dist, P_assume, ShearSpan, LoadSpacing, L_span)
       |   |   | DeadLoad ← Dead_Load(x_dist, L_span, x_bearing, x_bearing.roller, ShearSpan, w_beam, DC_1, DC_2, DW, P_diaphragm)
       |   |   | V_assume ← [1.00(DeadLoad^⟨5⟩ + DeadLoad^⟨7⟩) + 1.00·DeadLoad^⟨9⟩ + 1.00 LiveLoad^⟨3⟩]·kip
       |   |   | M_assume1 ← [1.00·(DeadLoad^⟨6⟩ + DeadLoad^⟨8⟩) + 1.00 DeadLoad^⟨10⟩ + 1.00 LiveLoad^⟨4⟩]·kip·ft
       |   |   | V_p ← V_p.(x_dist)
       |   |   | cg_harp ← cg_harp.(x_dist)
       |   |   | f_c'c ← | f_c'deck  if  f_c'deck > 0
       |   |   |         | f_c'  otherwise
       |   |   | β_1 ← β_1.(f_c'c)
       |   | for  i ∈ 1.. rows(x_dist)
       |   |   | cg_ps_i ← (Num_straight·cg_straight + Num_harp·cg_harp_i) / Num_strand
       |   |   | d_p_i ← h_c − cg_ps_i
       |   | c ← c_calc(x_dist, A_ps, f_pu, A_s.bot, A_s.top, f_y, f_c'c, β_1, b_eff, b_v, h_flange, k, d_p)
```

Figure K-1. Mathcad program used to calculate the design shear strength of a girder.

$c \leftarrow c_{calc}(x_{dist}, A_{ps}, f_{pu}, A_{s.bot}, A_{s.top}, f_y, f_{c'c}, \beta_1, b_{eff}, b_v, h_{flange}, k, d_p)$

for $i \in 1..\text{rows}(x_{dist})$

$f_{ps.max_i} \leftarrow f_{pu} \cdot \left(1 - k \cdot \frac{c_i}{d_{p_i}}\right)$

$l_{d.ps_i} \leftarrow \kappa \cdot \left(f_{ps.max_i} - \frac{2}{3} \cdot f_{pe}\right)\varphi$

$f_{ps} \leftarrow f_{ps.}(x_{dist}, l_{d.ps}, f_{ps.max})$

$\varepsilon_{s.yield} \leftarrow \frac{f_y}{E_s}$

$Num_{strand.bot} \leftarrow Num_{strand.bot.}(x_{dist}, cg_{harp})$

$cg_{ps.bot} \leftarrow cg_{ps.bot.}(x_{dist}, cg_{straight}, cg_{harp}, h_c, Num_{straight})$

for $i \in 1..\text{rows}(x_{dist})$

$d_{p.bot_i} \leftarrow h_c - cg_{ps.bot_i}$

$d_{s.bot_i} \leftarrow h_c - cg_{s.bot_i}$

$A_{ps.bot_i} \leftarrow Num_{strand.bot_i} A_{strand}$

$d_{e_i} \leftarrow \frac{A_{ps.bot_i} \cdot f_{ps_i} \cdot d_{p.bot_i} + A_{s.bot_i} \cdot f_y \cdot d_{s.bot_i}}{A_{ps.bot_i} \cdot f_{ps_i} + A_{s.bot_i} \cdot f_y}$

$\varepsilon_{s_i} \leftarrow \frac{0.003}{c_i} \cdot \left(d_{e_i} - c_i\right)$

return $\left(\text{"Tension steel does not yield at x.dist (inches)"} \quad \frac{x_{dist_i}}{in}\right)$ if $\varepsilon_{s_i} < \varepsilon_{s.yield}$

$a_i \leftarrow \beta_1 \cdot c_i$

$d_{v_i} \leftarrow \max\left(d_{e_i} - \frac{a_i}{2}, 0.9 d_{e_i}, 0.72 h_c\right)$

$M_{assume_i} \leftarrow \max\left(M_{assume1_i}, \left|V_{assume_i} - V_{p_i}\right| \cdot d_{v_i}\right)$

$v_u \leftarrow v_{u.}(x_{dist}, V_{assume}, V_p, d_v, MinReinforcingCheck)$

$l_{d.mild} \leftarrow l_{d.mild.}(d_{long.rebar}, f_{c'}, f_y, IsTopBarEffectApplicable, IsLongSteelEpoxyCoated, LongSteelCover, LongSteelCl$

for $i \in 1..\text{rows}(x_{dist})$

$RedFactor_{\varepsilon x.ps_i} \leftarrow \begin{cases} \frac{x_{dist_i} + x_{bearing}}{l_{d.ps_i}} & \text{if } x_{dist_i} + x_{bearing} < l_{d.ps_i} \\ 1 & \text{if } x_{dist_i} + x_{bearing} \ge l_{d.ps_i} \end{cases}$

$A_{ps.bot.\varepsilon x_i} \leftarrow Num_{strand.bot_i} \cdot A_{strand} \cdot RedFactor_{\varepsilon x.ps_i}$

Figure K-1 (cont.) Mathcad program used to calculate the design shear strength

```
A_ps.bot.εx_i ← Num_strand.bot_i · A_strand · RedFactor_εx.ps_i

RedFactor_εx.s_i ← | (x_dist_i + x_bearing) / l_d.mild   if x_dist_i + x_bearing < l_d.mild
                   | 1  if  x_dist_i + x_bearing ≥ l_d.mild

A_s.bot.εx_i ← A_s.bot_i · RedFactor_εx.s_i

θβ ← θ_iterate(x_dist, A_ps.bot.εx, A_s.bot.εx, f_ps, c, d_p, M_assume, d_v, V_assume, V_p, θ, cg_harp, v_u, MinReinforcingCheck ,
θ ← θβ_1
β ← θβ_2
iterations_θ.tot ← iterations_θ.tot + θβ_3   if θβmethod = "General"
V_r ← V_r.(x_dist, β, d_v, θ, s_v.design, V_p)
for i ∈ 1.. rows(x_dist)
    ShearStrengthCheck_i ← "OK"   if V_r_i − V_assume_i ≤ 0.1kip ∧ V_r_i − V_assume_i ≥ 0kip
    if V_r_i − V_assume_i > 0.1kip ∨ V_r_i − V_assume_i < 0kip
        ShearStrengthCheck_i ← "NG!!!"
        ShearStrengthSum ← ShearStrengthSum + 1
        V_assume_i ← 1/2 (V_r_i + V_assume_i) − 0.01kip
        P_assume_i ← | [V_assume_i − [1.00[(DeadLoad^⟨5⟩)_i + (DeadLoad^⟨7⟩)_i] + 1.00·(DeadLoad^⟨9⟩)_i]·kip]·L_span / [2(L_span − ShearSpan) − LoadSpacing]   if x_d
                     | [V_assume_i − [1.00[(DeadLoad^⟨5⟩)_i + (DeadLoad^⟨7⟩)_i] + 1.00·(DeadLoad^⟨9⟩)_i]·kip]·L_span / (L_span − 2ShearSpan − LoadSpacing)   if Sh
                     | [V_assume_i − [1.00[(DeadLoad^⟨5⟩)_i + (DeadLoad^⟨7⟩)_i] + 1.00·(DeadLoad^⟨9⟩)_i]·kip]·L_span / (2ShearSpan + LoadSpacing)   if x_d
vect_elemnt_x.critical ← x_θ(x_critical.assume)_2 / in
for i ∈ 1.. 1
    ShearStrengthCheckFinal ← "OK"   if ShearStrengthSum = 0 ∨ iterations > 500
    if rows(vect_elemnt_x.critical) > 1
        d_v.critical ← d_v(vect_elemnt_x.critical_1)
        θ_critical ← θ(vect_elemnt_x.critical_1)
    if rows(vect_elemnt_x.critical) ≤ 1
        d_v.critical ← d_v(vect_elemnt_x.critical)
        θ_critical ← θ(vect_elemnt_x.critical)
```


Figure K-1 (cont.) Mathcad program used to calculate the design shear strength

$$\theta_{critical} \leftarrow \theta_{(vect\_elemnt_{x.critical})}$$

$$x_{critical.assume} \leftarrow \max\left(d_{v.critical}, \frac{1}{2} \cdot d_{v.critical} \cdot \cot\left(\theta_{critical} \cdot \frac{\pi}{180}\right)\right)$$

$$\left(V_{n.critical} \quad x_{critical}\right) \leftarrow (0 \quad 0)$$

$$\text{for } i \in 1..\text{rows}(vect\_elemnt_{x.critical}) \quad \text{if rows}(vect\_elemnt_{x.critical}) > 1$$

$$V_{n.critical_i} \leftarrow V_{r\left(vect\_elemnt_{x.critical_i}\right)}$$

$$x_{critical_i} \leftarrow x_{dist\left(vect\_elemnt_{x.critical_i}\right)}$$

$$\text{if rows}(vect\_elemnt_{x.critical}) \le 1$$

$$V_{n.critical} \leftarrow V_{r_{vect\_elemnt_{x.critical}}}$$

$$x_{critical} \leftarrow x_{dist_{vect\_elemnt_{x.critical}}}$$

$$\text{for } i \in 1..\text{rows}(x_{dist})$$

$$\theta\beta calc_i \leftarrow \text{"Simple"} \quad \text{if } \theta\beta method = \text{"Simple"} \wedge \left(N_u = 0 \wedge MinReinforcingCheck_i = \text{"OK"} \vee h_c < 16in\right)$$

$$\theta\beta calc_i \leftarrow \text{"General"} \quad \text{if } \theta\beta method = \text{"General"}$$

$$\text{"error"} \quad \text{otherwise}$$

$$\left(\frac{V_r}{kip} \quad \frac{P_{assume}}{kip} \quad \theta \quad \beta \quad \frac{x_{dist}}{in} \quad \frac{x_{critical}}{in} \quad \frac{V_{n.critical}}{kip} \quad iterations \quad iterations_{\theta.tot} \quad \theta\beta calc \quad MinReinforcingCheck \quad \varepsilon_s\right)$$

Figure K-1 (cont.) Mathcad program used to calculate the design shear strength

$$\kappa = \frac{in^2}{kip} \cdot \begin{cases} 1.6 & \text{if } h \geq 24in \\ 1.0 & \text{if } h < 24in \\ \text{"error"} & \text{otherwise} \end{cases}$$

$$f_{r.V} = \begin{cases} 0.20 \cdot \sqrt{\frac{f_{c'}}{ksi}}\, ksi & \text{if FineAggType = "sand"} \\ \left(0.17 \cdot \sqrt{\frac{f_{c'}}{ksi}}\, ksi\right) & \text{if FineAggType = "lightweight"} \\ \text{"error"} & \text{otherwise} \end{cases}$$

$$cg_{harp.}(x_{dist}) = \left| \begin{array}{l} cg_{harp} \leftarrow 0 \\ \text{for } i \in 1..\, rows(x_{dist}) \\ \quad \left| \begin{array}{l} cg_{harp_i} \leftarrow \left[cg_{harp.end} - \left(x_{dist_i} + x_{bearing}\right)\tan\left(\Psi_{harp}\right)\right] \ \text{ if } x_{dist_i} \leq HarpDist \\ cg_{harp_i} \leftarrow cg_{harp.ms} \ \text{ if } x_{dist_i} > HarpDist \\ cg_{harp_i} \leftarrow \text{"error"} \ \text{ otherwise} \end{array} \right. \\ cg_{harp} \end{array} \right.$$

$$A_{rebar}(r, RebarSize) = \left| \begin{array}{l} \text{for } i \in 1..\, r \\ \quad \left| \begin{array}{l} A_{rebar_i} \leftarrow 0.0438 \text{ if } RebarSize_i = 1.9 \\ A_{rebar_i} \leftarrow 0.0491 \text{ if } RebarSize_i = 2 \\ A_{rebar_i} \leftarrow 0.078 \text{ if } RebarSize_i = 2.5 \\ A_{rebar_i} \leftarrow 0.11 \text{ if } RebarSize_i = 3 \\ A_{rebar_i} \leftarrow 0.20 \text{ if } RebarSize_i = 4 \\ A_{rebar_i} \leftarrow 0.31 \text{ if } RebarSize_i = 5 \\ A_{rebar_i} \leftarrow 0.44 \text{ if } RebarSize_i = 6 \\ A_{rebar_i} \leftarrow 0.60 \text{ if } RebarSize_i = 7 \\ A_{rebar_i} \leftarrow 0.79 \text{ if } RebarSize_i = 8 \\ A_{rebar_i} \leftarrow 1.00 \text{ if } RebarSize_i = 9 \\ A_{rebar_i} \leftarrow 1.27 \text{ if } RebarSize_i = 10 \\ A_{rebar_i} \leftarrow 1.56 \text{ if } RebarSize_i = 11 \\ A_{rebar_i} \leftarrow 0 \text{ if } RebarSize_i = 0 \end{array} \right. \\ A_{rebar} \end{array} \right. \cdot in^2$$

Figure K-2. Subroutines used in the main calculation program given in Figure K-1.

$$\alpha_v = \begin{cases} 1 & \text{if ConcreteType = "NWC"} \vee \text{ConcreteType = "LWC"} \wedge \text{Value\_}f_{ct} = \text{"specified"} \wedge 4.7 \cdot f_{ct} \geq \sqrt{f_{c'} \cdot ksi} \\ \dfrac{4.7 \cdot f_{ct}}{\sqrt{f_{c'} \cdot ksi}} & \text{if ConcreteType = "LWC"} \wedge \text{Value\_}f_{ct} = \text{"specified"} \wedge 4.7 \cdot f_{ct} \leq \sqrt{f_{c'} \cdot ksi} \\ 0.85 & \text{if ConcreteType = "LWC"} \wedge \text{Value\_}f_{ct} = \text{"not specified"} \wedge \text{FineAggType = "sand"} \\ 0.75 & \text{if ConcreteType = "LWC"} \wedge \text{Value\_}f_{ct} = \text{"not specified"} \wedge \text{FineAggType = "lightweight"} \\ \text{"error"} & \text{otherwise} \end{cases}$$

$$\text{MinReinforcingCheck}_r = \begin{cases} \text{"OK"} & \text{if } 0.0316\alpha_v \cdot \sqrt{f_{c'} \cdot (ksi)} \cdot \dfrac{b_v \cdot s_{v.design_r}}{f_{yv}} \leq A_{v_r} \\ \text{"NG!!!"} & \text{if } 0.0316\alpha_v \cdot \sqrt{f_{c'} \cdot (ksi)} \cdot \dfrac{b_v \cdot s_{v.design_r}}{f_{yv}} > A_{v_r} \\ \text{"error"} & \text{otherwise} \end{cases}$$

$$\beta_1.(f_{c'deck}) = \begin{cases} 0.85 & \text{if } f_{c'deck} \leq 4ksi \\ \max\left[0.85 - 0.05 \cdot \left(\dfrac{f_{c'deck}}{ksi} - 4.0\right), 0.65\right] & \text{if } f_{c'deck} > 4ksi \end{cases}$$

$\text{x\_}\theta(x_{critical.assume}) =$

```
(x  x_1  m  o) ← (0  0  1  0)
x ← 0
x_1 ← 0
m ← 1
for i ∈ 1..12
    if 0.1ShearSpan·(i − 1) < x_critical.assume ∧ x_critical.assume ≤ 0.1ShearSpan·(i)
        x_(i+1) ← x_critical.assume
        n ← i + 1
    if 0.1ShearSpan·(i − 1) < ShearSpan − x_critical.assume ∧ ShearSpan − x_critical.assume ≤ 0.1ShearSpan·
        x_(i+2) ← ShearSpan − x_critical.assume
        o ← i + 2
for i ∈ 2..13
    m ← 2  if i = n
    m ← 3  if i = o
    (break)  if i = 13 ∧ x_critical.assume > (1/2)ShearSpan
    x_i ← 0.1ShearSpan·(i − m)  otherwise
X_1 ← x
X_2 ← | (n o)^T·in  if o > 0
      | (n·in)  if o = 0
      | "error"  otherwise
X
```


Figure K-2 (cont.) Subroutines used in the main calculation program given in Figure K-1.

$$
\begin{aligned}
\mathrm{Load}_{\mathrm{Live}}(x_{dist}) = \;\; & x_{dist} \leftarrow \frac{x_{dist}}{ft} \\
& V_{assume} \leftarrow \frac{V_{assume}}{kip} \\
& \mathrm{ShearSpan} \leftarrow \frac{\mathrm{ShearSpan}}{ft} \\
& \mathrm{LoadSpacing} \leftarrow \frac{\mathrm{LoadSpacing}}{ft} \\
& L_{span} \leftarrow \frac{L_{span}}{ft} \\
& \text{for } i \in 1..\, \mathrm{rows}(x_{dist}) \\
& \quad x\%_i \leftarrow \frac{x_{dist_i}}{\mathrm{ShearSpan}} \\
& \quad \text{if } x_{dist_i} \le \mathrm{ShearSpan} + 10^{-12} \\
& \quad\quad V_{LL_i} \leftarrow \frac{V_{assume_i}}{L_{span}} \cdot \left[2\left(L_{span} - \mathrm{ShearSpan}\right) - \mathrm{LoadSpacing}\right] \\
& \quad\quad M_{LL_i} \leftarrow \frac{V_{assume_i}}{L_{span}} \cdot \left[2\left(L_{span} - \mathrm{ShearSpan}\right) - \mathrm{LoadSpacing}\right] \cdot x_{dist_i} \\
& \quad \text{if } \mathrm{ShearSpan} + 10^{-12} < x_{dist_i} \wedge x_{dist_i} \le \mathrm{ShearSpan} + \mathrm{LoadSpacing} \\
& \quad\quad V_{LL_i} \leftarrow \frac{V_{assume_i}}{L_{span}} \left(L_{span} - 2\mathrm{ShearSpan} - \mathrm{LoadSpacing}\right) \\
& \quad\quad M_{LL_i} \leftarrow \frac{V_{assume_i}}{L_{span}} \cdot \left[2\left(L_{span} - \mathrm{ShearSpan}\right) - \mathrm{LoadSpacing}\right] \cdot x_{dist_i} - V_{assume_i} \cdot \left(x_{dist_i} - \mathrm{ShearSpan}\right) \\
& \quad \text{if } x_{dist_i} > \mathrm{ShearSpan} + \mathrm{LoadSpacing} \\
& \quad\quad V_{LL_i} \leftarrow -\frac{V_{assume_i}}{L_{span}} \cdot (2\mathrm{ShearSpan} + \mathrm{LoadSpacing}) \\
& \quad\quad M_{LL_i} \leftarrow \frac{V_{assume_i}}{L_{span}} \cdot (2\mathrm{ShearSpan} + \mathrm{LoadSpacing}) \cdot \left(L_{span} - x_{dist_i}\right) \\
& \mathrm{ans} \leftarrow \mathrm{augment}\left(x_{dist}, x\%, V_{LL}, M_{LL}\right) \\
& \mathrm{ans}
\end{aligned}
$$

Figure K-2 (cont.) Subroutines used in the main calculation program given in Figure K-1.

$$
\mathrm{Dead}_{\mathrm{Load}}(x_{dist}) =
\begin{array}{|l}
x_{dist} \leftarrow \dfrac{x_{dist}}{ft} \\
L_{span} \leftarrow \dfrac{L_{span}}{ft} \\
x_{bearing} \leftarrow \dfrac{x_{bearing}}{ft} \\
x_{bearing.roller} \leftarrow \dfrac{x_{bearing.roller}}{ft} \\
ShearSpan \leftarrow \dfrac{ShearSpan}{ft} \\
w_{beam} \leftarrow \dfrac{w_{beam}}{klf} \\
DC_1 \leftarrow \dfrac{DC_1}{klf} \\
DC_2 \leftarrow \dfrac{DC_2}{klf} \\
DW \leftarrow \dfrac{DW}{klf} \\
P_{diaphragm} \leftarrow \dfrac{P_{diaphragm}}{kip} \\
\text{for } i \in 1..\, rows(x_{dist}) \\
\quad \begin{array}{|l}
x\%_i \leftarrow \dfrac{x_{dist_i}}{ShearSpan} \\
V_{beam_i} \leftarrow \dfrac{w_{beam}}{2L_{span}} \cdot (x_{bearing} + L_{span} + x_{bearing.roller})^2 - \dfrac{w_{beam} \cdot x_{bearing.roller}}{L_{span}} (x_{bearing} + L_{span} + x_{bearing.roller}) - w_{beam} \cdot \left(x_{dist_i} + x_{bearing}\right) \\
M_{beam_i} \leftarrow \left[\left(\dfrac{w_{beam}}{2L_{span}}\right)(x_{bearing} + L_{span} + x_{bearing.roller})^2 - \dfrac{w_{beam} \cdot x_{bearing.roller}}{L_{span}} (x_{bearing} + L_{span} + x_{bearing.roller})\right] \cdot x_{dist_i} - \dfrac{1}{2} w_{beam} \cdot \left(x_{dist_i} + x_{bea}\right. \\
V_{diaphragm_i} \leftarrow P_{diaphragm} \quad \text{if } x_{dist_i} < \dfrac{L_{span}}{3}
\end{array}
\end{array}
$$

Figure K-2 (cont.) Subroutines used in the main calculation program given in Figure K-1.

$$V_{diaphragm_i} \leftarrow P_{diaphragm} \quad \text{if } x_{dist_i} < \frac{L_{span}}{3}$$

$$V_{diaphragm_i} \leftarrow 0 \quad \text{otherwise}$$

$$M_{diaphragm_i} \leftarrow P_{diaphragm} \cdot x_{dist_i} \quad \text{if } x_{dist_i} < \frac{L_{span}}{3}$$

$$M_{diaphragm_i} \leftarrow P_{diaphragm} \cdot \frac{L_{span}}{3} \quad \text{otherwise}$$

$$V_{DC1_i} \leftarrow \frac{DC_1}{2L_{span}} \cdot \left(x_{bearing} + L_{span} + x_{bearing.roller}\right)^2 - \frac{DC_1 \cdot x_{bearing.roller}}{L_{span}}\left(x_{bearing} + L_{span} + x_{bearing.roller}\right) - DC_1 \cdot \left(x_{dist_i} + x_{bearing}\right) + V_{diaphragm_i}$$

$$M_{DC1_i} \leftarrow \left[\left(\frac{DC_1}{2L_{span}}\right)\left(x_{bearing} + L_{span} + x_{bearing.roller}\right)^2 - \frac{DC_1 \cdot x_{bearing.roller}}{L_{span}}\left(x_{bearing} + L_{span} + x_{bearing.roller}\right)\right] \cdot x_{dist_i} - \frac{1}{2} DC_1 \cdot \left(x_{dist_i} + x_{bearing}\right)^2 + M_{diaphragm_i}$$

$$V_{DC2_i} \leftarrow \frac{DC_2}{2L_{span}} \cdot \left(x_{bearing} + L_{span} + x_{bearing.roller}\right)^2 - \frac{DC_2 \cdot x_{bearing.roller}}{L_{span}}\left(x_{bearing} + L_{span} + x_{bearing.roller}\right) - DC_2 \cdot \left(x_{dist_i} + x_{bearing}\right)$$

$$M_{DC2_i} \leftarrow \left[\left(\frac{DC_2}{2L_{span}}\right)\left(x_{bearing} + L_{span} + x_{bearing.roller}\right)^2 - \frac{DC_2 \cdot x_{bearing.roller}}{L_{span}}\left(x_{bearing} + L_{span} + x_{bearing.roller}\right)\right] \cdot x_{dist_i} - \frac{1}{2} DC_2 \cdot \left(x_{dist_i} + x_{bearing}\right)^2$$

$$V_{DW_i} \leftarrow \frac{DW}{2L_{span}} \cdot \left(x_{bearing} + L_{span} + x_{bearing.roller}\right)^2 - \frac{DW \cdot x_{bearing.roller}}{L_{span}}\left(x_{bearing} + L_{span} + x_{bearing.roller}\right) - DW \cdot \left(x_{dist_i} + x_{bearing}\right)$$

$$M_{DW_i} \leftarrow \left[\left(\frac{DW}{2L_{span}}\right)\left(x_{bearing} + L_{span} + x_{bearing.roller}\right)^2 - \frac{DW \cdot x_{bearing.roller}}{L_{span}}\left(x_{bearing} + L_{span} + x_{bearing.roller}\right)\right] \cdot x_{dist_i} - \frac{1}{2} DW \cdot \left(x_{dist_i} + x_{bearing}\right)^2$$

$$ans \leftarrow augment\left(x_{dist}, x\%, V_{beam}, M_{beam}, V_{DC1}, M_{DC1}, V_{DC2}, M_{DC2}, V_{DW}, M_{DW}\right)$$

$$ans$$

Figure K-2 (cont.) Subroutines used in the main calculation program given in Figure K-1.

$$V_{p.}(x_{dist}) = \left| \begin{array}{l} V_p \leftarrow 0 \\ \text{for } i \in 1..\text{rows}(x_{dist}) \\ \quad \left| \begin{array}{l} V_{p_i} \leftarrow \dfrac{f_{pe}\cdot\left(x_{dist_i} + x_{bearing}\right)}{l_t}\cdot Num_{harp}\cdot A_{strand}\cdot \sin\left(\Psi_{harp}\right) \ \text{ if } x_{dist_i} + x_{bearing} \le l_t \wedge x_{dist_i} \le L_{span}\cdot HarpDistRatio \\ V_{p_i} \leftarrow f_{pe}\cdot Num_{harp}\cdot A_{strand}\cdot \sin\left(\Psi_{harp}\right) \ \text{ if } x_{dist_i} + x_{bearing} > l_t \wedge x_{dist_i} \le L_{span}\cdot HarpDistRatio \\ V_{p_i} \leftarrow 0 \ \text{ if } x_{dist_i} > L_{span}\cdot HarpDistRatio \\ \text{"error"} \quad \text{otherwise} \end{array} \right. \\ V_p \end{array} \right.$$

$$f_{ps.}(x_{dist}, l_d, f_{ps.max}) = \left| \begin{array}{l} f_{ps} \leftarrow 0 \\ \text{for } i \in 1..\text{rows}(x_{dist}) \\ \quad \left| \begin{array}{l} f_{ps_i} \leftarrow \dfrac{f_{pe}\cdot\left(x_{dist_i} + x_{bearing}\right)}{l_t} \ \text{ if } x_{dist_i} + x_{bearing} \le l_t \\ f_{ps_i} \leftarrow f_{pe} + \dfrac{x_{dist_i} + x_{bearing} - l_t}{l_{d_i} - l_t}\cdot\left(f_{ps.max_i} - f_{pe}\right) \ \text{ if } x_{dist_i} + x_{bearing} > l_t \wedge x_{dist_i} + x_{bearing} < l_{d_i} \\ f_{ps_i} \leftarrow f_{ps.max_i} \ \text{ if } x_{dist_i} + x_{bearing} \ge l_{d_i} \\ f_{ps_i} \leftarrow \text{"error"} \quad \text{otherwise} \end{array} \right. \\ f_{ps} \end{array} \right.$$

$$c_{calc}(x_{dist}) = \left| \begin{array}{l} \text{for } i \in 1..\text{rows}(x_{dist}) \\ \quad \left| \begin{array}{l} d_{p_i} \leftarrow 10^6 in \ \text{ if } d_{p_i} = 0 \\ c_i \leftarrow \dfrac{A_{ps}\cdot f_{pu} + A_{s.bot_i}\cdot f_y - A_{s.top}\cdot f_y}{0.85\cdot f_{c'c}\cdot\beta_1\cdot b_{eff} + k\cdot A_{ps}\cdot\dfrac{f_{pu}}{d_{p_i}}} \\ c_i \leftarrow \dfrac{A_{ps}\cdot f_{pu} + A_{s.bot_i}\cdot f_y - A_{s.top}\cdot f_y - 0.85\cdot f_{c'c}\cdot\left(b_{eff} - b_v\right)\cdot h_{flange}}{0.85\cdot f_{c'c}\cdot\beta_1\cdot b_v + k\cdot A_{ps}\cdot\dfrac{f_{pu}}{d_{p_i}}} \ \text{ if } c_i > h_{flange} \end{array} \right. \\ c \end{array} \right.$$

Figure K-2 (cont.) Subroutines used in the main calculation program given in Figure K-1

$$
l_{d.mild}\left(d_{long.rebar}\right) = \left|
\begin{array}{l}
A_{long.rebar} \leftarrow A_{rebar}\left(\text{rows}\left(d_{long.rebar}\right), d_{long.rebar}\right) \\
\text{for } i \in 1..\text{rows}\left(d_{long.rebar}\right) \\
\quad \left|
\begin{array}{l}
l_{db_i} \leftarrow \max\left(\dfrac{1.25 A_{long.rebar_i} \cdot f_y}{\sqrt{f_{c'} \cdot ksi}\, in}, 0.4 \dfrac{d_{long.rebar_i}}{8} \cdot \dfrac{f_y}{ksi} in\right) \\
\kappa_{1_i} \leftarrow \left|
\begin{array}{l}
1.0 \text{ if IsTopBarEffectApplicable = "No"} \\
1.4 \text{ if IsTopBarEffectApplicable = "Yes"} \\
\text{"error" otherwise}
\end{array}\right. \\
\kappa_{2_i} \leftarrow \left|
\begin{array}{l}
1.0 \text{ if IsLongSteelEpoxyCoated = "No"} \\
1.5 \text{ if IsLongSteelEpoxyCoated = "Yes"} \wedge \left(\text{LongSteelCover} < 3 \dfrac{d_{long.rebar_i}}{8} \cdot in \vee \text{LongSteelClearSpacing} < 6 \dfrac{d_{long.rebar_i}}{8} \cdot in\right) \\
1.2 \text{ if IsLongSteelEpoxyCoated = "Yes"} \wedge \text{LongSteelCover} \geq 3 \dfrac{d_{long.rebar_i}}{8} \cdot in \wedge \text{LongSteelClearSpacing} \geq 6. \dfrac{d_{long.rebar_i}}{8} \cdot in \\
\text{"error" otherwise}
\end{array}\right. \\
\kappa_{12_i} \leftarrow \min\left(\kappa_1 \cdot \kappa_2, 1.7\right) \\
f_{ct} \leftarrow 10^6 ksi \text{ if } f_{ct} = 0 \wedge \text{Value\_}f_{ct} = \text{"not specified"} \\
\kappa_{3_i} \leftarrow \left|
\begin{array}{l}
1 \text{ if ConcreteType = "NWC"} \\
\max\left(0.22 \dfrac{\sqrt{f_{c'} \cdot ksi}}{f_{ct}}, 1.0\right) \text{ if ConcreteType = "LWC"} \wedge \text{Value\_}f_{ct} = \text{"specified"} \\
1.3 \text{ if ConcreteType = "LWC"} \wedge \text{Value\_}f_{ct} = \text{"not specified"} \wedge \text{FineAggType = "lightweight"} \\
1.2 \text{ if ConcreteType = "LWC"} \wedge \text{Value\_}f_{ct} = \text{"not specified"} \wedge \text{FineAggType = "sand"} \\
\text{"error" otherwise}
\end{array}\right. \\
\kappa_{123_i} \leftarrow \kappa_{12_i} \cdot \kappa_{3_i} \\
l_{d.mild_i} \leftarrow l_{db_i} \cdot \kappa_{123_i}
\end{array}\right. \\
l_{d.mild_1}
\end{array}\right.
$$

Figure K-2 (cont.) Subroutines used in the main calculation program given in Figure K-1.

$$
\text{Num}_{\text{strand.bot.}}\left(x_{dist}, cg_{harp}\right) = \left|
\begin{array}{l}
\text{Num}_{\text{strand.bot}} \leftarrow 0 \\
\text{for } i \in 1..\,\text{rows}\left(x_{dist}\right) \\
\quad \left|
\begin{array}{l}
\text{Num}_{\text{strand.bot}\,i} \leftarrow \left(\text{Num}_{\text{strand}} - \text{Num}_{\text{harp}}\right) \text{ if } cg_{harp_i} - 2in \geq \frac{1}{2}h_c \\
\text{Num}_{\text{strand.bot}\,i} \leftarrow \left(\text{Num}_{\text{strand}} - \text{Num}_{\text{harp}} + 2\right) \text{ if } cg_{harp_i} - 2in < \frac{1}{2}h_c \wedge cg_{harp_i} \geq \frac{1}{2}h_c \\
\text{Num}_{\text{strand.bot}\,i} \leftarrow \text{Num}_{\text{strand}} - \text{Num}_{\text{harp}} + 4 \text{ if } cg_{harp_i} < \frac{1}{2}h_c \wedge cg_{harp_i} + 2in \geq \frac{1}{2}h_c \\
\text{Num}_{\text{strand.bot}\,i} \leftarrow \text{Num}_{\text{strand}} \text{ if } cg_{harp_i} + 2in < \frac{1}{2}h_c \\
\text{Num}_{\text{strand.bot}\,i} \leftarrow \text{"error"} \text{ otherwise}
\end{array}
\right. \\
\text{Num}_{\text{strand.bot}}
\end{array}
\right.
$$

$$
\varepsilon_{x.}\left(x_{dist}\right) = \left|
\begin{array}{l}
\left(\varepsilon_{x1}\ \varepsilon_{x2}\ \varepsilon_{x3}\ \varepsilon_{x}\right) \leftarrow (0\ 0\ 0\ 0) \\
\theta \leftarrow \theta \cdot \frac{\pi}{180} \\
\text{for } i \in 1..\,\text{rows}\left(x_{dist}\right) \\
\quad \left|
\begin{array}{l}
\varepsilon_{x1_i} \leftarrow \dfrac{\dfrac{\left|M_{assume\,i}\right|}{d_{v_i}} + 0.5 \cdot N_u + 0.5 \cdot \left|V_{assume\,i} - V_{p_i}\right| \cot\left(\theta_i\right) - A_{ps.bot.\,\varepsilon x_i} \cdot f_{po}}{2 \cdot \left(E_s \cdot A_{s.bot.\,\varepsilon x_i} + E_p \cdot A_{ps.bot.\,\varepsilon x_i}\right)} \\
\varepsilon_{x2_i} \leftarrow \dfrac{\dfrac{\left|M_{assume\,i}\right|}{d_{v_i}} + 0.5 \cdot N_u + 0.5 \cdot \left|V_{assume\,i} - V_{p_i}\right| \cot\left(\theta_i\right) - A_{ps.bot.\,\varepsilon x_i} \cdot f_{po}}{E_s \cdot A_{s.bot.\,\varepsilon x_i} + E_p \cdot A_{ps.bot.\,\varepsilon x_i}} \\
\varepsilon_{x3_i} \leftarrow \dfrac{\dfrac{\left|M_{assume\,i}\right|}{d_{v_i}} + 0.5 \cdot N_u + 0.5 \cdot \left|V_{assume\,i} - V_{p_i}\right| \cot\left(\theta_i\right) - A_{ps.bot.\,\varepsilon x_i} \cdot f_{po}}{2 \cdot \left(E_{beam} \cdot A_{ct} + E_s \cdot A_{s.bot.\,\varepsilon x_i} + E_p \cdot A_{ps.bot.\,\varepsilon x_i}\right)} \\
\varepsilon_{x_i} \leftarrow \left|
\begin{array}{l}
\varepsilon_{x1_i} \text{ if MinReinforcingCheck}_i = \text{"OK"} \wedge \varepsilon_{x1_i} \geq 0 \\
\varepsilon_{x2_i} \text{ if MinReinforcingCheck}_i = \text{"NG!!!"} \wedge \varepsilon_{x2_i} \geq 0 \\
\varepsilon_{x3_i} \text{ if } \varepsilon_{x1_i} < 0 \vee \varepsilon_{x2_i} < 0
\end{array}
\right.
\end{array}
\right. \\
\varepsilon_x
\end{array}
\right.
$$

Figure K-2 (cont.) Subroutines used in the main calculation program given in Figure K-1.

$$
cg_{ps.bot.}(x_{dist}, cg_{straight}, cg_{harp}, h_c, Num_{straight}) = \left|
\begin{array}{l}
\text{for } i \in 1..\text{rows}(x_{dist}) \\
\quad \left|
\begin{array}{l}
cg_{ps.bot_i} \leftarrow cg_{straight} \quad \text{if } cg_{harp_i} - 2in \geq \frac{1}{2}h_c \\
cg_{ps.bot_i} \leftarrow \dfrac{Num_{straight} \cdot cg_{straight} + 2\cdot(cg_{harp_i} - 2in)}{Num_{straight} + 2} \quad \text{if } cg_{harp_i} - 2in < \frac{1}{2}h_c \wedge cg_{harp_i} \geq \frac{1}{2}h_c \\
cg_{ps.bot_i} \leftarrow \dfrac{Num_{straight} \cdot cg_{straight} + 2\cdot(cg_{harp_i} - 2in + cg_{harp_i})}{Num_{straight} + 4} \quad \text{if } cg_{harp_i} < \frac{1}{2}h_c \wedge cg_{harp_i} + 2in \geq \frac{1}{2}h_c \\
cg_{ps.bot_i} \leftarrow \dfrac{Num_{straight} \cdot cg_{straight} + 6\cdot cg_{harp_i}}{Num_{straight} + 6} \quad \text{if } cg_{harp_i} + 2in < \frac{1}{2}h_c
\end{array}
\right. \\
cg_{ps.bot}
\end{array}
\right.
$$

$$
v_{u.}(x_{dist}, V_{assume}, V_p, d_v, MinReinforcingCheck) = \left|
\begin{array}{l}
(v_1 \ \ s_x \ \ s_{xe} \ \ v) \leftarrow (0 \ \ 0 \ \ 0 \ \ 0) \\
\text{for } i \in 1..\text{rows}(x_{dist}) \\
\quad \left|
\begin{array}{l}
v_{1_i} \leftarrow \dfrac{\left|V_{assume_i} - \phi_v \cdot V_{p_i}\right|}{\phi_v \cdot b_v \cdot d_{v_i}} \\
s_{x_i} \leftarrow d_{v_i} \\
s_{xe_i} \leftarrow \min\left(s_{x_i} \cdot \dfrac{1.38in}{a_g + 0.63in}, 80in\right) \\
v_i \leftarrow \left|
\begin{array}{l}
\dfrac{v_{1_i}}{f_{c'}} \quad \text{if } MinReinforcingCheck_i = \text{"OK"} \\
\dfrac{s_{xe_i}}{in} \quad \text{if } MinReinforcingCheck_i = \text{"NG!!!"}
\end{array}
\right.
\end{array}
\right. \\
v
\end{array}
\right.
$$

Figure K-2 (cont.) Subroutines used in the main calculation program given in Figure K-1.

$$\theta\beta(x_{dist}, cg_{harp}, \varepsilon_x, v_u, MinReinforcingCheck) =$$

$$(\theta_L\ \ \theta_R\ \ \theta_r\ \ \beta_L\ \ \beta_R\ \ \beta) \leftarrow (0\ \ 0\ \ 0\ \ 0\ \ 0\ \ 0)$$

$$u \leftarrow rows(x_{dist})$$

$$Num_{strand.bot} \leftarrow Num_{strand.bot.}(x_{dist}, cg_{harp})$$

for $i \in 1..1$

$$v_{u1.} \leftarrow v_{u1}(v_u, \varepsilon_x, u, MinReinforcingCheck)$$
$$v_{u2.} \leftarrow v_{u2}(v_u, \varepsilon_x, u, MinReinforcingCheck)$$
$$\varepsilon_{xL.} \leftarrow \varepsilon_{xL}(v_u, \varepsilon_x, u, MinReinforcingCheck)$$
$$\varepsilon_{xR.} \leftarrow \varepsilon_{xR}(v_u, \varepsilon_x, u, MinReinforcingCheck)$$

for $i \in 1..1$

$$MinOK1\theta_{1L.} \leftarrow MinOK1\theta_{1L}(v_{u1.}, \varepsilon_{xL.}, u, MinReinforcingCheck)$$
$$MinOK2\theta_{1L.} \leftarrow MinOK2\theta_{1L}(v_{u1.}, \varepsilon_{xL.}, u, MinReinforcingCheck)$$
$$MinNG1\theta_{1L.} \leftarrow MinNG1\theta_{1L}(v_{u1.}, \varepsilon_{xL.}, u, MinReinforcingCheck)$$
$$MinNG2\theta_{1L.} \leftarrow MinNG2\theta_{1L}(v_{u1.}, \varepsilon_{xL.}, u, MinReinforcingCheck)$$

for $i \in 1..1$

$$MinOK1\theta_{1R.} \leftarrow MinOK1\theta_{1R}(v_{u1.}, \varepsilon_{xR.}, u, MinReinforcingCheck)$$
$$MinOK2\theta_{1R.} \leftarrow MinOK2\theta_{1R}(v_{u1.}, \varepsilon_{xR.}, u, MinReinforcingCheck)$$
$$MinNG1\theta_{1R.} \leftarrow MinNG1\theta_{1R}(v_{u1.}, \varepsilon_{xR.}, u, MinReinforcingCheck)$$
$$MinNG2\theta_{1R.} \leftarrow MinNG2\theta_{1R}(v_{u1.}, \varepsilon_{xR.}, u, MinReinforcingCheck)$$

for $i \in 1..1$

$$MinOK1\beta_{1L.} \leftarrow MinOK1\beta_{1L}(v_{u1.}, \varepsilon_{xL.}, u, MinReinforcingCheck)$$
$$MinOK2\beta_{1L.} \leftarrow MinOK2\beta_{1L}(v_{u1.}, \varepsilon_{xL.}, u, MinReinforcingCheck)$$
$$MinNG1\beta_{1L.} \leftarrow MinNG1\beta_{1L}(v_{u1.}, \varepsilon_{xL.}, u, MinReinforcingCheck)$$
$$MinNG2\beta_{1L.} \leftarrow MinNG2\beta_{1L}(v_{u1.}, \varepsilon_{xL.}, u, MinReinforcingCheck)$$

for $i \in 1..1$

$$MinOK1\beta_{1R.} \leftarrow MinOK1\beta_{1R}(v_{u1.}, \varepsilon_{xR.}, u, MinReinforcingCheck)$$
$$MinOK2\beta_{1R.} \leftarrow MinOK2\beta_{1R}(v_{u1.}, \varepsilon_{xR.}, u, MinReinforcingCheck)$$
$$MinNG1\beta_{1R.} \leftarrow MinNG1\beta_{1R}(v_{u1.}, \varepsilon_{xR.}, u, MinReinforcingCheck)$$
$$MinNG2\beta_{1R.} \leftarrow MinNG2\beta_{1R}(v_{u1.}, \varepsilon_{xR.}, u, MinReinforcingCheck)$$

for $i \in 1..1$

$$MinOK1\theta_{2L.} \leftarrow MinOK1\theta_{2L}(v_{u2.}, \varepsilon_{xL.}, u, MinReinforcingCheck)$$
$$MinOK2\theta_{2L.} \leftarrow MinOK2\theta_{2L}(v_{u2.}, \varepsilon_{xL.}, u, MinReinforcingCheck)$$
$$MinNG1\theta_{2L.} \leftarrow MinNG1\theta_{2L}(v_{u2.}, \varepsilon_{xL.}, u, MinReinforcingCheck)$$
$$MinNG2\theta_{2L.} \leftarrow MinNG2\theta_{2L}(v_{u2.}, \varepsilon_{xL.}, u, MinReinforcingCheck)$$

for $i \in 1..1$

Figure K-2 (cont.) Subroutines used in the main calculation program given in Error!

$$\text{for } i \in 1..1$$
$$\quad MinOK1\theta_{2R.} \leftarrow MinOK1\theta_{2R}(v_{u2.}, \varepsilon_{xR.}, u, MinReinforcingCheck)$$
$$\quad MinOK2\theta_{2R.} \leftarrow MinOK2\theta_{2R}(v_{u2.}, \varepsilon_{xR.}, u, MinReinforcingCheck)$$
$$\quad MinNG1\theta_{2R.} \leftarrow MinNG1\theta_{2R}(v_{u2.}, \varepsilon_{xR.}, u, MinReinforcingCheck)$$
$$\quad MinNG2\theta_{2R.} \leftarrow MinNG2\theta_{2R}(v_{u2.}, \varepsilon_{xR.}, u, MinReinforcingCheck)$$
$$\text{for } i \in 1..1$$
$$\quad MinOK1\beta_{2L.} \leftarrow MinOK1\beta_{2L}(v_{u2.}, \varepsilon_{xL.}, u, MinReinforcingCheck)$$
$$\quad MinOK2\beta_{2L.} \leftarrow MinOK2\beta_{2L}(v_{u2.}, \varepsilon_{xL.}, u, MinReinforcingCheck)$$
$$\quad MinNG1\beta_{2L.} \leftarrow MinNG1\beta_{2L}(v_{u2.}, \varepsilon_{xL.}, u, MinReinforcingCheck)$$
$$\quad MinNG2\beta_{2L.} \leftarrow MinNG2\beta_{2L}(v_{u2.}, \varepsilon_{xL.}, u, MinReinforcingCheck)$$
$$\text{for } i \in 1..1$$
$$\quad MinOK1\beta_{2R.} \leftarrow MinOK1\beta_{2R}(v_{u2.}, \varepsilon_{xR.}, u, MinReinforcingCheck)$$
$$\quad MinOK2\beta_{2R.} \leftarrow MinOK2\beta_{2R}(v_{u2.}, \varepsilon_{xR.}, u, MinReinforcingCheck)$$
$$\quad MinNG1\beta_{2R.} \leftarrow MinNG1\beta_{2R}(v_{u2.}, \varepsilon_{xR.}, u, MinReinforcingCheck)$$
$$\quad MinNG2\beta_{2R.} \leftarrow MinNG2\beta_{2R}(v_{u2.}, \varepsilon_{xR.}, u, MinReinforcingCheck)$$
$$\text{for } i \in 1..1$$
$$\quad \theta_{1L} \leftarrow MinOK1\theta_{1L.} + MinOK2\theta_{1L.} + MinNG1\theta_{1L.} + MinNG2\theta_{1L.}$$
$$\quad \theta_{1R} \leftarrow MinOK1\theta_{1R.} + MinOK2\theta_{1R.} + MinNG1\theta_{1R.} + MinNG2\theta_{1R.}$$
$$\quad \beta_{1L} \leftarrow MinOK1\beta_{1L.} + MinOK2\beta_{1L.} + MinNG1\beta_{1L.} + MinNG2\beta_{1L.}$$
$$\quad \beta_{1R} \leftarrow MinOK1\beta_{1R.} + MinOK2\beta_{1R.} + MinNG1\beta_{1R.} + MinNG2\beta_{1R.}$$
$$\quad \theta_{2L} \leftarrow MinOK1\theta_{2L.} + MinOK2\theta_{2L.} + MinNG1\theta_{2L.} + MinNG2\theta_{2L.}$$
$$\quad \theta_{2R} \leftarrow MinOK1\theta_{2R.} + MinOK2\theta_{2R.} + MinNG1\theta_{2R.} + MinNG2\theta_{2R.}$$
$$\quad \beta_{2L} \leftarrow MinOK1\beta_{2L.} + MinOK2\beta_{2L.} + MinNG1\beta_{2L.} + MinNG2\beta_{2L.}$$
$$\quad \beta_{2R} \leftarrow MinOK1\beta_{2R.} + MinOK2\beta_{2R.} + MinNG1\beta_{2R.} + MinNG2\beta_{2R.}$$
$$\text{for } i \in 1..rows(x_{dist})$$
$$\quad \theta_{L_i} \leftarrow \begin{cases} \theta_{2L_i} & \text{if } v_{u2._i} - v_{u1._i} = 0 \\ \left[(\theta_{1L_i} - \theta_{2L_i}) \cdot \dfrac{(v_{u2._i} - v_{u_i})}{v_{u2._i} - v_{u1._i}} + \theta_{2L_i}\right] & \text{otherwise} \end{cases}$$
$$\quad \theta_{R_i} \leftarrow \begin{cases} \theta_{2R_i} & \text{if } v_{u2._i} - v_{u1._i} = 0 \\ (\theta_{1R_i} - \theta_{2R_i}) \cdot \dfrac{(v_{u2._i} - v_{u_i})}{v_{u2._i} - v_{u1._i}} + \theta_{2R_i} & \text{otherwise} \end{cases}$$
$$\quad \theta_{r_i} \leftarrow \begin{cases} \theta_{R_i} & \text{if } \varepsilon_{xR_1} - \varepsilon_{xL_1} = 0 \\ (\theta_{L_i} - \theta_{R_i}) \cdot \dfrac{(\varepsilon_{xR_1} - \varepsilon_{x_i})}{\varepsilon_{xR_1} - \varepsilon_{xL_1}} + \theta_{R_i} & \text{otherwise} \end{cases}$$

Figure K-2 (cont.) Subroutines used in the main calculation program given in Figure K-1.

$$\left(\theta_{L_i}-\theta_{R_i}\right)\cdot\frac{\left(\varepsilon_{xR_i}-\varepsilon_{x_i}\right)}{\varepsilon_{xR_i}-\varepsilon_{xL_i}}+\theta_{R_i}\quad\text{otherwise}$$

$$\beta_{L_i}\leftarrow\begin{cases}\beta_{2L_i} & \text{if } v_{u2._i}-v_{u1._i}=0\\ \left(\beta_{1L_i}-\beta_{2L_i}\right)\cdot\dfrac{\left(v_{u2._i}-v_{u_i}\right)}{v_{u2._i}-v_{u1._i}}+\beta_{2L_i} & \text{otherwise}\end{cases}$$

$$\beta_{R_i}\leftarrow\begin{cases}\beta_{2R_i} & \text{if } v_{u2._i}-v_{u1._i}=0\\ \left(\beta_{1R_i}-\beta_{2R_i}\right)\cdot\dfrac{\left(v_{u2._i}-v_{u_i}\right)}{v_{u2._i}-v_{u1._i}}+\beta_{2R_i} & \text{otherwise}\end{cases}$$

$$\beta_i\leftarrow\begin{cases}\beta_{R_i} & \text{if } \varepsilon_{xR_i}-\varepsilon_{xL_i}=0\\ \left(\beta_{L_i}-\beta_{R_i}\right)\cdot\dfrac{\left(\varepsilon_{xR_i}-\varepsilon_{x_i}\right)}{\varepsilon_{xR_i}-\varepsilon_{xL_i}}+\beta_{R_i} & \text{otherwise}\end{cases}$$

$$\begin{pmatrix}\theta_r\\ \beta\end{pmatrix}$$

$$V_{r.}\left(x_{dist},\beta,d_v,\theta,s_{v.design},V_p\right)=\left|\begin{aligned}&\left(V_c\ \ V_s\ \ V_n\ \ V_r\right)\leftarrow(0\ \ 0\ \ 0\ \ 0)\\ &\theta\leftarrow\theta\cdot\frac{\pi}{180}\\ &\text{for } i\in 1..\,\text{rows}\left(x_{dist}\right)\\ &\quad\left|\begin{aligned}&V_{c_i}\leftarrow 0.0316\beta_i\cdot\alpha_v\sqrt{f_{c'}\cdot ksi}\cdot b_v\cdot d_{v_i}\\ &V_{s_i}\leftarrow\frac{A_{v_i}\cdot f_{yv}\cdot d_{v_i}\cdot\left(\cot\left(\theta_i\right)+\cot(\alpha)\right)\cdot\sin(\alpha)}{s_{v.design_i}}\end{aligned}\right.\\ &V_{n1}\leftarrow V_c+V_s+V_p\\ &V_{n2}\leftarrow 0.25\cdot f_{c'}\cdot b_v\cdot d_v+V_p\\ &\text{for } i\in 1..\,\text{rows}\left(x_{dist}\right)\\ &\quad V_{n_i}\leftarrow\min\left(V_{n1_i},V_{n2_i}\right)\\ &V_r\leftarrow\phi_v\cdot V_n\\ &V_r\end{aligned}\right.$$

Figure K-2 (cont.) Subroutines used in the main calculation program given in Figure K-1.

$$\theta_{iterate}(x_{dist}) = \text{for } i \in 1..\text{rows}(x_{dist}) \text{ if } \theta\beta method = \text{"Simple"} \wedge (N_u = 0 \wedge MinReinforcingCheck_1 = \text{"OK"} \vee h_c < 16in)$$

$$\theta_{r_i} \leftarrow 45$$

$$\beta_i \leftarrow 2$$

otherwise

$$AngleCheck \leftarrow \text{"NG"}$$

$$iterations_{\theta} \leftarrow 0$$

$$Num_{strand.bot} \leftarrow Num_{strand.bot.}(x_{dist}, cg_{harp})$$

$$\text{while } AngleCheck = \text{"NG"}$$

$$iterations_{\theta} \leftarrow iterations_{\theta} + 1$$

$$iterations_{\theta.tot} \leftarrow iterations_{\theta.tot} + 1$$

$$\theta_{sum} \leftarrow 0$$

$$\varepsilon_x \leftarrow \left| \begin{array}{l} (\varepsilon_{x1}\ \ \varepsilon_{x2}\ \ \varepsilon_{x3}\ \ \varepsilon_x) \leftarrow (0\ \ 0\ \ 0\ \ 0) \\ \theta \leftarrow \theta \cdot \frac{\pi}{180} \\ \text{for } i \in 1..\text{rows}(x_{dist}) \end{array} \right.$$

$$\varepsilon_{x1_i} \leftarrow \frac{\frac{\left|M_{assume_i}\right|}{d_{v_i}} + 0.5 \cdot N_u + 0.5 \cdot \left|V_{assume_i} - V_{p_i}\right| \cot(\theta_i) - A_{ps.bot.\varepsilon x_i} \cdot f_{po}}{2 \cdot \left(E_s \cdot A_{s.bot.\varepsilon x_i} + E_p \cdot A_{ps.bot.\varepsilon x_i}\right)}$$

$$\varepsilon_{x2_i} \leftarrow \frac{\frac{\left|M_{assume_i}\right|}{d_{v_i}} + 0.5 \cdot N_u + 0.5 \cdot \left|V_{assume_i} - V_{p_i}\right| \cot(\theta_i) - A_{ps.bot.\varepsilon x_i} \cdot f_{po}}{E_s \cdot A_{s.bot.\varepsilon x_i} + E_p \cdot A_{ps.bot.\varepsilon x_i}}$$

$$\varepsilon_{x3_i} \leftarrow \frac{\frac{\left|M_{assume_i}\right|}{d_{v_i}} + 0.5 \cdot N_u + 0.5 \cdot \left|V_{assume_i} - V_{p_i}\right| \cot(\theta_i) - A_{ps.bot.\varepsilon x_i} \cdot f_{po}}{2 \cdot \left(E_{beam} \cdot A_{ct} + E_s \cdot A_{s.bot.\varepsilon x_i} + E_p \cdot A_{ps.bot.\varepsilon x_i}\right)}$$

$$\varepsilon_{x_i} \leftarrow \left| \begin{array}{l} \varepsilon_{x1_i} \text{ if } MinReinforcingCheck_i = \text{"OK"} \wedge \varepsilon_{x1_i} \geq 0 \\ \varepsilon_{x2_i} \text{ if } MinReinforcingCheck_i = \text{"NG!!!"} \wedge \varepsilon_{x2_i} \geq 0 \\ \varepsilon_{x3_i} \text{ if } \varepsilon_{x1_i} < 0 \vee \varepsilon_{x2_i} < 0 \end{array} \right.$$

$$\varepsilon_x$$

$$\theta_r \leftarrow \theta\beta(x_{dist}, cg_{harp}, \varepsilon_x, v_u, MinReinforcingCheck)_1$$

$$\beta \leftarrow \theta\beta(x_{dist}, cg_{harp}, \varepsilon_x, v_u, MinReinforcingCheck)_2$$

$$\theta \leftarrow \theta \cdot \frac{180}{\pi}$$

$$\text{for } i \in 1..\text{rows}(x_{dist})$$

Figure K-2 (cont.) Subroutines used in the main calculation program given in Figure K-1.

```
for i ∈ 1.. rows(x_dist)
  if |θr_i − θ_i| > .0005
      θsum ← θsum + 1
      θ_i ← 1/2 (θr_i + θ_i)
AngleCheck ← "OK"  if θsum = 0 ∨ iterations_θ = 50
```

$$\begin{pmatrix} \theta_r \\ \beta \\ iterations_{\theta} \\ \varepsilon_x \end{pmatrix}$$

Figure K-2 (cont.) Subroutines used in the main calculation program given in Figure K-1.

```
calc = | ShearStrengthCheckFinal ← "NG"
       | iterations ← 0
       | while iterations < 1
       |   | iterations ← iterations + 1
       |   | for i ∈ 1..1
       |   |   | x_dist ← x_θ(x_critical.assume)_1
       |   |   | if rows(x_dist) ≠ rows(P_assume)
       |   |   |   | for i ∈ 1..rows(x_dist)          if rows(x_dist) < rows(P_assume)
       |   |   |   |   P_assume.old_i ← P_assume_i
       |   |   |   | for i ∈ 1..rows(x_dist) − rows(P_assume)          if rows(x_dist) > rows(P_assume)
       |   |   |   |   | P_assume.old ← P_assume
       |   |   |   |   | P_assume.old_(i+rows(P_assume)) ← P_assume_rows(P_assume)
       |   |   |   | P_assume ← P_assume.old
       |   |   | LiveLoad ← Load_Live(x_dist, P_assume, ShearSpan, LoadSpacing, L_span)
       |   |   | DeadLoad ← Dead_Load(x_dist, L_span, x_bearing, x_bearing.roller, ShearSpan, w_beam, DC_1, DC_2, DW, P_diaphragm)
       |   |   | (LiveLoad^⟨4⟩)_1 ← 10^5  if (LiveLoad^⟨4⟩)_1 = 0
       |   |   | V_assume ← [1.00(DeadLoad^⟨5⟩ + DeadLoad^⟨7⟩) + 1.00·DeadLoad^⟨9⟩ + 1.00LiveLoad^⟨3⟩]·kip
       |   |   | M_assume ← [1.00(DeadLoad^⟨6⟩ + DeadLoad^⟨8⟩) + 1.00DeadLoad^⟨10⟩ + 1.00LiveLoad^⟨4⟩]·kip·ft
       |   |   | M_DC1 ← DeadLoad^⟨6⟩·kip·ft
       |   |   | V_d ← (DeadLoad^⟨5⟩ + DeadLoad^⟨7⟩ + DeadLoad^⟨9⟩)·kip
```

Figure K-3. Mathcad program used to calculate the shear strength following the Simplified Procedure.

$V_d \leftarrow \left(DeadLoad^{\langle 5\rangle} + DeadLoad^{\langle 7\rangle} + DeadLoad^{\langle 9\rangle}\right)\cdot kip$

$V_i \leftarrow V_{assume} - V_d$

$M_{max} \leftarrow M_{assume} - \left(DeadLoad^{\langle 6\rangle} + DeadLoad^{\langle 8\rangle} + DeadLoad^{\langle 10\rangle}\right)\cdot kip\cdot ft$

$V_p \leftarrow V_{p.}\left(x_{dist}\right)$

$cg_{harp} \leftarrow cg_{harp.}\left(x_{dist}\right)$

$f_{c'c} \leftarrow \begin{cases} f_{c'deck} & \text{if } f_{c'deck} > 0 \\ f_{c'} & \text{otherwise} \end{cases}$

$\beta_1 \leftarrow \beta_{1.}\left(f_{c'c}\right)$

$\varepsilon_{s.yield} \leftarrow \dfrac{f_y}{E_s}$

$Num_{strand.bot} \leftarrow Num_{strand.bot.}\left(x_{dist}, cg_{harp}\right)$

$cg_{ps.bot} \leftarrow cg_{ps.bot.}\left(x_{dist}, cg_{straight.bot}, cg_{harp}, h_c, Num_{straight.bot}\right)$

for $i \in 1..\,rows\left(x_{dist}\right)$

$cg_{ps_i} \leftarrow \dfrac{Num_{straight}\cdot cg_{straight} + Num_{harp}\cdot cg_{harp_i}}{Num_{strand}}$

$d_{p_i} \leftarrow h_c - cg_{ps_i}$

$c_i \leftarrow$

$d_{p_i} \leftarrow 10^6 in$ if $d_{p_i} = 0$

$c_i \leftarrow \dfrac{A_{ps}\cdot f_{pu} + A_{s.bot_i}\cdot f_y - A_{s.top}\cdot f_y}{0.85 f_{c'c}\cdot\beta_1\cdot b_{eff} + k\cdot A_{ps}\cdot\dfrac{f_{pu}}{d_{p_i}}}$

$c_i \leftarrow \dfrac{A_{ps}\cdot f_{pu} + A_{s.bot_i}\cdot f_y - A_{s.top}\cdot f_y - 0.85 f_{c'c}\cdot\left(b_{eff} - b_v\right)\cdot h_{flange}}{0.85 f_{c'c}\cdot\beta_1\cdot b_v + k\cdot A_{ps}\cdot\dfrac{f_{pu}}{d_{p_i}}}$ if $c_i > h_{flange}$

$f_{ps.max_i} \leftarrow f_{pu}\cdot\left(1 - k\cdot\dfrac{c_i}{d_{p_i}}\right)$

$l_{d.ps_i} \leftarrow \kappa\cdot\left(f_{ps.max_i} - \dfrac{2}{3}\cdot f_{pe}\right)\varphi$

$f_{ps} \leftarrow f_{ps.}\left(x_{dist}, l_{d.ps}, f_{ps.max}\right)$

for $i \in 1..\,rows\left(x_{dist}\right)$

$A_{ps.bot_i} \leftarrow Num_{strand.bot_i}\cdot A_{strand}$

$d_{p.bot_i} \leftarrow h_c - cg_{ps.bot_i}$

$d_{s.bot_i} \leftarrow h_c - cg_{s.bot_i}$

Figure K-3 (cont.) Mathcad program used to calculate the shear strength following the Simplified Procedure.

$$d_{s.bot_i} \leftarrow h_c - cg_{s.bot_i}$$

$$d_{e_i} \leftarrow \frac{A_{ps.bot_i} \cdot f_{ps_i} \cdot d_{p.bot_i} + A_{s.bot_i} \cdot f_y \cdot d_{s.bot_i}}{A_{ps.bot_i} \cdot f_{ps_i} + A_{s.bot_i} \cdot f_y}$$

$$\varepsilon_{s_i} \leftarrow \frac{0.003}{c_i} \cdot \left(d_{e_i} - c_i\right)$$

$$\text{return} \left(\text{"Tension steel does not yield at x.dist"} \quad \frac{x_{dist_i}}{in} \right) \text{ if } \varepsilon_{s_i} < \varepsilon_{s.yield}$$

$$a_i \leftarrow \beta_1 \cdot c_i$$

$$d_{v_i} \leftarrow \max\left(d_{e_i} - \frac{a_i}{2}, 0.9 d_{e_i}, 0.72 h_c\right)$$

$$f_{r.V} \leftarrow \begin{cases} 0.20 \sqrt{\frac{f_{c'}}{ksi}} \, ksi & \text{if FineAggType = "sand"} \\ \left(0.17 \cdot \sqrt{\frac{f_{c'}}{ksi}} \, ksi\right) & \text{if FineAggType = "lightweight"} \\ \text{"error"} & \text{otherwise} \end{cases}$$

$$e_{strand} \leftarrow y_b - cg_{ps}$$

$$l_t \leftarrow 60 \cdot \varphi$$

$$\text{for } i \in 1 .. \text{rows}(x_{dist})$$

$$P_{f.cpe_i} \leftarrow \begin{cases} f_{pe} \cdot A_{strand} \cdot Num_{strand} \cdot \frac{x_{dist_i} + x_{bearing}}{l_t} & \text{if } x_{dist_i} + x_{bearing} < l_t \\ f_{pe} \cdot A_{strand} \cdot Num_{strand} & \text{if } x_{dist_i} + x_{bearing} \geq l_t \\ \text{"error"} & \text{otherwise} \end{cases}$$

$$f_{cpe_i} \leftarrow \frac{P_{f.cpe_i}}{A_{beam}} + \frac{P_{f.cpe_i} \cdot e_{strand_i}}{S_b}$$

$$M_{cre_i} \leftarrow S_{bc} \cdot \left[f_{r.V} + f_{cpe_i} - \frac{\left(DeadLoad^{\langle 6 \rangle} \cdot kip \cdot ft\right)_i}{S_b} \right]$$

$$V_{ci_i} \leftarrow \max\left(0.02 \alpha_V \cdot \sqrt{\frac{f_{c'}}{ksi}} \cdot ksi \cdot b_v \cdot d_{v_i} + V_{d_i} + \frac{V_i \cdot M_{cre_i}}{M_{max_i}}, 0.06 \alpha_V \sqrt{\frac{f_{c'}}{ksi}} \cdot ksi \cdot b_v \cdot d_{v_i}\right)$$

$$P_{f.pc_i} \leftarrow f_{ps_i} \cdot A_{strand} \cdot Num_{strand}$$

$$f_{pc_i} \leftarrow \begin{cases} \frac{P_{f.pc_i}}{A_{beam}} + \frac{P_{f.pc_i} \cdot e_{strand_i} \cdot \left(y_b - y_{bc}\right)}{I_{beam}} - \frac{M_{DC1_i} \cdot \left(y_b - y_{bc}\right)}{I_{beam}} & \text{if } y_{bc} \leq h_{top.flange} \\ \frac{P_{f.pc_i}}{A_{beam}} + \frac{P_{f.pc_i} \cdot e_{strand_i} \cdot \left(y_b - h_{top.flange}\right)}{I_{beam}} - \frac{M_{DC1_i} \cdot \left(y_b - h_{top.flange}\right)}{I_{beam}} & \text{if } y_{bc} > h_{top.flange} \end{cases}$$

$$V_{cw_i} \leftarrow \left(0.06 \alpha_V \cdot \sqrt{\frac{f_{c'}}{ksi}} \cdot ksi + 0.30 f_{pc_i}\right) \cdot b_v \cdot d_{v_i} + V_{p_i}$$

Figure K-3 (cont.) Mathcad program used to calculate the shear strength following the Simplified Procedure.

$$V_{cw_i} \leftarrow \left(0.06\alpha_v\cdot\sqrt{\frac{f_{c'}}{ksi}}\cdot ksi + 0.30 f_{pc_i}\right)\cdot b_v\cdot d_{v_i} + V_{p_i}$$

$$V_{c_i} \leftarrow \min\left(V_{ci_i}, V_{cw_i}\right)$$

$$\cot\theta_i \leftarrow \begin{cases} 1 & \text{if } V_{ci_i} < V_{cw_i} \\ \min\left(1 + 3\cdot\frac{f_{pc_i}}{\alpha_v\cdot\sqrt{f_{c'}}\cdot ksi^{0.5}}, 1.8\right) & \text{if } V_{ci_i} \ge V_{cw_i} \end{cases}$$

$$V_{s_i} \leftarrow \frac{A_{v_i}\cdot f_{yv}\cdot d_{v_i}\cdot\left(\cot\theta_i + \cot(\alpha)\right)\cdot\sin(\alpha)}{s_{v.design_i}}$$

$$V_{n1} \leftarrow V_c + V_s$$

$$V_{n2} \leftarrow 0.25 f_{c'}\cdot b_v\cdot d_v + V_p$$

$$\text{for } i \in 1..\text{rows}(x_{dist})$$

$$V_{r_i} \leftarrow \phi_v\cdot\min\left(V_{n1_i}, V_{n2_i}\right)$$

$$ShearStrengthCheck_i \leftarrow \text{"OK"} \quad \text{if } V_{r_i} - V_{assume_i} \le 0.1kip \wedge V_{r_i} - V_{assume_i} \ge 0kip$$

$$\text{if } V_{r_i} - V_{assume_i} > 0.1kip \vee V_{r_i} - V_{assume_i} < 0kip$$

$$ShearStrengthCheck_i \leftarrow \text{"NG!!!"}$$

$$ShearStrengthSum \leftarrow ShearStrengthSum + 1$$

$$V_{assume_i} \leftarrow \frac{1}{2}\left(V_{r_i} + V_{assume_i}\right) - 0.01kip$$

$$P_{assume.r_i} \leftarrow P_{assume_i}$$

$$P_{assume_i} \leftarrow \begin{cases} \frac{\left[V_{assume_i} - \left[1.00\left[\left(DeadLoad^{\langle 5\rangle}\right)_i + \left(DeadLoad^{\langle 7\rangle}\right)_i\right] + 1.00\left(DeadLoad^{\langle 9\rangle}\right)_i\right]\cdot kip\right]\cdot L_{span}}{\left[2\left(L_{span} - ShearSpan\right) - LoadSpacing\right]} & \text{if } x_{dist_i} \le ShearSpan \\ \frac{\left[V_{assume_i} - \left[1.00\left[\left(DeadLoad^{\langle 5\rangle}\right)_i + \left(DeadLoad^{\langle 7\rangle}\right)_i\right] + 1.00\left(DeadLoad^{\langle 9\rangle}\right)_i\right]\cdot kip\right]\cdot L_{span}}{L_{span} - 2ShearSpan - LoadSpacing} & \text{if } ShearSpan + 10^{-1:} \\ \frac{\left[V_{assume_i} - \left[1.00\left[\left(DeadLoad^{\langle 5\rangle}\right)_i + \left(DeadLoad^{\langle 7\rangle}\right)_i\right] + 1.00\left(DeadLoad^{\langle 9\rangle}\right)_i\right]\cdot kip\right]\cdot L_{span}}{2ShearSpan + LoadSpacing} & \text{if } x_{dist_i} > ShearSpan \end{cases}$$

$$vect\_elemnt_{x.critical} \leftarrow \frac{x\_\theta\left(x_{critical.assume}\right)_2}{in}$$

$$\text{for } i \in 1..1$$

$$ShearStrengthCheckFinal \leftarrow \text{"OK"} \quad \text{if } ShearStrengthSum = 0 \vee iterations > 500$$

$$d_{v.critical} \leftarrow d_{v\left(vect\_elemnt_{x.critical_1}\right)} \quad \text{if rows}\left(vect\_elemnt_{x.critical}\right) > 1$$

$$d_{v.critical} \leftarrow d_{v_{vect\_elemnt_{x.critical}}} \quad \text{if rows}\left(vect\_elemnt_{x.critical}\right) \le 1$$

$$x_{critical.assume} \leftarrow \max\left[d_{v.critical}, \frac{1}{2}\cdot d_{v.critical}\cdot\cot\theta_{\left(vect\_elemnt_{x.critical_1}\right)}\right] \quad \text{if rows}\left(vect\_elemnt_{x.critical}\right) > 1$$

Figure K-3 (cont.) Mathcad program used to calculate the shear strength following the Simplified Procedure.

$x_{critical.assume} \leftarrow \max\left[d_{v.critical}, \frac{1}{2}\cdot d_{v.critical}\cdot \cot\theta\left(vect\_elemnt_{x.critical_1}\right)\right]$ if $rows(vect\_elemnt_{x.critical}) > 1$

$x_{critical.assume} \leftarrow \max\left(d_{v.critical}, \frac{1}{2}\cdot d_{v.critical}\cdot \cot\theta_{vect\_elemnt_{x.critical}}\right)$ if $rows(vect\_elemnt_{x.critical}) \le 1$

$\left(V_{n.critical}\ \ x_{critical}\right) \leftarrow (0\ \ 0)$

for $i \in 1..rows(vect\_elemnt_{x.critical})$ if $rows(vect\_elemnt_{x.critical}) > 1$

$V_{n.critical_i} \leftarrow V_r\left(vect\_elemnt_{x.critical_i}\right)$

$x_{critical_i} \leftarrow x_{dist}\left(vect\_elemnt_{x.critical_i}\right)$

otherwise

$V_{n.critical} \leftarrow V_{r_{vect\_elemnt_{x.critical}}}$

$x_{critical} \leftarrow x_{dist_{vect\_elemnt_{x.critical}}}$

Figure K-3 (cont.) Mathcad program used to calculate the shear strength following the Simplified Procedure.

Beam Example Following the General Procedure using Appendix B5

The following calculations are for a simply-supported, Type II prestressed girder with a cast-in-place composite deck, containing a typical amount of shear reinforcement found in such a girder spanning 60 ft. As discussed in Section 3.1.2.1, for the actual beam in this example, a portion of the girder was removed from the original 60-ft design such that that girder was shortened by some distance between the harping points. The drawing details for this example beam, T2.8.Typ, is shown in Figure A-2. The parameters that are necessary to perform the calculations are given the section below.

Inputs

ConcreteType = "NWC"

FineAggType = "sand"

Programming mechanism used for setting the lightweight concrete modifier. In this example, the assumption is that the lightweight concrete should not have a modifier; hence the concrete is assumed to be normal weight.

$\gamma_c = 121.5\,pcf$

$f_{c'} = 8865\,psi$

$f_{ci'} = 6090\,psi$

$f_{c'deck} = 5829\,psi$

$\gamma_{c.deck} = 123.4\,pcf$

$E_{beam} = 3605\,ksi$

$E_{beam.i} = 3585\,ksi$

$E_{slab} = 3566\,ksi$

$Value\_f_{ct}$ = "not specified" — the splitting tensile strength was assumed to be unspecified

$h = 36\,in$ — height of the beam

$A_{beam} = 369\,in^2$

$I_{beam} = 50979\,in^4$

$L_{beam} = 41\,ft$

$b_v = 6\,in$ — web width

$y_b = 15.83\,in$ — distance from bottom of beam to beam centroid

$y_t = 20.17\,in$ — distance from top of beam to beam centroid

$S = 7\,ft$ — girder spacing, which in this case, is the width of the deck

$t_{haunch} = 1\,in$ — thickness of the haunch

$t_{struct} = 8.5\,in$ — structural depth of the deck

$A_{ct} = 243\,in^2$ — area of concrete in the flexural tension zone, as defined in A. 5.8.3.4.2

$h_{flange} = 8.5\,in$ — distance from the extreme compression flange to the web-flange intersection

$Num_{strand} = 24$

$Num_{straight} = 18$ — number of unharped tendons

$Num_{straight.bot} = 16$ — number of unharped tendons near the bottom of the beam

$Num_{harp} = 6$ — number of harped tendons

$cg_{straight} = 7in$ — centroid of the unharped tendons

$cg_{harp.end} = 29in$ — centroid of the harped tendons at the end of the beam

$cg_{harp.ms} = 4in$ — centroid of the harped tendons at the harping location

$cg_{straight.bot} = 3.75in$ — centroid of the unharped tendons near the bottom of the beam

$A_{strand} = 0.153\,in^2$

$\varphi = 0.5\,in$ strand diameter

$f_{pu} = 270\,ksi$

$f_{pe} = 164.96\,ksi$

$E_p = 28500\,ksi$

$HarpDist = 17.5ft$ distance from the support to the harping location

$f_y = 67.3\,ksi$

$f_{yv} = 67.3\,ksi$ yield strength of the stirrups

$E_s = 29000\,ksi$

$RebarSize = 4$ stirrup size

$A_v = 0.4\,in^2$ area of a double-legged stirrup

$\alpha = \frac{\pi}{2}$ angle of the stirrups relative to the longitudinal axis of the beam

$A_{s.top} = 0in^2$ area of the mild steel reinforcement at the top of the girder

$d_{top} = 9.5\,in$ distance from the extreme compression fiber to the steel in the top of the girder

$cg_s = 4.4\,in$ distance from the girder bottom to the centroid of the mild steel

$cg_{s.bot} = 4.4\,in$ distance from the bottom of the girder to the centroid of the mild steel used for tension reinforcement

$d_{long.rebar} = 5$ size of the longitudinal mild reinforcement

IsLongSteelEpoxyCoated = "No"

LongSteelClearSpacing = 3.38 in

LongSteelCover = 1.75 in

IsTopBarEffectApplicable = "No"

$s_{v.design} = (2.5\ \ 6\ \ 6\ \ 9\ \ 9\ \ 9\ \ 9\ \ 9\ \ 9\ \ 9\ \ 9\ \ 9)^T\,in$ stirrup spacing, listed at distinct points along the shear span; see calculation for variable x_{dist} below

$A_{s.bot} = (2.04\ \ 2.04\ \ 2.04\ \ 2.04\ \ 2.04\ \ 2.04\ \ 2.04\ \ 2.04\ \ 2.04\ \ 2.04\ \ 2.04\ \ 2.04)^T\,in^2$

area of mild reinforcing steel in the bottom of the beam, listed at distinct points along the shear span; see explanation for variable x_{dist} below.

$A_{long.rebar} = 0.31in^2$ area of the mild steel in the longitudinal direction

$A_{diaphragm} = 0\,in^2$

$t_{wear} = 0\,in$

$\gamma_{wear} = 0\,pcf$

$b_{barrier} = 0\,in$

$w_{barrier} = 0\,klf$

$b_{bridge} = 0\,in$

additional parameters for dead load that were all set to equal zero since the beam being tested was a stand-alone structure with a cast-in-place composite deck

$ShearSpan = 57.34in$

$LoadSpacing = 174.19\,in$

$x_{bearing} = 6\,in$ distance from the end of the beam to the center of bearing of the pin support

$x_{bearing.roller} = 6\,in$ distance from the end of the beam to the center of bearing of the roller support

$x_{critical.assume} = 38.69\,in$ assumed distance from the support to the critical section

$N_u = 0$ axial force, assumed to be equal to zero

$\phi_v = 1.00$ resistance factor for shear, assumed to be equal to zero for analysis purposes

$\theta\beta method$ = "General" programming mechanism used to calculate the shear strength following A. 5.8.3.4.1 (if applicable) or A. 5.8.3.4.2

$P_{assume} = (369.68\;\; 196.22\;\; 199.24\;\; 148.17\;\; 150.98\;\; 151.77\;\; 146.7\;\; 147.75\;\; 147.81\;\; 148.07\;\; 148.01\;\; 148.65)\,kip$

Note that individual values for P_{assume} are listed at distinct locations along the shear span (see the calculations for x_{dist} below. Each value is the assumed load applied by each of the actuators, whose locations are specified by the parameters *ShearSpan* and *LoadSpacing*, that would result in a shear failure at the corresponding section indicated in x_{dist}. Ordinarily, the calculation would start with an arbitrary value for all of the section locations, say 150 kips or 250 kips. However, for the purposes of this example, the given P_{assume} values are used to mitigate the number of iterations necessary to reach convergence.

Subsequent calculations will require knowing the location of the sections for which the shear strength is being calculated. Those locations are defined by the term x_{dist}, given in this example in terms of the distance from the support closest to the point loads:

$$x_{dist} = (0\;\; 5.73\;\; 11.47\;\; 17.2\;\; 22.93\;\; 28.67\;\; 34.4\;\; 36.5\;\; 40.14\;\; 45.87\;\; 51.6\;\; 57.34)\,in$$

where each location is a tenth point along the length of the shear span, with the exception of the critical section, which in this case, is assumed to be 36.5 in.

Basic Geometry Calculations

$$h_c = h + t_{haunch} + t_{struct}$$

$$h_c = 36in + 1in + 8.5in$$

$$h_c = 45.5\,in$$

$$L_{span} = L_{beam} - \left(x_{bearing} + x_{bearing.roller}\right)$$

$$L_{span} = 41ft - (6in + 6in)$$

$$L_{span} = 40\,ft$$

$$A_{ps} = Num_{strand} \cdot A_{strand}$$

$$A_{ps} = 24 \cdot 0.153in^2$$

$$A_{ps} = 3.67\,in^2$$

$$A_{ps.bot} = Num_{strand.bot} \cdot A_{strand}$$

Area of unharped prestessing tendons along the bottom of the girder.

$$A_{ps.bot} = 16 \cdot 0.153in^2$$

$$A_{ps.bot} = 2.45\,in^2$$

$$b_{eff} = S = 7\,ft$$

$$\Psi_{harp} = atan\left(\frac{cg_{harp.end} - cg_{harp.ms}}{HarpDist + x_{bearing}}\right)$$

Angle of the harped tendon, relative to the longitudinal axis of the beam

$$\Psi_{harp} = atan\left(\frac{29in - 4in}{17.5ft + 6in}\right)$$

$$\Psi_{harp} = 0.12$$

$$d_s = h_c - cg_s$$

depth from the top of the composite section to the centroid of the mild steel reinforcement at the bottom of the beam.

$$d_s = 45.5in - 4.4in$$

$$d_s = 41.1\,in$$

$$cg_{harp_i} = cg_{harp.end} - \left(x_{dist_i} + x_{bearing}\right) \cdot \tan\left(\Psi_{harp}\right)$$ centroid of the harped tedons

$$cg_{harp_2} = 29in - (5.73in + 6in)\tan(0.12)$$

$$cg_{harp_2} = 27.64\,in$$

$$cg_{harp}^{T} = (28.31 \;\; 27.64 \;\; 26.98 \;\; 26.31 \;\; 25.65 \;\; 24.99 \;\; 24.32 \;\; 24.08 \;\; 23.66 \;\; 23 \;\; 22.33 \;\; 21.67)\,in$$

Note that the centroid of the harped tendons changes along the length of the shear span. Thus, the example above and all other example calculations that are dependent on the location of the section give a detailed calculation at a specific location, x_{dist} = 5.73 in., which is the second location given in the parameter x_{dist}. The results for all sections are then given at the end of each specific calculation.

Basic Material Calculations

$$f_{po} = 0.70 f_{pu}$$

$$f_{po} = 0.70 \cdot 270\text{ksi}$$

$$f_{po} = 189\ \text{ksi}$$

$$\kappa = \frac{in^2}{kip} \cdot \begin{cases} 1.6 & \text{if } h \geq 24in \\ 1.0 & \text{if } h < 24in \\ \text{"error"} & \text{otherwise} \end{cases}$$

$$\kappa = 1.6\ \frac{in^2}{kip}$$

$$f_{r.V} = \begin{cases} 0.20 \cdot \sqrt{\dfrac{f_{c'}}{ksi}}\ ksi & \text{if FineAggType = "sand"} \\ \left(0.17 \cdot \sqrt{\dfrac{f_{c'}}{ksi}}\ ksi\right) & \text{if FineAggType = "lightweight"} \\ \text{"error"} & \text{otherwise} \end{cases}$$

modululs of rupture for shear calculations

$$f_{r.V} = 0.20 \cdot \sqrt{8.87ksi}$$

$$f_{r.V} = 595.48\ \text{psi}$$

$$\beta_{1.}(f_{c'deck}) = \begin{cases} 0.85 & \text{if } f_{c'deck} \leq 4ksi \\ \max\left[0.85 - 0.05 \cdot \left(\dfrac{f_{c'deck}}{ksi} - 4.0\right), 0.65\right] & \text{if } f_{c'deck} > 4ksi \end{cases}$$

$$\beta_{1.}(5.83ksi) = \max[0.85 - 0.05 \cdot (5.83 - 4.0), 0.65]$$

$$\beta_1 = 0.76$$

$$\alpha_v = 1 \quad \text{if ConcreteType = "NWC"}$$

As discussed earlier, although the concrete in this beam was actually lightweight concrete, the assumption was that the lightweight modifier was not necessary. Hence, this example assumes that lightweight concrete behaves similarly to normal weight concrete.

Load Effects

Live Loads

For a simply-supported beam subjected to two point loads, the shear at any point along the beam within the shear span, V_{LL}, can be calculated as

$$V_{LL_i} = \frac{P_{assume_i}}{L_{span}} \cdot \left[2\left(L_{span} - ShearSpan\right) - LoadSpacing\right]$$

$$V_{LL_2} = \frac{196.22kip}{40ft} \cdot [2 \cdot (40ft - 57.34in) - 14.52ft]$$

$$V_{LL.2} = 274.4kip$$

$$V_{LL}^T = (516.9 \quad 274.4 \quad 278.6 \quad 207.2 \quad 211.1 \quad 212.2 \quad 205.1 \quad 206.6 \quad 206.7 \quad 207 \quad 206.9 \quad 207.8)\ kip$$

The moment at the same locations, M_{LL}, can be calculated as

$$M_{LL_i} = \frac{P_{assume_i}}{L_{span}} \cdot \left[2\left(L_{span} - ShearSpan\right) - LoadSpacing\right] \cdot x_{dist_i}$$

$$M_{LL_2} = \frac{196.22kip}{40ft} \cdot [2(40ft - 57.34in) - 14.52ft]\, 5.73in$$

$$M_{LL_2} = 131.1ft \cdot kip$$

$$M_{LL}^T = (0\ \ 131.1\ \ 266.2\ \ 297\ \ 403.5\ \ 507\ \ 588.1\ \ 666.5\ \ 691.2\ \ 791.4\ \ 889.9\ \ 993.1)\ ft \cdot kip$$

Dead Loads

The uniformly distributed forces due to the weight of the beam, the haunch and the deck are calculated as:

$$w_{beam} = \gamma_c \cdot A_{beam}$$

$$w_{beam} = 121.5pcf \cdot 369in^2$$

$$w_{beam} = 311.34\,plf$$

$$w_{deck} = t_s \cdot S \cdot \gamma_{c.deck}$$

$$w_{deck} = 8.5in \cdot 7ft \cdot 123.4pcf$$

$$w_{deck} = 611.86\,plf$$

$$w_{haunch} = t_{haunch} \cdot b_f \cdot \gamma_{c.deck}$$

$$w_{haunch} = 1in \cdot 12in \cdot 123.4pcf$$

$$w_{haunch} = 10.28\,plf$$

$$DC_1 = w_{beam} + w_{deck} + w_{haunch}$$

$$DC_1 = 311.34plf + 611.86plf + 10.28plf$$

$$DC_1 = 933.49\,plf$$

where DC_1 is the dead load of the composite structure. There were no other dead loads present. These results can be used to calculate the shear and moment due to composite dead loads, V_{DC1} and M_{DC1}, respectively, as:

$$V_{DC1_i} = \frac{DC_1}{2L_{span}}\cdot(x_{bearing} + L_{span} + x_{bearing.roller})^2 - \frac{DC_1\cdot x_{bearing.roller}}{L_{span}}(x_{bearing} + L_{span} + x_{bearing.roller})$$
$$-DC_1\cdot\left(x_{dist_i} + x_{bearing}\right) + V_{diaphragm_i}$$

$$V_{DC1_2} = \frac{933.49plf}{2\cdot 40ft}\cdot(6in + 40ft + 6in)^2 - \frac{933.49plf\cdot 6in}{40ft}\cdot(6in + 40ft + 6in) - 933.49plf\cdot(6in + 6in) + 0$$

$$V_{DC1_2} = 18.22kip$$

$$V_{DC1}^T = (18.67 \;\; 18.22 \;\; 17.78 \;\; 17.33 \;\; 16.89 \;\; 16.44 \;\; 15.99 \;\; 15.83 \;\; 15.55 \;\; 15.1 \;\; 14.66 \;\; 14.21)\,kip$$

$$M_{DC1_i} \leftarrow \left[\left(\frac{DC_1}{2L_{span}}\right)(x_{bearing} + L_{span} + x_{bearing.roller})^2 - \frac{DC_1\cdot x_{bearing.roller}}{L_{span}}(x_{bearing} + L_{span} + x_{bearing.roller})\right]\cdot x_{dist_i}$$
$$-\frac{1}{2}DC_1\cdot\left(x_{dist_i} + x_{bearing}\right)^2 + M_{diaphragm_i}$$

$$M_{DC1_2} = \left[\left(\frac{933.49plf}{2\cdot 40ft}\right)\cdot(6in + 40ft + 6in)^2 - \frac{933.49plf\cdot 6in}{40ft}(6in + 40ft + 6in)\right]\cdot 5.37in - \frac{1}{2}933.49plf\cdot(6in + 6in)^2 + 0$$

$$M_{DC1_2} = 8.7ft\cdot kip$$

$$M_{DC1}^T = (-0.12 \;\; 8.7 \;\; 17.3 \;\; 25.69 \;\; 33.86 \;\; 41.82 \;\; 49.57 \;\; 52.35 \;\; 57.11 \;\; 64.43 \;\; 71.54 \;\; 78.43)\,ft\cdot kip$$

Total Load Effects

Given the assumed live loads, the total assumed shear and moment in the girder, V_{assume} and $M_{assume1}$ are the sum of the live and dead loads given in Sections 0 and 0 above, such that:

$$V_{assume} = V_{LL} + V_{DC1}$$

$$V_{assume_2} = 274.35kip + 18.22kip$$

$$V_{assume_2} = 292.6kip$$

$$V_{assume}^T = (535.6 \;\; 292.6 \;\; 296.4 \;\; 224.5 \;\; 228 \;\; 228.6 \;\; 221.1 \;\; 222.3 \;\; 222.2 \;\; 222.1 \;\; 221.6 \;\; 222.1)\,kip$$

$M_{assume1} = M_{LL} + M_{DC1}$

$M_{assume1_2} = 131.09ft \cdot kip + 8.7ft \cdot kip$

$M_{assume1_2} = 139.8 \cdot ft \cdot kip$

$M_{assume1}^T = (-0.1 \;\; 139.8 \;\; 283.5 \;\; 322.6 \;\; 437.3 \;\; 548.8 \;\; 637.6 \;\; 721.8 \;\; 748.3 \;\; 855.8 \;\; 961.5 \;\; 1071.5)\, ft \cdot kip$

Calculate the Shear Resistance

Determine β and θ

Calculate the Effective Shear Depth of the Beam, d_v

Calculate the Depth of the Compression Block, *c*

Assuming that the depth of the compression block is less than the thickness of the deck, and thus the compressive strength of the concrete, $f_{c'c}$, is that of the deck concrete, $f_{c'deck}$, then

$$cg_{ps_i} = \frac{Num_{straight} \cdot cg_{straight} + Num_{harp} \cdot cg_{harp_i}}{Num_{strand}}$$

$$cg_{ps_2} = \frac{18 \cdot 7in + 6 \cdot 27.64in}{24}$$

$$cg_{ps_2} = 12.16\, in$$

$$cg_{ps}^T = (12.33 \;\; 12.16 \;\; 11.99 \;\; 11.83 \;\; 11.66 \;\; 11.5 \;\; 11.33 \;\; 11.27 \;\; 11.16 \;\; 11 \;\; 10.83 \;\; 10.67)\, in$$

$$d_{p_i} = h_c - cg_{ps_i}$$

$$d_{p_2} = 45.5in - 12.16in$$

$$d_{p_2} = 33.34\, in$$

$$d_p^T = (33.17 \;\; 33.34 \;\; 33.51 \;\; 33.67 \;\; 33.84 \;\; 34 \;\; 34.17 \;\; 34.23 \;\; 34.34 \;\; 34.5 \;\; 34.67 \;\; 34.83)\, in$$

$$c_i = \frac{A_{ps} \cdot f_{pu} + A_{s.bot_i} \cdot f_y - A_{s.top} \cdot f_y}{0.85 \cdot f_{c'c} \cdot \beta_1 \cdot b_{eff} + k \cdot A_{ps} \cdot \frac{f_{pu}}{d_{p_i}}}$$

$$c_2 = \frac{3.67in^2 \cdot 270ksi + 2.04in^2 \cdot 67.3ksi - 0}{0.85 \cdot 5.83ksi \cdot 0.76 \cdot 7ft + 0.28 \cdot 3.67in^2 \cdot \frac{270ksi}{33.34in}}$$

$$c_2 = 3.48\,in$$

$$c^T = (3.48 \;\; 3.48 \;\; 3.48 \;\; 3.48 \;\; 3.48 \;\; 3.49 \;\; 3.49 \;\; 3.49 \;\; 3.49 \;\; 3.49 \;\; 3.49 \;\; 3.49)\,in$$

$$a = \beta_1 \cdot c$$

$$a_2 = 0.76 \cdot 3.48in$$

$$a_2 = 2.64\,in$$

$$a^T = (2.64 \;\; 2.64 \;\; 2.64 \;\; 2.64 \;\; 2.64 \;\; 2.64 \;\; 2.64 \;\; 2.64 \;\; 2.64 \;\; 2.64 \;\; 2.64 \;\; 2.65)\,in$$

Calculate the Stress in the Prestressing Strands, f_{ps}

Let $f_{ps.max}$ be the stress in the steel according to Eq. 5.7.3.1.1-1 in the AASHTO LRFD Bridge Specifications, and $l_{d.ps}$ be the development length of the prestress. Then,

$$f_{ps.max_i} = f_{pu} \cdot \left(1 - k \cdot \frac{c_i}{d_{p_i}}\right)$$

$$f_{ps.max_2} = 270ksi \cdot \left(1 - \frac{0.28 \cdot 3.48in}{33.34in}\right)$$

$$f_{ps.max_2} = 262.1\,ksi$$

$$f_{ps.max}^T = (262.06\ \ 262.1\ \ 262.14\ \ 262.18\ \ 262.21\ \ 262.25\ \ 262.29\ \ 262.3\ \ 262.32\ \ 262.36\ \ 262.4\ \ 262.43)\,ksi$$

$$l_{d.ps_i} = \kappa \cdot \left(f_{ps.max_i} - \frac{2}{3} \cdot f_{pe}\right) \cdot \varphi$$

$$l_{d.ps_2} = \frac{1.6}{ksi}\left(262.1ksi - \frac{2}{3}164.96ksi\right)0.5in$$

$$l_{d.ps_2} = 121.7\,in$$

$$l_{d.ps}^T = (121.67\ \ 121.7\ \ 121.73\ \ 121.76\ \ 121.79\ \ 121.82\ \ 121.85\ \ 121.86\ \ 121.88\ \ 121.91\ \ 121.94\ \ 121.97)\,in$$

$$f_{ps_i} = \begin{cases} \dfrac{f_{pe} \cdot \left(x_{dist_i} + x_{bearing}\right)}{l_t} & \text{if } x_{dist_i} + x_{bearing} \le l_t \\[2ex] f_{pe} + \dfrac{x_{dist_i} + x_{bearing} - l_t}{l_{d.ps_i} - l_t} \cdot \left(f_{ps.max_i} - f_{pe}\right) & \text{if } x_{dist_i} + x_{bearing} > l_t \wedge x_{dist_i} + x_{bearing} < l_{d.ps_i} \\[2ex] f_{ps.max_i} & \text{if } x_{dist_i} + x_{bearing} \ge l_{d.ps_i} \end{cases}$$

$$f_{ps_2} = \frac{164.96ksi \cdot (5.73in + 6in)}{30in} \quad \text{if } 5.73in + 6in \le 30in$$

$$f_{ps_2} = 64.5\,ksi$$

$$f_{ps}^T = (32.99\ \ 64.5\ \ 96.06\ \ 127.57\ \ 159.08\ \ 169.91\ \ 175.98\ \ 178.21\ \ 182.06\ \ 188.14\ \ 194.21\ \ 200.3)\,ksi$$

Find the Effective Depth, d_e

The centroid of the prestressing steel in the flexural tension region of the beam is calculated as:

$$cg_{ps.bot_i} = \begin{cases} cg_{straight.bot} & \text{if } cg_{harp_i} - 2in \geq \frac{1}{2}h_c \\ \dfrac{Num_{straight.bot} \cdot cg_{straight.bot} + 2\cdot\left(cg_{harp_i} - 2in\right)}{Num_{straight.bot} + 2} & \text{if } cg_{harp_i} - 2in < \frac{1}{2}h_c \wedge cg_{harp_i} \geq \frac{1}{2}h_c \\ \dfrac{Num_{straight.bot} \cdot cg_{straight.bot} + 2\cdot\left(cg_{harp_i} - 2in + cg_{harp_i}\right)}{Num_{straight.bot} + 4} & \text{if } cg_{harp_i} < \frac{1}{2}h_c \wedge cg_{harp_i} + 2in \geq \frac{1}{2}h_c \\ \dfrac{Num_{straight.bot} \cdot cg_{straight.bot} + 6\cdot cg_{harp_i}}{Num_{straight.bot} + 6} & \text{if } cg_{harp_i} + 2in < \frac{1}{2}h_c \end{cases}$$

$$cg_{ps.bot_2} = cg_{strand.bot} \quad \text{if} \quad cg_{harp_2} - 2in \geq \frac{1}{2}h_c$$

$$cg_{ps.bot_2} = 3.75in \quad \text{if} \quad 27.64in - 2in \geq \frac{1}{2}45.5in$$

$$cg_{ps.bot_2} = 3.75in \quad \text{if} \quad 25.64in \geq 22.75in$$

$$cg_{ps.bot_2} = 3.75\,in$$

$$cg_{ps.bot}^T = (3.75 \;\; 3.75 \;\; 3.75 \;\; 3.75 \;\; 3.75 \;\; 3.75 \;\; 5.81 \;\; 5.79 \;\; 5.74 \;\; 5.67 \;\; 7.27 \;\; 7.13)\,in$$

Therefore, $d_{p.bot}$ and $d_{s.bot}$, the depths from the top of the composite section to the centroid of the prestressing steel and mild steel, respectively, that are on the flexural tension side of the beam, are calculated as:

$$d_{p.bot} = h_c - cg_{ps.bot}$$

$$d_{p.bot_2} = 45.5in - 3.75in$$

$$d_{p.bot_2} = 41.75\,in$$

$$d_{p.bot}^{T} = (41.75\ \ 41.75\ \ 41.75\ \ 41.75\ \ 41.75\ \ 41.75\ \ 39.69\ \ 39.71\ \ 39.76\ \ 39.83\ \ 38.23\ \ 38.37)\,in$$

$$d_{s.bot} = h_c - cg_{s.bot}$$

$$d_{s.bot_2} = 45.5in - 4.4in$$

$$d_{s.bot_2} = 41.1\,in$$

$$d_{s.bot}^{T} = (41.1\ \ 41.1\ \ 41.1\ \ 41.1\ \ 41.1\ \ 41.1\ \ 41.1\ \ 41.1\ \ 41.1\ \ 41.1\ \ 41.1\ \ 41.1)\,in$$

In order to calculate the area of strand in the flexural tension side of the beam, the number of strands is determined as:

$$Num_{strand.bot_i} = \begin{vmatrix} Num_{strand} - Num_{harp} - Num_{strand.top} & \text{if } cg_{harp_i} - 2in \geq \frac{1}{2}h_c \\ Num_{strand} - Num_{harp} - Num_{strand.top} + 2 & \text{if } cg_{harp_i} - 2in < \frac{1}{2}h_c \wedge cg_{harp_i} \geq \frac{1}{2}h_c \\ Num_{strand} - Num_{harp} - Num_{strand.top} + 4 & \text{if } cg_{harp_i} < \frac{1}{2}h_c \wedge cg_{harp_i} + 2in \geq \frac{1}{2}h_c \\ Num_{strand} - Num_{strand.top} & \text{if } cg_{harp_i} + 2in < \frac{1}{2}h_c \end{vmatrix}$$

$$Num_{strand.bot_2} = Num_{strand} - Num_{harp} - Num_{strand.top} \quad \text{if } cg_{harp_2} - 2in \geq \frac{1}{2}h_c$$

$$Num_{strand.bot_2} = 24 - 6 - 2 \quad \text{if } 27.64in \geq \frac{1}{2}45.5in$$

$$Num_{strand.bot_2} = 16 \quad \text{if } 27.64in \geq 22.75in$$

$$Num_{strand.bot_2} = 16$$

$$Num_{strand.bot}^T = (16 \ \ 16 \ \ 16 \ \ 16 \ \ 16 \ \ 16 \ \ 18 \ \ 18 \ \ 18 \ \ 18 \ \ 20 \ \ 20)$$

Consequently, the area of strand in the flexural tension side of the beam is:

$$A_{ps.bot_i} = Num_{strand.bot_i} A_{strand}$$

$$A_{ps.bot_2} = Num_{strand.bot_2} \cdot A_{strand}$$

$$A_{ps.bot_2} = 16 \cdot 0.153in^2$$

$$A_{ps.bot_2} = 2.45\,in^2$$

$$A_{ps.bot}^T = (2.45 \ \ 2.45 \ \ 2.45 \ \ 2.45 \ \ 2.45 \ \ 2.45 \ \ 2.75 \ \ 2.75 \ \ 2.75 \ \ 2.75 \ \ 3.06 \ \ 3.06)\,in^2$$

Using the information above, the effective depth, d_e, is calculated as:

$$d_{e_i} = \frac{A_{ps.bot_i} \cdot f_{ps_i} \cdot d_{p.bot_i} + A_{s.bot_i} \cdot f_y \cdot d_{s.bot_i}}{A_{ps.bot_i} \cdot f_{ps_i} + A_{s.bot_i} \cdot f_y}$$

$$d_{e_2} = \frac{A_{ps.bot_2} \cdot f_{ps_2} \cdot d_{p.bot_2} + A_{s.bot_2} \cdot f_y \cdot d_{s.bot_2}}{A_{ps.bot_2} \cdot f_{ps_2} + A_{s.bot_2} \cdot f_y}$$

$$d_{e_2} = \frac{2.45in^2 \cdot 64.5ksi \cdot 41.75in + 2.04in^2 \cdot 67.3ksi \cdot 41.1in}{2.45in^2 \cdot 64.5ksi + 2.04in^2 \cdot 67.3ksi}$$

$$d_{e_2} = 41.45\,in$$

$$d_e^T = (41.34 \quad 41.45 \quad 41.51 \quad 41.55 \quad 41.58 \quad 41.59 \quad 40 \quad 40.02 \quad 40.05 \quad 40.1 \quad 38.77 \quad 38.87)\,in$$

Ensure that the mild steel in the flexural tension side yields:

$$\varepsilon_{s.yield} = \frac{f_y}{E_s}$$

$$\varepsilon_{s.yield} = \frac{67.3ksi}{29000ksi}$$

$$\varepsilon_{s.yield} = 0.002$$

$$\varepsilon_{s_i} = \frac{0.003}{c_i} \cdot \left(d_{e_i} - c_i\right)$$

$$\varepsilon_{s_2} = \frac{0.003}{c_2} \cdot \left(d_{e_2} - c_2\right)$$

$$\varepsilon_{s_2} = \frac{0.003}{3.48in} \cdot (41.45in - 3.48in)$$

$$\varepsilon_{s_2} = 0.033$$

$$\varepsilon_s^T = (0.03 \;\; 0.03 \;\; 0.03 \;\; 0.03 \;\; 0.03 \;\; 0.03 \;\; 0.03 \;\; 0.03 \;\; 0.03 \;\; 0.03 \;\; 0.03 \;\; 0.03)$$

Since the strain in the steel is greater than the yield strain, all assumptions used in calculating the depth of the compression block, *c*, are validated.

Find the effective shear depth, d_v

$$d_{v_i} = \max\left(d_{e_i} - \frac{a_i}{2}, 0.9\, d_{e_i}, 0.72 h_c\right)$$

$$d_{v_2} = \max\left(d_{e_2} - \frac{a_2}{2}, 0.9\, d_{e_2}, 0.72 h_c\right)$$

$$d_{v_2} = \max\left(41.45in - \frac{2.64in}{2}, 0.9 \cdot 41.45in, 0.72 \cdot 45.5in\right)$$

$$d_{v_2} = \max(40.13in, 37.31in, 32.76in)$$

$$d_{v_2} = 40.13\, in$$

$$d_v^T = (40.02 \;\; 40.13 \;\; 40.19 \;\; 40.23 \;\; 40.26 \;\; 40.27 \;\; 38.68 \;\; 38.69 \;\; 38.73 \;\; 38.78 \;\; 37.45 \;\; 37.54)\, in$$

Find the Factored Moment, M_{assume}

According to Article 5.8.3.4.2 of the AASHTO LRFD Bridge Specifications, the factored moment used in determining β and θ should not exceed

$$|M_u| \geq |V_u - V_p| d_v \qquad \textbf{(K - 1)}$$

where V_p is calculated as:

$$V_{p_i} = \begin{cases} \dfrac{f_{pe} \cdot \left(x_{dist_i} + x_{bearing}\right)}{l_t} \cdot Num_{harp} \cdot A_{strand} \cdot \sin\left(\Psi_{harp}\right) & \text{if } x_{dist_i} + x_{bearing} \leq l_t \wedge x_{dist_i} \leq HarpDist \\ f_{pe} \cdot Num_{harp} \cdot A_{strand} \cdot \sin\left(\Psi_{harp}\right) & \text{if } x_{dist_i} + x_{bearing} > l_t \wedge x_{dist_i} \leq HarpDist \\ 0 & \text{if } x_{dist_i} > L_{span} \cdot HarpDistRatio \end{cases}$$

$$V_{p_2} = \frac{f_{pe} \cdot \left(x_{dist_2} + x_{bearing}\right)}{l_t} \cdot Num_{harp} \cdot A_{strand} \cdot \sin\left(\Psi_{harp}\right) \quad \text{if } x_{dist_2} + x_{bearing} \leq l_t \wedge x_{dist_2} \leq HarpDist$$

$$V_{p_2} = \frac{164.96ksi \cdot (5.73in + 6in)}{30in} \cdot 6 \cdot 0.153in^2 \cdot \sin(0.1152) \quad \text{if } 5.73in + 6in \leq 30in \wedge 5.73in \leq 17.5ft$$

$$V_{p_2} = 6.81kip \quad \text{if } 11.73in \leq 30in \wedge 5.73in \leq 17.5ft$$

$$V_{p_2} = 6.81kip$$

$$V_p^T = (3.48 \ \ 6.81 \ \ 10.14 \ \ 13.46 \ \ 16.79 \ \ 17.41 \ \ 17.41 \ \ 17.41 \ \ 17.41 \ \ 17.41 \ \ 17.41 \ \ 17.41)\,kip$$

Therefore, the assumed moment in the girder at the time of failure, M_{assume}, is the maximum of $M_{assume1}$ found in (K - 1):

$$M_{assume_i} = \max\left(M_{assume1_i}, \left|V_{assume_i} - V_{p_i}\right| \cdot d_{v_i}\right)$$

$$M_{assume_2} = \max\left(M_{assume1_2}, \left|V_{assume_2} - V_{p_2}\right| \cdot d_{v_2}\right)$$

$$M_{assume_2} = \max(139.79ft \cdot kip, |292.58kip - 6.81kip| \cdot 40.13in)$$

$$M_{assume_2} = \max(139.79ft \cdot kip, 955.66ft \cdot kip)$$

$$M_{assume_2} = 955.59\,ft \cdot kip$$

Find The Average Factored Shear Stress on the Concrete, v_u

Check for Minimum Reinforcement Requirements

$$MinReinforcingCheck_i = \begin{cases} \text{"OK"} & \text{if } 0.0316\alpha_v \cdot \sqrt{f_{c'} \cdot (ksi)} \cdot \dfrac{b_v \cdot s_{v.design_i}}{f_{yv}} \le A_{v_i} \\ \text{"NG!!!"} & \text{if } 0.0316\alpha_v \cdot \sqrt{f_{c'} \cdot (ksi)} \cdot \dfrac{b_v \cdot s_{v.design_i}}{f_{yv}} > A_{v_i} \\ \text{"error"} & \text{otherwise} \end{cases}$$

$$MinReinforcingCheck_2 = \text{"OK"} \quad \text{if } 0.0316\alpha_v \cdot \sqrt{f_{c'} \cdot (ksi)} \cdot \frac{b_v \cdot s_{v.design_2}}{f_{yv}} \le A_{v_2}$$

$$MinReinforcingCheck_2 = \text{"OK"} \quad \text{if } 0.0316(1) \cdot \sqrt{8.87ksi} \cdot \frac{6in \cdot 6in}{67.3ksi} \le 0.4in^2$$

$$MinReinforcingCheck_2 = \text{"OK"} \quad \text{if } 0.05in^2 \le 0.4in^2$$

$$MinReinforcingCheck^T = (\text{"OK"} \quad \text{"OK"} \quad \text{"OK"} \quad \text{"OK"} \quad \text{"OK"} \quad \text{"OK"} \quad \text{"OK"} \quad \text{"OK"} \quad \text{"OK"}$$

Calculate v_u

$$v_{u_i} = \begin{cases} \dfrac{\dfrac{\left|V_{assume_i} - \phi_v \cdot V_{p_i}\right|}{\phi_v \cdot b_v \cdot d_{v_i}}}{f_{c'}} & \text{if } MinReinforcingCheck_i = \text{"OK"} \\ \dfrac{\min\left(s_{x_i} \cdot \dfrac{1.38in}{a_g + 0.63in}, 80in\right)}{in} & \text{if } MinReinforcingCheck_i = \text{"NG!!!"} \end{cases}$$

$$v_{u_2} = \frac{\frac{\left|V_{assume_2} - \phi_v \cdot V_{p_2}\right|}{\phi_v \cdot b_v \cdot d_{v_2}}}{f_{c'}} \quad \text{if MinReinforcingCheck}_2 = \text{"OK"}$$

$$v_{u_2} = \frac{\frac{\left|292.58\text{kip} - (1.00) \cdot 6.81\text{kip}\right|}{(1.00) \cdot 6\text{in} \cdot 40.13\text{in}}}{8.87\text{ksi}} \quad \text{if MinReinforcingCheck}_2 = \text{"OK"}$$

$$v_{u_2} = 0.134$$

$$v_u^T = (0.25 \quad 0.134 \quad 0.134 \quad 0.099 \quad 0.099 \quad 0.099 \quad 0.099 \quad 0.1 \quad 0.099 \quad 0.099 \quad 0.103 \quad 0.102)$$

Determine the Reduced Area of Steel, $A_{ps.bot.ex}$ and $A_{s.bot.ex}$

According the Article 5.8.3.4.2, if the full development length has not been reached at a given section, then the area of steel must be reduced proportionately to the ratio of the length of the steel at that section versus the development length.

Calculate the Development Length of the Mild Reinforcement

$$l_{db} = \max\left(\frac{1.25A_{long.rebar} \cdot f_y}{\sqrt{f_{c'} \cdot ksi}\,in}, 0.4\,\frac{d_{long.rebar}}{8} \cdot \frac{f_y}{ksi}\,in\right)$$

$$l_{db} = \max\left(\frac{1.25 \cdot 0.31in^2 \cdot 67.3ksi}{\sqrt{8.87ksi^2} \cdot in}, 0.4 \cdot \frac{5}{8} \cdot \frac{67.3ksi}{ksi}\,in\right)$$

$$l_{db} = \max(8.76in, 16.82in)$$

$$l_{db} = 16.82\,in$$

$$\kappa_1 = \begin{cases} 1.0 & \text{if IsTopBarEffectApplicable = "No"} \\ 1.4 & \text{if IsTopBarEffectApplicable = "Yes"} \\ \text{"error"} & \text{otherwise} \end{cases}$$

$$\kappa_1 = 1.0 \;\; \text{if IsTopBarEffectApplicable = "No"}$$

$$\kappa_1 = 1$$

$$\kappa_2 = \begin{cases} 1.0 \ \text{if IsLongSteelEpoxyCoated = "No"} \\ 1.5 \ \text{if IsLongSteelEpoxyCoated = "Yes"} \wedge \left(\text{LongSteelCover} < 3\dfrac{d_{long.rebar}}{8}\cdot in \vee \text{LongSteelClearSpacing} < 6\dfrac{d_{long.rebar}}{8}\cdot in\right) \\ 1.2 \ \text{if IsLongSteelEpoxyCoated = "Yes"} \wedge \text{LongSteelCover} \geq 3\dfrac{d_{long.rebar}}{8}\cdot in \wedge \text{LongSteelClearSpacing} \geq 6.\dfrac{d_{long.rebar}}{8}\cdot in \end{cases}$$

$\kappa_2 = 1.0$ if IsLongSteelEpoxyCoated = "No"

$\kappa_2 = 1$

$\kappa_{12} = \min(\kappa_1 \cdot \kappa_2, 1.7)$

$\kappa_{12} = \min(1 \cdot 1, 1.7$

$\kappa_{12} = \min(1, 1.7)$

$\kappa_{12} = 1$

$$\kappa_3 = \begin{cases} 1 \ \text{if ConcreteType = "NWC"} \\ \max\left(0.22\dfrac{\sqrt{f_{c'} \cdot ksi}}{f_{ct}}, 1.0\right) \ \text{if ConcreteType = "LWC"} \wedge \text{Value\_}f_{ct} = \text{"specified"} \\ 1.3 \ \text{if ConcreteType = "LWC"} \wedge \text{Value\_}f_{ct} = \text{"not specified"} \wedge \text{FineAggType = "lightweight"} \\ 1.2 \ \text{if ConcreteType = "LWC"} \wedge \text{Value\_}f_{ct} = \text{"not specified"} \wedge \text{FineAggType = "sand"} \\ \text{"error" otherwise} \end{cases}$$

$\kappa_3 = 1$ if ConcreteType = "NWC"

$\kappa_3 = 1$

$\kappa_{123} = \kappa_{12} \cdot \kappa_3$

$\kappa_{123} = 1 \cdot 1$

$\kappa_{123} = 1$

$l_{d.mild} = l_{db} \cdot \kappa_{123}$

$l_{d.mild} = 16.82 in \cdot 1$

$l_{d.mild} = 16.82 \, in$

Determine the Area Reduction Factors

$$RedFactor_{\varepsilon x.s_i} = \begin{cases} \dfrac{x_{dist_i} + x_{bearing}}{l_{d.mild}} & \text{if } x_{dist_i} + x_{bearing} < l_{d.mild} \\ 1 & \text{if } x_{dist_i} + x_{bearing} \geq l_{d.mild} \end{cases}$$

$$RedFactor_{\varepsilon x.s_2} = \frac{x_{dist_2} + x_{bearing}}{l_{d.mild}} \quad \text{if } x_{dist_2} + x_{bearing} < l_{d.mild}$$

$$RedFactor_{\varepsilon x.s_2} = \frac{5.73in + 6in}{16.82in} \quad \text{if } 5.73in + 6in < 16.82in$$

$$RedFactor_{\varepsilon x.s_2} = 0.697 \quad \text{if } 11.73in < 16.82in$$

$$RedFactor_{\varepsilon x.s_2} = 0.697$$

$$RedFactor_{\varepsilon x.s}^T = (0.357 \;\; 0.697 \;\; 1 \;\; 1 \;\; 1 \;\; 1 \;\; 1 \;\; 1 \;\; 1 \;\; 1 \;\; 1 \;\; 1)$$

$$RedFactor_{\varepsilon x.ps_i} = \begin{cases} \dfrac{x_{dist_i} + x_{bearing}}{l_{d.ps_i}} & \text{if } x_{dist_i} + x_{bearing} < l_{d.ps_i} \\ 1 & \text{if } x_{dist_i} + x_{bearing} \geq l_{d.ps_i} \end{cases}$$

$$RedFactor_{\varepsilon x.ps_2} = \frac{x_{dist_2} + x_{bearing}}{l_{d.ps_2}} \quad \text{if } x_{dist_2} + x_{bearing} < l_{d.ps_2}$$

$$RedFactor_{\varepsilon x.ps_2} = \frac{5.73in + 6in}{121.7in} \quad \text{if } 5.73in + 6in < 121.7in$$

$$RedFactor_{\varepsilon x.ps_2} = 0.096$$

$$RedFactor_{\varepsilon x.ps}^T = (0.049 \;\; 0.096 \;\; 0.144 \;\; 0.191 \;\; 0.238 \;\; 0.285 \;\; 0.332 \;\; 0.349 \;\; 0.379 \;\; 0.425 \;\; 0.472 \;\; 0.519)$$

Calculate the Reduced Area of Steel, $A_{s.bot.\varepsilon x}$ and $A_{ps.bot.\varepsilon x}$

$$A_{s.bot.\varepsilon x_i} = A_{s.bot_i} \cdot RedFactor_{\varepsilon x.s_i}$$

$$A_{s.bot.\varepsilon x_2} = A_{s.bot_2} \cdot RedFactor_{\varepsilon x.s_2}$$

$$A_{s.bot.\varepsilon x_2} = 2.04in^2 \cdot 0.697$$

$$A_{s.bot.\varepsilon x_2} = 1.42\,in^2$$

$$A_{s.bot.\varepsilon x}{}^T = (0.73\ \ 1.42\ \ 2.04\ \ 2.04\ \ 2.04\ \ 2.04\ \ 2.04\ \ 2.04\ \ 2.04\ \ 2.04\ \ 2.04\ \ 2.04)\,in^2$$

$$A_{ps.bot.\varepsilon x_i} = Num_{strand.bot_i} \cdot A_{strand} \cdot RedFactor_{\varepsilon x.ps_i}$$

$$A_{ps.bot.\varepsilon x_2} = Num_{strand.bot_2} \cdot A_{strand} \cdot RedFactor_{\varepsilon x.ps_2}$$

$$A_{ps.bot.\varepsilon x_2} = 16 \cdot 0.153in^2 \cdot 0.096$$

$$A_{ps.bot.\varepsilon x_2} = 0.24\,in^2$$

$$A_{ps.bot.\varepsilon x}{}^T = (0.12\ \ 0.24\ \ 0.35\ \ 0.47\ \ 0.58\ \ 0.7\ \ 0.91\ \ 0.96\ \ 1.04\ \ 1.17\ \ 1.45\ \ 1.59)\,in^2$$

Determine **β *and*** **θ**

Even within each iteration for calculating the shear strength of a girder, the process for finding θ itself can be iterative. The reason is because θ, the predicted crack angle relative to the horizontal axis, depends on the longitudinal strain at mid-depth of the beam, ε_x, which in turn, depends on θ, according to Article B5.2. If following the General Procedures in Article 5.8.3.4.2, then this process is not as iterative because the cracking angle was removed from the equation for longitudinal strain as a conservative simplification. If using Appendix B5, one must assume an initial value for the cracking angle and then repeat the calculation until a value for θ converges. In the case of this example, which again, follows the tabularized method in Appendix B5 for finding β and θ, the assumed values for θ (in radians) at specific sections along the length of the shear span are:

$$\theta_{assume} = (0.6231\ \ 0.6476\ \ 0.6476\ \ 0.6402\ \ 0.6402\ \ 0.6402\ \ 0.6382\ \ 0.6357\ \ 0.636\ \ 0.6369\ \ 0.6198\ \ 0.62)^T$$

Having assumed θ, and knowing all of the other necessary parameters, one can calculate ε_x as:

$$\varepsilon_{x_i} = \left| \begin{array}{l} \varepsilon_{x1_i} \leftarrow \dfrac{\dfrac{\left|M_{assume_i}\right|}{d_{v_i}} + 0.5 \cdot N_u + 0.5 \cdot \left|V_{assume_i} - V_{p_i}\right| \cot\left(\theta_{assume_i}\right) - A_{ps.bot.\varepsilon x_i} \cdot f_{po}}{2 \cdot \left(E_s \cdot A_{s.bot.\varepsilon x_i} + E_p \cdot A_{ps.bot.\varepsilon x_i}\right)} \\ \varepsilon_{x2_i} \leftarrow \dfrac{\dfrac{\left|M_{assume_i}\right|}{d_{v_i}} + 0.5 \cdot N_u + 0.5 \cdot \left|V_{assume_i} - V_{p_i}\right| \cot\left(\theta_{assume_i}\right) - A_{ps.bot.\varepsilon x_i} \cdot f_{po}}{E_s \cdot A_{s.bot.\varepsilon x_i} + E_p \cdot A_{ps.bot.\varepsilon x_i}} \\ \varepsilon_{x3_i} \leftarrow \dfrac{\dfrac{\left|M_{assume_i}\right|}{d_{v_i}} + 0.5 \cdot N_u + 0.5 \cdot \left|V_{assume_i} - V_{p_i}\right| \cot\left(\theta_{assume_i}\right) - A_{ps.bot.\varepsilon x_i} \cdot f_{po}}{2 \cdot \left(E_{beam} \cdot A_{ct} + E_s \cdot A_{s.bot.\varepsilon x_i} + E_p \cdot A_{ps.bot.\varepsilon x_i}\right)} \\ \varepsilon_{x_i} \leftarrow \left| \begin{array}{ll} \varepsilon_{x1_i} & \text{if MinReinforcingCheck}_i = \text{"OK"} \wedge \varepsilon_{x1_i} \ge 0 \\ \varepsilon_{x2_i} & \text{if MinReinforcingCheck}_i = \text{"NG!!!"} \wedge \varepsilon_{x2_i} \ge 0 \\ \varepsilon_{x3_i} & \text{if } \varepsilon_{x1_i} < 0 \vee \varepsilon_{x2_i} < 0 \end{array} \right. \end{array} \right.$$

$$\varepsilon_{x_2} = \frac{\dfrac{\left|M_{assume_2}\right|}{d_{v_2}} + 0.5 \cdot N_u + 0.5 \cdot \left|V_{assume_2} - V_{p_2}\right| \cot\left(\theta_{assume_2}\right) - A_{ps.bot.\varepsilon x_2} \cdot f_{po}}{2 \cdot \left(E_s \cdot A_{s.bot.\varepsilon x_2} + E_p \cdot A_{ps.bot.\varepsilon x_2}\right)} \text{ if Mi}$$

$$\varepsilon_{x_2} = \frac{\dfrac{|955.59\text{ft}\cdot\text{kip}|}{40.13\text{in}} + 0 + 0.5 \cdot |292.58\text{kip} - 6.81\text{kip}| \cdot \cot(0.6476) - 0.24\text{in}^2 \cdot 189\text{ksi}}{2 \cdot \left(29000\text{ksi} \cdot 1.42\text{in}^2 + 28500\text{ksi} \cdot 0.24\text{in}^2\right)} \text{ if MinReinfor}$$

$$\varepsilon_{x_2} = 0.00448 \text{ if MinReinforcingCheck}_2 = \text{"OK"} \wedge 0.00448 \ge 0$$

$$\varepsilon_{x_2} = 0.00448$$

$$\varepsilon_x^T = (0.01792 \;\; 0.00448 \;\; 0.00296 \;\; 0.00183 \;\; 0.0016 \;\; 0.0014 \;\; 0.00099 \;\; 0.00105 \;\; 0.00098 \;\; 0.00098 \;\; 0.00089 \;\; 0.00089$$

Using the results for ε_x and for v_u, foundpreviously, one can go to the tables in Appendix B5 of the AASHTO LRFD Bridge Specifications to obtain β and θ. Note that Article B5.2 states that if ε_x is greater than zero, then the initial value for ε_x should not be greater than 0.001 if at least the minimum transverse reinforcement is used or 0.002 if the beam has less than the minimum transverse reinforcement. Hence, in this example, most of the values for ε_x along the length of the shear span were taken as 0.001. As discussed earlier, a separate computer program was developed to facilitate linear interpolation of these values using the ranges given in the aforementioned tables. That program is not discussed here, but is a relatively basic routine. Using the values for ε_x and v_u, the resulting values for β and θ are:

$$\theta^T = (0.6231\ \ 0.6476\ \ 0.6476\ \ 0.6402\ \ 0.6402\ \ 0.6402\ \ 0.6382\ \ 0.6357\ \ 0.6359\ \ 0.637\ \ 0.6198\ \ 0.62)$$

$$\beta^T = (1.5\ \ 2.11\ \ 2.11\ \ 2.18\ \ 2.18\ \ 2.18\ \ 2.19\ \ 2.2\ \ 2.19\ \ 2.19\ \ 2.24\ \ 2.24)$$

Note that the results for θ are quite similar to the assumed cracking angle, θ_{assume}. In terms of degrees, θ is:

$$\theta^T = (35.7\ \ 37.107\ \ 37.107\ \ 36.683\ \ 36.683\ \ 36.683\ \ 36.566\ \ 36.694\ \ 36.438\ \ 36.495\ \ 35.512\ \ 35.523)$$

Calculate the Concrete Contribution to the Shear Resistance, V_c

$$V_{c_i} = 0.0316 \cdot \beta_i \cdot \alpha_v \sqrt{f_c' \cdot ksi} \cdot b_v \cdot d_{v_i}$$

$$V_{c_2} = 0.0316 \cdot \beta_2 \cdot \alpha_v \sqrt{f_c' \cdot ksi} \cdot b_v \cdot d_{v_2}$$

$$V_{c_2} = 0.0316 \cdot 2.11 \cdot (1) \cdot \sqrt{8.87 ksi^2} \cdot 6in \cdot 40.13in$$

$$V_{c_2} = 47.85\, kip$$

$$V_c^T = (33.89\ \ 47.85\ \ 47.92\ \ 49.57\ \ 49.61\ \ 49.62\ \ 47.78\ \ 47.97\ \ 47.97\ \ 47.98\ \ 47.31\ \ 47.42)\, kip$$

Calculate the Steel Contribution to the Shear Resistance, V_s

$$V_{s_i} = \frac{A_{v_i} \cdot f_{yv} \cdot d_{v_i} \cdot \left(\cot\left(\theta_i\right) + \cot(\alpha)\right) \cdot \sin(\alpha)}{s_{v.design_i}}$$

$$V_{s_2} \leftarrow \frac{A_{v_2} \cdot f_{yv} \cdot d_{v_2} \cdot \left(\cot\left(\theta_2\right) + \cot(\alpha)\right) \cdot \sin(\alpha)}{s_{v.design_2}}$$

$$V_{s_2} = \frac{0.4in^2 \cdot 67.3ksi \cdot 40.13 \cdot \left(\cot(0.6476) + \cot\left(\frac{\pi}{2}\right)\right) \sin\left(\frac{\pi}{2}\right)}{6in}$$

$$V_{s_2} = 237.99\,kip$$

$$V_s^T = (599.7 \quad 238 \quad 238.4 \quad 161.5 \quad 161.7 \quad 161.7 \quad 156 \quad 156.9 \quad 156.9 \quad 156.8 \quad 157 \quad 157.3)\,kip$$

Calculate the Nominal Shear Resistance

$$V_{n1} = V_c + V_s + V_p$$

$$V_{n1_2} = V_{c_2} + V_{s_2} + V_{p_2}$$

$$V_{n1_2} = 47.85\text{kip} + 237.99\text{kip} + 6.81\text{kip}$$

$$V_{n1_2} = 292.6\,\text{kip}$$

$$V_{n1}^T = (637.1 \quad 292.6 \quad 296.4 \quad 224.6 \quad 228 \quad 228.7 \quad 221.2 \quad 222.3 \quad 222.3 \quad 222.2 \quad 221.7 \quad 222.1)\,\text{kip}$$

$$V_{n2} = 0.25 \cdot f_{c'} \cdot b_v \cdot d_v + V_p$$

$$V_{n2_2} = 0.25 \cdot f_{c'} \cdot b_v \cdot d_{v_2} + V_{p_2}$$

$$V_{n2_2} = 0.25 \cdot 8.87\text{ksi} \cdot 6\text{in} \cdot 40.13\text{in} + 6.81\text{kip}$$

$$V_{n2_2} = 540.4\,\text{kip}$$

$$V_{n2}^T = (535.6 \quad 540.4 \quad 544.6 \quad 548.4 \quad 552.1 \quad 552.9 \quad 531.7 \quad 532.2 \quad 532.4 \quad 533 \quad 515.4 \quad 516.7)\,\text{kip}$$

$$V_{n_i} = \min\left(V_{n1_i}, V_{n2_i}\right)$$

$$V_{n_2} = \min\left(V_{n1_2}, V_{n2_2}\right)$$

$$V_{n_2} = \min(292.64\text{kip}, 540.39\text{kip})$$

$$V_{n_2} = 292.6\,\text{kip}$$

$$V_n^T = (535.6 \quad 292.6 \quad 296.4 \quad 224.6 \quad 228 \quad 228.7 \quad 221.2 \quad 222.3 \quad 222.3 \quad 222.2 \quad 221.7 \quad 222.1)\,\text{kip}$$

Reiterate with New Value for P_{assume}

In order to refine the calculations for the nominal shear strength, the engineer might need to assume a different value for the externally applied load to the beam, P_{assume}, based on a revised input for the shear in the beam, V_{assume}. The new V_{assume} can be taken as the midpoint between the original V_{assume} and V_n found in Section 0 above. In the case of this example,

$$V_{assume.new_i} = \frac{1}{2}\left(V_{n_i} + V_{assume_i}\right)$$

$$V_{assume.new_2} = \frac{1}{2}\left(V_{n_2} + V_{assume_2}\right)$$

$$V_{assume.new_2} = \frac{1}{2}(292.6\text{kip} + 292.58\text{kip})$$

$$V_{assume.new_2} = 292.6\ \text{kip}$$

$$V_{assume.new}^{T} = (535.6\ \ 292.6\ \ 296.4\ \ 224.5\ \ 228\ \ 228.7\ \ 221.1\ \ 221.3\ \ 222.3\ \ 222.1\ \ 221.7\ \ 222.1)\ \text{kip}$$

Therefore, the new assumed load from each of the two actuators located at the distances indicated by the parameters *ShearSpan* and *LoadSpacing* that would result in a shear failure

$$P_{assume.new_i} = \frac{\left(V_{assume.new_i} - V_{DC1_i}\right)\cdot L_{span}}{2\left(L_{span} - \text{ShearSpan}\right) - \text{LoadSpacing}} \quad \text{if } x_{dist_i} \le \text{ShearSpan}$$

$$P_{assume.new_2} = \frac{\left(V_{assume.new_2} - V_{DC1_2}\right)\cdot L_{span}}{2\left(L_{span} - \text{ShearSpan}\right) - \text{LoadSpacing}} \quad \text{if } x_{dist_2} \le \text{ShearSpan}$$

$$P_{assume.new_2} = \frac{(292.6\text{kip} - 18.22\text{kip})\cdot 40\text{ft}}{2\cdot(40\text{ft} - 57.34\text{in}) - 14.52\text{ft}} \quad \text{if } 5.73\text{in} \le 57.34\text{in}$$

$$P_{assume.new_2} = 196.2\ \text{kip}$$

$$P_{assume.new}^{T} = (369.7\ \ 196.2\ \ 199.3\ \ 148.2\ \ 151\ \ 151.8\ \ 146.7\ \ 147.8\ \ 147.8\ \ 148.1\ \ 148\ \ 148.7)\ \text{kip}$$

However, note that $P_{assume.new}$ is practically the same as P_{assume} given in Section 0. In this case, the calculations for the shear strength have converged, resulting in the shear strengths at the various sections along the shear span, indicated by V_n in Section 0. The lowest value in V_n is taken as the beam's shear strength, provided that the distance from the support to the corresponding section is not less than the critical section. The critical section, $x_{critical}$, depends on the effective shear depth and the theoretical cracking angle, which in turn, are indirectly dependent on the critical section. Hence, finding $x_{critical}$ is also iterative in nature, and this iteration has been incorporated into the program indicated in Figure K-1. Using $x_{critical.assume}$ = 38.69 in., which is the eighth element in the parameter x_{dist}, the shear depth at the critical section, $d_{v.critical}$ is the eighth element in d_v . Likewise, the corresponding cracking angle at the critical section is the eighth element of θ, given in radians as 0.6357. Thus, $x_{critical}$ can be calculated as:

$$x_{critical} = \max\left(d_{v.critical}, \frac{1}{2} \cdot d_{v.critical} \cdot \cot\left(\theta_{critical}\right)\right)$$

$$x_{critical} = \max\left(38.69in, \frac{1}{2} 38.69in \cdot \cot(0.6357)\right)$$

$$x_{critical} = \max(38.69in, 26.22in)$$

$$x_{critical} = 38.69\ in$$

Again, note that the calculated value for $x_{critical}$ is the same as $x_{critical.assume}$, so no further iterations are required. So, for this example, the smallest shear strength given in V_n is 221.1 kip at x_{dist} = 34.40 in. However, since the distance to this section is less than the critical section, the nominal shear strength for the beam should be taken as 222.3 kip, which is rounded to 222 kip.

Inputs and Detailed Results for Shear Calculations Following the General Procedure Using Appendix B5

Beam T2.8.Typ.1

Inputs

γ_c (pcf)	121.5
f_c' (psi)	8865
f_{ci}' (psi)	6090
$f_{c.deck}$ (psi)	5829
$\gamma_{c.deck}$ (pcf)	123.4
E_{beam} (ksi)	3605
$E_{beam.i}$ (ksi)	3585
E_{slab} (ksi)	3566
h (in)	36
A_{beam} (in^2)	369
I_{beam} (in^4)	50979
L_{beam} (ft)	41
b_v (in)	6
y_b (in)	15.83
y_t (in)	20.17
S (ft)	7
t_{haunch} (in)	1

t_{struct} (in)	8.5
A_{ct} (in^2)	243
h_{flange} (in)	8.5
Num_{strand}	24
$Num_{straight}$	18
$Num_{straight.bot}$	16
Num_{harp}	6
$cg_{straight}$ (in)	7.00
$cg_{harp.end}$ (in)	29
$cg_{harp.ms}$ (in)	4
$cg_{straight.bot}$ (in)	3.75
A_{strand} (in^2)	0.15
φ (in)	0.5
f_{pu} (ksi)	270
f_{pe} (ksi)	164.96
E_p (ksi)	28500
$HarpDist$ (ft)	17.5

f_y (ksi)	67.3
f_{yv} (ksi)	67.3
E_s (ksi)	29000
α	1.57
$A_{s.top}$ (in^2)	0
d_{top} (in)	9.5
$d_{long.rebar}$	5
$IsLongSteelEpoxyCoated$	No
$LongSteelClearSpacing$ (in)	3.38
$LongSteelCover$ (in)	1.75
$IsTopBarEffectApplicable$	No
$A_{long.rebar}$ (in2)	0.31
$ShearSpan$ (in)	57.34
$x_{bearing}$ (in)	6
$x_{bearing.roller}$ (in)	6
$x_{critical.assume}$ (in)	34.12

x_{dist} (in)	A_{ct} (in^2)	$cg_{s.bot}$ (in)	cg_s (in)	$s_{v.design}$ (in)	A_v (in^2)	P_{assume} (kip)	θ_{assume} (rad)
0	2.04	4.4	4.4	2.5	0.4	150	0.62
5.73	2.04	4.4	4.4	6	0.4	150	0.65
11.47	2.04	4.4	4.4	6	0.4	150	0.6500
17.20	2.04	4.4	4.4	9	0.4	150	0.64
22.93	2.04	4.4	4.4	9	0.4	150	0.64
28.67	2.04	4.4	4.4	9	0.4	150	0.64
34.40	2.04	4.4	4.4	9	0.4	150	0.64
38.71	2.04	4.4	4.4	9	0.4	150	0.64
40.14	2.04	4.4	4.4	9	0.4	150	0.64
45.87	2.04	4.4	4.4	9	0.4	150	0.6400
51.60	2.04	4.4	4.4	9	0.4	150	0.62
57.34	2.04	4.4	4.4	9	0.4	150	0.62

Basic Geometry and Material Calculations

x_{dist} (in)	d_s (in)	$A_{ps.bot}$ (in^2)	cg_{harp} (in)
0.00	41.10	2.45	28.31
5.73	41.10	2.45	27.64
11.47	41.10	2.45	26.98
17.20	41.10	2.45	26.31
22.94	41.10	2.45	25.65
28.67	41.10	2.45	24.99
34.40	41.10	2.75	24.32
38.71	41.10	2.75	23.82
40.14	41.10	2.75	23.66
45.87	41.10	2.75	23.00
51.60	41.10	3.06	22.33
57.34	41.10	3.06	21.67

h_c (in)	L_{span} (ft)	A_{ps} (in^2)	Ψ_{harp} (rad)	f_{po} (ksi)	$f_{r.V}$ (psi)	β_1
45.5	40	3.672	0.1152	189	595.5	0.7585

Load Effect Calculations

x_{dist} (in)	V_{LL} (kip)	M_{LL} (ft-kip)	V_{DC1} (kip)	M_{DC1} (ft-kip)	V_{assume} (kip)	$M_{assume1}$ (ft-kip)	M_{assume} (ft-kip)	V_p (kip)
0.0	516.9	0.0	18.7	-0.1	535.5	-0.1	1774.4	3.5
5.7	274.3	131.1	18.2	8.7	292.6	139.8	955.5	6.8
11.5	278.5	266.2	17.8	17.3	296.3	283.5	958.5	10.1
17.2	207.2	297.1	17.3	25.7	224.6	322.7	707.7	13.5
22.9	211.1	403.4	16.9	33.9	228.0	437.3	708.4	16.8
28.7	212.2	506.9	16.4	41.8	228.6	548.8	708.8	17.4
34.4	205.1	588.1	16.0	49.6	221.1	637.7	656.6	17.4
38.7	206.6	666.6	15.7	55.3	222.3	721.8	721.8	17.4
40.1	206.7	691.3	15.5	57.1	222.2	748.4	748.4	17.4
45.9	207.0	791.4	15.1	64.4	222.1	855.9	855.9	17.4
51.6	207.0	890.2	14.7	71.5	221.7	961.7	961.7	17.4
57.3	207.9	993.3	14.2	78.4	222.1	1071.7	1071.7	17.4

Calculations for β and θ

x_{dist} (in)	cg_{ps} (in)	d_p (in)	c (in)	a (in)	$f_{ps.max}$ (ksi)	$l_{d.ps}$ (in)	f_{ps} (ksi)	$cg_{ps.bot}$ (in)	$d_{p.bot}$ (in)	$d_{s.bot}$ (in)	$Num_{strand.bot}$	$RedFactor_{\varepsilon x.s}$	$RedFactor_{\varepsilon x.ps}$
0.00	12.33	33.17	3.48	2.64	262.1	121.67	32.99	3.75	41.75	41.10	16.00	0.36	0.05
5.73	12.16	33.34	3.48	2.64	262.1	121.70	64.52	3.75	41.75	41.10	16.00	0.70	0.10
11.47	11.99	33.51	3.48	2.64	262.1	121.73	96.05	3.75	41.75	41.10	16.00	1.00	0.14
17.20	11.83	33.67	3.48	2.64	262.2	121.76	127.58	3.75	41.75	41.10	16.00	1.00	0.19
22.94	11.66	33.84	3.48	2.64	262.2	121.79	159.10	3.75	41.75	41.10	16.00	1.00	0.24
28.67	11.50	34.00	3.49	2.64	262.3	121.82	169.91	3.75	41.75	41.10	16.00	1.00	0.28
34.40	11.33	34.17	3.49	2.64	262.3	121.85	175.98	5.81	39.69	41.10	18.00	1.00	0.33
38.71	11.21	34.29	3.49	2.64	262.3	121.87	180.55	5.76	39.74	41.10	18.00	1.00	0.37
40.14	11.17	34.34	3.49	2.64	262.3	121.88	182.06	5.74	39.76	41.10	18.00	1.00	0.38
45.87	11.00	34.50	3.49	2.64	262.4	121.91	188.14	5.67	39.83	41.10	18.00	1.00	0.43
51.60	10.83	34.67	3.49	2.65	262.4	121.94	194.21	7.27	38.23	41.10	20.00	1.00	0.47
57.34	10.67	34.83	3.49	2.65	262.4	121.97	200.29	7.13	38.37	41.10	20.00	1.00	0.52

x_{dist} (in)	$A_{ps.bot}$ (in^2)	d_e (in)	ε_s	d_v (in)	v_u	$A_{s.bot.\varepsilon x}$ (in^2)	$A_{ps.bot.\varepsilon x}$ (in^2)	ε_x	θ (rad)	β	$MinReinfCheck$
0.00	2.45	41.34	0.03	40.02	0.250	0.73	0.12	0.0179	0.6231	1.50	OK
5.73	2.45	41.45	0.03	40.13	0.134	1.42	0.24	0.0045	0.6476	2.11	OK
11.47	2.45	41.51	0.03	40.19	0.134	2.04	0.35	0.0030	0.6476	2.11	OK
17.20	2.45	41.55	0.03	40.23	0.099	2.04	0.47	0.0018	0.6403	2.18	OK
22.94	2.45	41.58	0.03	40.26	0.099	2.04	0.58	0.0016	0.6402	2.18	OK
28.67	2.45	41.59	0.03	40.27	0.099	2.04	0.70	0.0014	0.6402	2.18	OK
34.40	2.75	40.00	0.03	38.68	0.099	2.04	0.91	0.0010	0.6382	2.19	OK
38.71	2.75	40.04	0.03	38.71	0.100	2.04	1.01	0.0010	0.6358	2.19	OK
40.14	2.75	40.05	0.03	38.73	0.099	2.04	1.04	0.0010	0.6360	2.19	OK
45.87	2.75	40.10	0.03	38.78	0.099	2.04	1.17	0.0010	0.6370	2.19	OK
51.60	3.06	38.77	0.03	37.45	0.103	2.04	1.45	0.0009	0.6199	2.24	OK

57.34	3.06	38.87	0.03	37.54	0.103	2.04	1.59	0.0009	0.6201	2.24	OK

Final Results for Shear Strength

x_{dist} (in)	V_c (kip)	V_s (kip)	V_{n1} (kip)	V_{n2} (kip)	V_n (kip)
0.00	33.9	599.7	637.1	535.6	535.6
5.73	47.8	238.0	292.6	540.4	292.6
11.47	47.9	238.4	296.4	544.6	296.4
17.20	49.6	161.5	224.6	548.4	224.6
22.94	49.6	161.7	228.1	552.1	228.1
28.67	49.6	161.7	228.7	552.9	228.7
34.40	47.8	156.0	221.1	531.7	221.1
38.71	48.0	156.9	222.3	532.2	222.3
40.14	48.0	156.9	222.3	532.4	222.3
45.87	48.0	156.8	222.2	533.0	222.2
51.60	47.3	157.0	221.7	515.4	221.7
57.34	47.4	157.3	222.1	516.6	222.1

Beam T2.8.Typ.2

Inputs

γ_c (pcf)	121.5
f_c' (psi)	8890
f_{ci}' (psi)	6090
$f_{c.deck}$ (psi)	6088
$\gamma_{c.deck}$ (pcf)	123.4
E_{beam} (ksi)	3605
$E_{beam.i}$ (ksi)	3585
E_{slab} (ksi)	3210
h (in)	36
A_{beam} (in^2)	369
I_{beam} (in^4)	50979
L_{beam} (ft)	41
b_v (in)	6
y_b (in)	15.83
y_t (in)	20.17
S (ft)	7
t_{haunch} (in)	1

t_{struct} (in)	8.5
A_{ct} (in^2)	243
h_{flange} (in)	8.5
Num_{strand}	24
$Num_{straight}$	18
$Num_{straight.bot}$	16
Num_{harp}	6
$cg_{straight}$ (in)	7.00
$cg_{harp.end}$ (in)	29
$cg_{harp.ms}$ (in)	4
$cg_{straight.bot}$ (in)	3.75
A_{strand} (in^2)	0.15
φ (in)	0.5
f_{pu} (ksi)	270
f_{pe} (ksi)	164.96
E_p (ksi)	28500
$HarpDist$ (ft)	17.5

f_y (ksi)	67.3
f_{yv} (ksi)	67.3
E_s (ksi)	29000
α	1.57
$A_{s.top}$ (in^2)	0
d_{top} (in)	9.5
$d_{long.rebar}$	5
$IsLongSteelEpoxyCoated$	No
$LongSteelClearSpacing$ (in)	3.38
$LongSteelCover$ (in)	1.75
$IsTopBarEffectApplicable$	No
$A_{long.rebar}$ (in2)	0.31
$ShearSpan$ (in)	118.76
$x_{bearing}$ (in)	6
$x_{bearing.roller}$ (in)	64.5
$x_{critical.assume}$ (in)	34.14

x_{dist} (in)	A_{ct} (in^2)	$cg_{s.bot}$ (in)	cg_s (in)	$s_{v.design}$ (in)	A_v (in^2)	P_{assume} (kip)	θ_{assume} (rad)
0	2.04	4.4	4.4	2.5	0.4	150	0.62
11.88	2.04	4.4	4.4	6	0.4	150	0.65
23.75	2.04	4.4	4.4	9	0.4	150	0.6400
35.63	2.04	4.4	4.4	9	0.4	150	0.64
38.77	2.04	4.4	4.4	9	0.4	150	0.64
47.50	2.04	4.4	4.4	9	0.4	150	0.64
59.38	2.04	4.4	4.4	9	0.4	150	0.62
71.26	0	0	0	9	0.4	150	0.64
79.99	0	0	0	10	0.4	150	0.63
83.13	0	0	0	10	0.4	150	0.62
95.01	0	0	0	10	0.4	150	0.6200
106.88	0	0	0	10	0.4	150	0.62
118.76	0	0	0	10	0.4	150	0.62

Basic Geometry and Material Calculations

x_{dist} (in)	d_s (in)	$A_{ps.bot}$ (in^2)	cg_{harp} (in)
0	41.10	2.45	28.31
11.88	41.10	2.45	26.93
23.75	41.10	2.45	25.56
35.63	41.10	2.75	24.18
38.77	41.10	2.75	23.82
47.50	41.10	2.75	22.81
59.38	41.10	3.06	21.43
71.26	45.50	3.37	20.06
79.99	45.50	3.37	19.05
83.13	45.50	3.37	18.68
95.01	45.50	3.37	17.31
106.88	45.50	3.37	15.93
118.76	45.50	3.37	14.56

h_c (in)	L_{span} (ft)	A_{ps} (in^2)	Ψ_{harp} (rad)	f_{po} (ksi)	$f_{r.V}$ (psi)	β_1
45.5	35.125	3.672	0.1152	189	596.3	0.7456

Load Effect Calculations

x_{dist} (in)	V_{LL} (kip)	M_{LL} (ft-kip)	V_{DC1} (kip)	M_{DC1} (ft-kip)	V_{assume} (kip)	$M_{assume1}$ (ft-kip)	M_{assume} (ft-kip)	V_p (kip)
0.0	521.8	0.0	16.0	-0.1	537.8	-0.1	1784.4	3.5
11.9	282.0	279.1	15.1	15.3	297.1	294.4	961.8	10.4
23.8	214.7	424.9	14.2	29.8	228.8	454.7	710.9	17.3
35.6	209.3	621.5	13.2	43.3	222.6	664.8	664.8	17.4
38.8	209.5	676.9	13.0	46.7	222.5	723.6	723.6	17.4
47.5	210.0	831.3	12.3	56.0	222.3	887.3	887.3	17.4
59.4	211.1	1044.4	11.4	67.7	222.5	1112.1	1112.1	17.4
71.3	196.9	1169.3	10.5	78.5	207.4	1247.8	1247.8	17.4
80.0	189.5	1263.0	9.8	85.9	199.3	1348.8	1348.8	17.4
83.1	190.7	1321.0	9.5	88.4	200.2	1409.4	1409.4	17.4
95.0	195.0	1544.1	8.6	97.4	203.7	1641.5	1641.5	17.4
106.9	199.1	1773.7	7.7	105.5	206.8	1879.2	1879.2	17.4
118.8	201.6	1995.0	6.8	112.7	208.4	2107.7	2107.7	17.4

Calculations for β and θ

x_{dist} (in)	cg_{ps} (in)	d_p (in)	c (in)	a (in)	$f_{ps.max}$ (ksi)	$l_{d.ps}$ (in)	f_{ps} (ksi)	$cg_{ps.bot}$ (in)	$d_{p.bot}$ (in)	$d_{s.bot}$ (in)	$Num_{strand.bot}$	$RedFactor_{\varepsilon x.s}$	$RedFactor_{\varepsilon x.ps}$
0.00	12.33	33.17	3.40	2.53	262.3	121.83	32.99	3.75	41.75	41.10	16.00	0.36	0.05
11.88	11.98	33.52	3.40	2.53	262.3	121.89	98.29	3.75	41.75	41.10	16.00	1.00	0.15
23.75	11.64	33.86	3.40	2.53	262.4	121.95	163.60	3.75	41.75	41.10	16.00	1.00	0.24
35.63	11.30	34.20	3.40	2.53	262.5	122.01	177.28	5.80	39.70	41.10	18.00	1.00	0.34
38.77	11.20	34.30	3.40	2.53	262.5	122.03	180.62	5.76	39.74	41.10	18.00	1.00	0.37
47.50	10.95	34.55	3.40	2.53	262.6	122.07	189.88	5.65	39.85	41.10	18.00	1.00	0.44
59.38	10.61	34.89	3.40	2.53	262.6	122.13	202.47	7.09	38.41	41.10	20.00	1.00	0.54
71.26	10.26	35.24	2.99	2.23	263.6	122.90	215.13	8.20	37.30	45.50	22.00	1.00	0.63
79.99	10.01	35.49	2.99	2.23	263.6	122.93	224.41	7.92	37.58	45.50	22.00	1.00	0.70
83.13	9.92	35.58	2.99	2.23	263.7	122.94	227.75	7.82	37.68	45.50	22.00	1.00	0.73
95.01	9.58	35.92	2.99	2.23	263.7	122.99	240.37	7.45	38.05	45.50	22.00	1.00	0.82
106.88	9.23	36.27	2.99	2.23	263.8	123.04	252.99	7.07	38.43	45.50	22.00	1.00	0.92
118.76	8.89	36.61	2.99	2.23	263.8	123.08	263.83	6.70	38.80	45.50	22.00	1.00	1.00

x_{dist} (in)	$A_{ps.bot}$ (in^2)	d_e (in)	ε_s	d_v (in)	v_u	$A_{s.bot.\varepsilon x}$ (in^2)	$A_{ps.bot.\varepsilon x}$ (in^2)	ε_x	θ (rad)	β	$MinReinfCheck$
0.00	2.45	41.34	0.03	40.08	0.250	0.73	0.12	0.0180	0.6231	1.50	OK
11.88	2.45	41.51	0.03	40.25	0.134	2.04	0.36	0.0029	0.6476	2.11	OK
23.75	2.45	41.58	0.03	40.32	0.098	2.04	0.60	0.0016	0.6402	2.18	OK
35.63	2.75	40.01	0.03	38.74	0.099	2.04	0.94	0.0010	0.6355	2.20	OK
38.77	2.75	40.04	0.03	38.77	0.099	2.04	1.01	0.0010	0.6361	2.19	OK
47.50	2.75	40.11	0.03	38.85	0.099	2.04	1.21	0.0010	0.6375	2.19	OK
59.38	3.06	38.90	0.03	37.63	0.102	2.04	1.64	0.0009	0.6204	2.24	OK
71.26	3.37	37.30	0.03	36.19	0.098	0.00	2.12	0.0012	0.6402	2.18	OK
79.99	3.37	37.58	0.03	36.46	0.094	0.00	2.35	0.0009	0.6258	2.23	OK
83.13	3.37	37.68	0.03	36.56	0.094	0.00	2.44	0.0009	0.6244	2.24	OK

95.01	3.37	38.05	0.04	36.94	0.095	0.00	2.76	0.0009	0.6199	2.25	OK
106.88	3.37	38.43	0.04	37.31	0.095	0.00	3.09	0.0009	0.6164	2.26	OK
118.76	3.37	38.80	0.04	37.69	0.095	0.00	3.37	0.0009	0.6174	2.26	OK

Final Results for Shear Strength

x_{dist} (in)	V_c (kip)	V_s (kip)	V_{n1} (kip)	V_{n2} (kip)	V_n (kip)
0.00	34.0	600.5	638.0	537.9	537.9
11.88	48.1	238.7	297.2	547.1	297.2
23.75	49.8	161.9	228.9	554.9	228.9
35.63	48.1	157.1	222.6	534.0	222.6
38.77	48.1	157.0	222.5	534.4	222.5
47.50	48.1	156.9	222.4	535.4	222.4
59.38	47.6	157.5	222.5	519.3	222.5
71.26	44.7	145.3	207.4	500.0	207.4
79.99	46.0	135.8	199.3	503.7	199.3
83.13	46.2	136.6	200.2	505.0	200.2
95.01	47.0	139.3	203.7	510.0	203.7
106.88	47.7	141.8	206.9	515.0	206.9
118.76	48.1	142.9	208.4	520.0	208.4

Beam T2.8.Min.1

Inputs

γ_c (pcf)	121.5
f_c' (psi)	8890
f_{ci}' (psi)	6090
$f_{c.deck}$ (psi)	5360
$\gamma_{c.deck}$ (pcf)	125
E_{beam} (ksi)	3605
$E_{beam.i}$ (ksi)	3585
E_{slab} (ksi)	3240
h (in)	36
A_{beam} (in^2)	369
I_{beam} (in^4)	50979
L_{beam} (ft)	40.9688
b_v (in)	6
y_b (in)	15.83
y_t (in)	20.17
S (ft)	7
t_{haunch} (in)	1.125

t_{struct} (in)	8
A_{ct} (in^2)	243
h_{flange} (in)	8.5
Num_{strand}	24
$Num_{straight}$	18
$Num_{straight.bot}$	16
Num_{harp}	6
$cg_{straight}$ (in)	7.00
$cg_{harp.end}$ (in)	29
$cg_{harp.ms}$ (in)	4
$cg_{straight.bot}$ (in)	3.75
A_{strand} (in^2)	0.15
φ (in)	0.5
f_{pu} (ksi)	270
f_{pe} (ksi)	162.64
E_p (ksi)	28500
$HarpDist$ (ft)	17.5

f_y (ksi)	67.3
f_{yv} (ksi)	67.3
E_s (ksi)	29000
α	1.57
$A_{s.top}$ (in^2)	0
d_{top} (in)	9.5
$d_{long.rebar}$	5
$IsLongSteelEpoxyCoated$	No
$LongSteelClearSpacing$ (in)	3.38
$LongSteelCover$ (in)	1.75
$IsTopBarEffectApplicable$	No
$A_{long.rebar}$ (in2)	0.31
$ShearSpan$ (in)	58.00
$x_{bearing}$ (in)	6
$x_{bearing.roller}$ (in)	6
$x_{critical.assume}$ (in)	34.19

x_{dist} (in)	A_{ct} (in^2)	$cg_{s.bot}$ (in)	cg_s (in)	$s_{v.design}$ (in)	A_v (in^2)	P_{assume} (kip)	θ_{assume} (rad)
0	2.04	4.4	4.4	2.5	0.4	150	0.62
5.80	2.04	4.4	4.4	9	0.4	150	0.64
11.60	2.04	4.4	4.4	12	0.4	150	0.6400
17.40	2.04	4.4	4.4	12	0.4	150	0.64
23.20	2.04	4.4	4.4	12	0.4	150	0.64
29.00	2.04	4.4	4.4	12	0.4	150	0.63
34.80	2.04	4.4	4.4	12	0.4	150	0.6
38.22	2.04	4.4	4.4	12	0.4	150	0.6
40.60	2.04	4.4	4.4	12	0.4	150	0.6
46.40	2.04	4.4	4.4	12	0.4	150	0.6000
52.20	2.04	4.4	4.4	12	0.4	150	0.58
58.00	2.04	4.4	4.4	12	0.4	150	0.58

Basic Geometry and Material Calculations

x_{dist} (in)	d_s (in)	$A_{ps.bot}$ (in^2)	cg_{harp} (in)
0.00	40.73	2.45	28.31
5.80	40.73	2.45	27.63
11.60	40.73	2.45	26.96
17.40	40.73	2.45	26.29
23.20	40.73	2.45	25.62
29.00	40.73	2.45	24.95
34.80	40.73	2.75	24.28
38.22	40.73	2.75	23.88
40.60	40.73	2.75	23.61
46.40	40.73	2.75	22.94
52.20	40.73	3.06	22.26
58.00	40.73	3.06	21.59

h_c (in)	L_{span} (ft)	A_{ps} (in^2)	Ψ_{harp} (rad)	f_{po} (ksi)	$f_{r.V}$ (psi)	β_1
45.125	39.9688	3.672	0.1152	189	596.3	0.782

Load Effect Calculations

x_{dist} (in)	V_{LL} (kip)	M_{LL} (ft-kip)	V_{DC1} (kip)	M_{DC1} (ft-kip)	V_{assume} (kip)	$M_{assume1}$ (ft-kip)	M_{assume} (ft-kip)	V_p (kip)
0.0	512.4	0.0	18.1	-0.1	530.5	-0.1	1736.1	3.4
5.8	197.2	95.3	17.7	8.5	214.8	103.8	687.3	6.8
11.6	163.1	157.7	17.2	17.0	180.4	174.7	563.4	10.1
17.4	167.1	242.2	16.8	25.2	183.9	267.4	564.6	13.4
23.2	171.0	330.5	16.4	33.2	187.3	363.7	565.4	16.7
29.0	172.7	417.3	15.9	41.0	188.6	458.3	568.2	17.2
34.8	178.0	516.1	15.5	48.6	193.5	564.7	564.7	17.2
38.2	178.4	568.3	15.2	53.0	193.7	621.3	621.3	17.2
40.6	178.7	604.7	15.0	56.0	193.8	660.7	660.7	17.2
46.4	179.5	693.9	14.6	63.1	194.1	757.0	757.0	17.2
52.2	180.1	783.5	14.2	70.1	194.3	853.6	853.6	17.2
58.0	181.3	876.1	13.7	76.8	195.0	953.0	953.0	17.2

Calculations for β and θ

x_{dist} (in)	cg_{ps} (in)	d_p (in)	c (in)	a (in)	$f_{ps.max}$ (ksi)	$l_{d.ps}$ (in)	f_{ps} (ksi)	$cg_{ps.bot}$ (in)	$d_{p.bot}$ (in)	$d_{s.bot}$ (in)	$Num_{strand.bot}$	$RedFactor_{\varepsilon x.s}$	$RedFactor_{\varepsilon x.ps}$
0.00	12.33	32.80	3.67	2.87	261.5	122.50	32.53	3.75	41.38	40.73	16.00	0.36	0.05
5.80	12.16	32.97	3.67	2.87	261.6	122.53	63.97	3.75	41.38	40.73	16.00	0.70	0.10
11.60	11.99	33.13	3.67	2.87	261.6	122.56	95.41	3.75	41.38	40.73	16.00	1.00	0.14
17.40	11.82	33.30	3.67	2.87	261.7	122.59	126.86	3.75	41.38	40.73	16.00	1.00	0.19
23.20	11.66	33.47	3.67	2.87	261.7	122.63	158.30	3.75	41.38	40.73	16.00	1.00	0.24
29.00	11.49	33.64	3.67	2.87	261.8	122.66	167.99	3.75	41.38	40.73	16.00	1.00	0.29
34.80	11.32	33.81	3.67	2.87	261.8	122.69	174.19	5.81	39.32	40.73	18.00	1.00	0.33
38.22	11.22	33.90	3.67	2.87	261.8	122.71	177.86	5.76	39.36	40.73	18.00	1.00	0.36
40.60	11.15	33.97	3.67	2.87	261.8	122.72	180.40	5.73	39.39	40.73	18.00	1.00	0.38
46.40	10.98	34.14	3.67	2.87	261.9	122.75	186.60	5.66	39.47	40.73	18.00	1.00	0.43
52.20	10.82	34.31	3.67	2.87	261.9	122.79	192.81	7.25	37.87	40.73	20.00	1.00	0.47
58.00	10.65	34.48	3.67	2.87	261.9	122.82	199.02	7.12	38.01	40.73	20.00	1.00	0.52

x_{dist} (in)	$A_{ps.bot}$ (in^2)	d_e (in)	ε_s	d_v (in)	v_u	$A_{s.bot.\varepsilon x}$ (in^2)	$A_{ps.bot.\varepsilon x}$ (in^2)	ε_x	θ (rad)	β	$MinReinfCheck$
0.00	2.45	40.96	0.03	39.53	0.250	0.73	0.12	0.0178	0.6231	1.50	OK
5.80	2.45	41.07	0.03	39.64	0.098	1.43	0.24	0.0031	0.6402	2.18	OK
11.60	2.45	41.13	0.03	39.70	0.080	2.04	0.35	0.0016	0.6364	2.22	OK
17.40	2.45	41.18	0.03	39.74	0.080	2.04	0.47	0.0014	0.6364	2.22	OK
23.20	2.45	41.21	0.03	39.77	0.080	2.04	0.58	0.0012	0.6364	2.22	OK
29.00	2.45	41.21	0.03	39.78	0.081	2.04	0.70	0.0010	0.6340	2.23	OK
34.80	2.75	39.63	0.03	38.19	0.087	2.04	0.92	0.0008	0.5973	2.33	OK
38.22	2.75	39.66	0.03	38.22	0.087	2.04	0.99	0.0008	0.5972	2.33	OK
40.60	2.75	39.68	0.03	38.24	0.087	2.04	1.05	0.0008	0.5971	2.33	OK
46.40	2.75	39.73	0.03	38.30	0.087	2.04	1.18	0.0008	0.5969	2.33	OK
52.20	3.06	38.41	0.03	36.97	0.090	2.04	1.45	0.0007	0.5779	2.39	OK

58.00	3.06	38.51	0.03	37.07	0.090	2.04	1.59	0.0007	0.5772	2.39	OK

Final Results for Shear Strength

x_{dist} (in)	V_c (kip)	V_s (kip)	V_{n1} (kip)	V_{n2} (kip)	V_n (kip)
0.00	33.5	592.4	629.3	530.6	530.6
5.80	48.9	159.2	214.8	535.3	214.8
11.60	49.8	120.5	180.4	539.5	180.4
17.40	49.9	120.6	183.9	543.3	183.9
23.20	49.9	120.7	187.3	547.0	187.3
29.00	50.1	121.4	188.6	547.6	188.6
34.80	50.3	126.0	193.5	526.5	193.5
38.22	50.4	126.1	193.7	526.9	193.7
40.60	50.4	126.2	193.8	527.2	193.8
46.40	50.5	126.4	194.1	527.8	194.1
52.20	50.0	127.2	194.3	510.2	194.3
58.00	50.1	127.7	195.0	511.5	195.0

Beam T2.8.Min.2

Inputs

γ_c (pcf)	121.5
f_c' (psi)	8890
f_{ci}' (psi)	6090
$f_{c.deck}$ (psi)	5360
$\gamma_{c.deck}$ (pcf)	125
E_{beam} (ksi)	3605
$E_{beam.i}$ (ksi)	3580
E_{slab} (ksi)	3240
h (in)	36
A_{beam} (in^2)	369
I_{beam} (in^4)	50979
L_{beam} (ft)	41
b_v (in)	6
y_b (in)	15.83
y_t (in)	20.17
S (ft)	7
t_{haunch} (in)	1

t_{struct} (in)	8.5
A_{ct} (in^2)	243
h_{flange} (in)	8.5
Num_{strand}	24
$Num_{straight}$	18
$Num_{straight.bot}$	16
Num_{harp}	6
$cg_{straight}$ (in)	7.00
$cg_{harp.end}$ (in)	29
$cg_{harp.ms}$ (in)	4
$cg_{straight.bot}$ (in)	3.75
A_{strand} (in^2)	0.15
φ (in)	0.5
f_{pu} (ksi)	270
f_{pe} (ksi)	162.64
E_p (ksi)	28500
$HarpDist$ (ft)	17.5

f_y (ksi)	67.3
f_{yv} (ksi)	67.3
E_s (ksi)	29000
α	1.57
$A_{s.top}$ (in^2)	0
d_{top} (in)	9.5
$d_{long.rebar}$	5
$IsLongSteelEpoxyCoated$	No
$LongSteelClearSpacing$ (in)	3.38
$LongSteelCover$ (in)	1.75
$IsTopBarEffectApplicable$	No
$A_{long.rebar}$ (in2)	0.31
$ShearSpan$ (in)	116.25
$x_{bearing}$ (in)	6
$x_{bearing.roller}$ (in)	69
$x_{critical.assume}$ (in)	34.07

x_{dist} (in)	A_{ct} (in^2)	$cg_{s.bot}$ (in)	cg_s (in)	$s_{v.design}$ (in)	A_v (in^2)	P_{assume} (kip)	θ_{assume} (rad)
0	2.04	4.4	4.4	2.5	0.4	150	0.62
11.63	2.04	4.4	4.4	9	0.4	150	0.64
23.25	2.04	4.4	4.4	12	0.4	150	0.6400
34.88	2.04	4.4	4.4	12	0.4	150	0.6
38.60	2.04	4.4	4.4	12	0.4	150	0.6
46.50	2.04	4.4	4.4	12	0.4	150	0.6
58.13	2.04	4.4	4.4	12	0.4	150	0.58
69.75	0	0	0	12	0.4	150	0.6
77.65	0	0	0	12	0.4	150	0.59
81.38	0	0	0	12	0.4	150	0.59
93.00	0	0	0	12	0.4	150	0.5900
104.63	0	0	0	12	0.4	150	0.58
116.25	0	0	0	12	0.4	150	0.58

Basic Geometry and Material Calculations

x_{dist} (in)	d_s (in)	$A_{ps.bot}$ (in^2)	cg_{harp} (in)
0.00	41.10	2.45	28.31
11.63	41.10	2.45	26.96
23.25	41.10	2.45	25.61
34.88	41.10	2.75	24.27
38.60	41.10	2.75	23.84
46.50	41.10	2.75	22.92
58.13	41.10	3.06	21.58
69.75	45.50	3.37	20.23
77.65	45.50	3.37	19.32
81.38	45.50	3.37	18.89
93.00	45.50	3.37	17.54
104.63	45.50	3.37	16.20
116.25	45.50	3.37	14.85

h_c (in)	L_{span} (ft)	A_{ps} (in^2)	Ψ_{harp} (rad)	f_{po} (ksi)	$f_{r.V}$ (psi)	β_1
45.5	34.75	3.672	0.1152	189	596.3	0.782

Load Effect Calculations

x_{dist} (in)	V_{LL} (kip)	M_{LL} (ft-kip)	V_{DC1} (kip)	M_{DC1} (ft-kip)	V_{assume} (kip)	$M_{assume1}$ (ft-kip)	M_{assume} (ft-kip)	V_p (kip)
0.0	519.5	0.0	15.9	-0.1	535.5	-0.1	1769.2	3.4
11.6	205.4	199.0	15.0	14.9	220.4	213.8	702.3	10.1
23.3	174.9	338.8	14.1	29.0	189.0	367.8	576.2	16.7
34.9	181.7	528.1	13.2	42.2	194.9	570.3	571.3	17.2
38.6	182.3	586.4	12.9	46.2	195.2	632.6	632.6	17.2
46.5	183.3	710.4	12.3	54.5	195.6	764.9	764.9	17.2
58.1	185.2	897.3	11.4	65.9	196.6	963.2	963.2	17.2
69.8	172.7	1003.9	10.4	76.5	183.2	1080.4	1080.4	17.2
77.6	175.8	1137.8	9.8	83.2	185.7	1221.0	1221.0	17.2
81.4	177.2	1202.0	9.5	86.2	186.8	1288.1	1288.1	17.2
93.0	181.5	1406.8	8.6	94.9	190.1	1501.8	1501.8	17.2
104.6	185.5	1617.7	7.7	102.9	193.2	1720.6	1720.6	17.2
116.3	189.3	1834.1	6.8	109.9	196.1	1944.0	1944.0	17.2

***Calculations for* β *and* θ**

x_{dist} (in)	cg_{ps} (in)	d_p (in)	c (in)	a (in)	$f_{ps.max}$ (ksi)	$l_{d.ps}$ (in)	f_{ps} (ksi)	$cg_{ps.bot}$ (in)	$d_{p.bot}$ (in)	$d_{s.bot}$ (in)	$Num_{strand.bot}$	$RedFactor_{\varepsilon x.s}$	$RedFactor_{\varepsilon x.ps}$
0.00	12.33	33.17	3.67	2.87	261.6	122.57	32.53	3.75	41.75	41.10	16.00	0.36	0.05
11.63	11.99	33.51	3.67	2.87	261.7	122.64	95.55	3.75	41.75	41.10	16.00	1.00	0.14
23.25	11.65	33.85	3.67	2.87	261.8	122.70	158.57	3.75	41.75	41.10	16.00	1.00	0.24
34.88	11.32	34.18	3.67	2.87	261.9	122.76	174.27	5.81	39.69	41.10	18.00	1.00	0.33
38.60	11.21	34.29	3.67	2.87	261.9	122.78	178.26	5.76	39.74	41.10	18.00	1.00	0.36
46.50	10.98	34.52	3.67	2.87	262.0	122.82	186.71	5.66	39.84	41.10	18.00	1.00	0.43
58.13	10.64	34.86	3.67	2.87	262.0	122.88	199.16	7.12	38.38	41.10	20.00	1.00	0.52
69.75	10.31	35.19	3.23	2.52	263.1	123.71	211.67	8.25	37.25	45.50	22.00	1.00	0.61
77.65	10.08	35.42	3.23	2.52	263.1	123.75	220.14	8.00	37.50	45.50	22.00	1.00	0.68
81.38	9.97	35.53	3.23	2.52	263.1	123.76	224.13	7.88	37.62	45.50	22.00	1.00	0.71
93.00	9.64	35.86	3.23	2.53	263.2	123.81	236.60	7.51	37.99	45.50	22.00	1.00	0.80
104.63	9.30	36.20	3.23	2.53	263.3	123.86	249.07	7.14	38.36	45.50	22.00	1.00	0.89
116.25	8.96	36.54	3.23	2.53	263.3	123.91	261.54	6.78	38.72	45.50	22.00	1.00	0.99

x_{dist} (in)	$A_{ps.bot}$ (in^2)	d_e (in)	ε_s	d_v (in)	v_u	$A_{s.bot.\varepsilon x}$ (in^2)	$A_{ps.bot.\varepsilon x}$ (in^2)	ε_x	θ (rad)	β	$MinReinfCheck$
0.00	2.45	41.34	0.03	39.90	0.250	0.73	0.12	0.0179	0.6231	1.50	OK
11.63	2.45	41.51	0.03	40.07	0.098	2.04	0.35	0.0021	0.6402	2.18	OK
23.25	2.45	41.58	0.03	40.14	0.080	2.04	0.58	0.0012	0.6364	2.22	OK
34.88	2.75	40.01	0.03	38.57	0.086	2.04	0.92	0.0008	0.5982	2.33	OK
38.60	2.75	40.04	0.03	38.60	0.086	2.04	1.00	0.0008	0.5978	2.33	OK
46.50	2.75	40.11	0.03	38.67	0.087	2.04	1.18	0.0008	0.5976	2.33	OK
58.13	3.06	38.88	0.03	37.45	0.090	2.04	1.60	0.0007	0.5779	2.39	OK
69.75	3.37	37.25	0.03	35.99	0.087	0.00	2.06	0.0008	0.5977	2.33	OK
77.65	3.37	37.50	0.03	36.24	0.087	0.00	2.28	0.0008	0.5934	2.34	OK
81.38	3.37	37.62	0.03	36.36	0.088	0.00	2.38	0.0008	0.5917	2.35	OK

93.00	3.37	37.99	0.03	36.73	0.088	0.00	2.69	0.0007	0.5867	2.36	OK
104.63	3.37	38.36	0.03	37.09	0.089	0.00	3.01	0.0007	0.5827	2.38	OK
116.25	3.37	38.72	0.03	37.46	0.090	0.00	3.32	0.0007	0.5793	2.39	OK

Final Results for Shear Strength

x_{dist} (in)	V_c (kip)	V_s (kip)	V_{n1} (kip)	V_{n2} (kip)	V_n (kip)
0.00	33.8	598.0	635.2	535.6	535.6
11.63	49.5	160.9	220.5	544.5	220.5
23.25	50.4	121.9	189.0	552.1	189.0
34.88	50.8	127.0	194.9	531.5	194.9
38.60	50.8	127.2	195.2	531.9	195.2
46.50	51.0	127.5	195.6	532.8	195.6
58.13	50.6	128.8	196.6	516.5	196.6
69.75	47.4	118.6	183.2	497.1	183.2
77.65	48.0	120.5	185.7	500.5	185.7
81.38	48.3	121.4	186.8	502.0	186.8
93.00	49.1	123.9	190.2	506.9	190.2
104.63	49.8	126.3	193.3	511.8	193.3
116.25	50.5	128.5	196.2	516.7	196.2

Beam BT.8N.Typ.1

Inputs

γ_c (pcf)	150
f_c' (psi)	8860
f_{ci}' (psi)	6183
$f_{c.deck}$ (psi)	4890
$\gamma_{c.deck}$ (pcf)	127
E_{beam} (ksi)	4823
$E_{beam.i}$ (ksi)	4670
E_{slab} (ksi)	2940
h (in)	45
A_{beam} (in^2)	746.7
I_{beam} (in^4)	207300
L_{beam} (ft)	58.875
b_v (in)	7
y_b (in)	22.23
y_t (in)	22.77
S (ft)	7
t_{haunch} (in)	1

t_{struct} (in)	8.5
A_{ct} (in^2)	423.25
h_{flange} (in)	8.5
Num_{strand}	34
$Num_{straight}$	28
$Num_{straight.bot}$	28
Num_{harp}	6
$cg_{straight}$ (in)	3.68
$cg_{harp.end}$ (in)	41
$cg_{harp.ms}$ (in)	4.25
$cg_{straight.bot}$ (in)	3.68
A_{strand} (in^2)	0.153
φ (in)	0.5
f_{pu} (ksi)	270
f_{pe} (ksi)	167.8
E_p (ksi)	28500
$HarpDist$ (ft)	26.5

f_y (ksi)	69.8
f_{yv} (ksi)	69.8
E_s (ksi)	29000
α	1.5708
$A_{s.top}$ (in^2)	0
d_{top} (in)	9.5
$d_{long.rebar}$	5
$IsLongSteelEpoxyCoated$	No
$LongSteelClearSpacing$ (in)	3.75
$LongSteelCover$ (in)	2
$IsTopBarEffectApplicable$	No
$A_{long.rebar}$ (in2)	0.31
$ShearSpan$ (in)	104.39
$x_{bearing}$ (in)	6
$x_{bearing.roller}$ (in)	6
$x_{critical.assume}$ (in)	48.98

x_{dist} (in)	A_{ct} (in^2)	$cg_{s.bot}$ (in)	cg_s (in)	$s_{v.design}$ (in)	A_v (in^2)	P_{assume} (kip)	θ_{assume} (rad)
0	2.04	4.6	4.6	2.5	0.4	250	0.6231
10.44	2.04	4.6	4.6	7	0.4	250	0.6424
20.88	2.04	4.6	4.6	8.75	0.4	250	0.6390
31.32	2.04	4.6	4.6	15	0.4	250	0.5734
41.75	2.04	4.6	4.6	15	0.4	250	0.5344
48.54	2.04	4.6	4.6	15	0.4	250	0.5201
52.19	2.04	4.6	4.6	15	0.4	250	0.5167
55.85	2.04	4.6	4.6	15	0.4	250	0.5136
62.63	2.04	4.6	4.6	15	0.4	250	0.5082
73.07	1.2	4.5	4.5	15	0.4	250	0.5087
83.51	0	0	0	15	0.4	250	0.5130
93.95	0	0	0	15	0.4	250	0.5056
104.39	0	0	0	15	0.4	250	0.4789

Basic Geometry and Material Calculations

x_{dist} (in)	d_s (in)	$A_{ps.bot}$ (in^2)	cg_{harp} (in)
0.00	49.90	4.28	40.32
10.44	49.90	4.28	39.14
20.88	49.90	4.28	37.95
31.32	49.90	4.28	36.77
41.75	49.90	4.28	35.58
48.54	49.90	4.28	34.81
52.19	49.90	4.28	34.40
55.85	49.90	4.28	33.99
62.63	49.90	4.28	33.22
73.07	50.00	4.28	32.03
83.51	54.50	4.28	30.85
93.95	54.50	4.28	29.66
104.39	54.50	4.59	28.48

h_c (in)	L_{span} (ft)	A_{ps} (in^2)	Ψ_{harp} (rad)	f_{po} (ksi)	$f_{r.V}$ (psi)	β_1
54.5	57.875	5.202	0.1129	189	595.315	0.8055

Load Effect Calculations

x_{dist} (in)	V_{LL} (kip)	M_{LL} (ft-kip)	V_{DC1} (kip)	M_{DC1} (ft-kip)	V_{assume} (kip)	$M_{assume1}$ (ft-kip)	M_{assume} (ft-kip)	V_p (kip)
0.0	709.0	0.0	41.9	-0.2	751.0	-0.2	3003.4	3.5
10.4	295.9	257.4	40.7	35.7	336.6	293.2	1320.0	9.5
20.9	254.6	442.9	39.4	70.6	294.0	513.5	1125.4	15.6
31.3	196.9	513.9	38.1	104.3	235.1	618.2	880.4	17.4
41.8	215.3	749.3	36.9	136.9	252.2	886.2	949.9	17.4
48.5	223.2	903.0	36.1	157.6	259.3	1060.5	1060.5	17.4
52.2	225.4	980.4	35.6	168.5	261.0	1148.9	1148.9	17.4
55.8	227.5	1058.7	35.2	179.3	262.7	1238.0	1238.0	17.4
62.6	231.0	1205.9	34.4	198.9	265.4	1404.8	1404.8	17.4
73.1	232.8	1417.5	33.1	228.3	265.9	1645.8	1645.8	17.4
83.5	232.8	1619.8	31.8	256.5	264.6	1876.3	1876.3	17.4
93.9	237.8	1861.8	30.6	283.7	268.4	2145.4	2145.4	17.4
104.4	245.0	2131.2	29.3	309.7	274.3	2440.9	2440.9	17.4

Calculations for β and θ

x_{dist} (in)	cg_{ps} (in)	d_p (in)	c (in)	a (in)	$f_{ps.max}$ (ksi)	$l_{d.ps}$ (in)	f_{ps} (ksi)	$cg_{ps.bot}$ (in)	$d_{p.bot}$ (in)	$d_{s.bot}$ (in)	$Num_{strand.bot}$	$RedFactor_{\varepsilon x.s}$	$RedFactor_{\varepsilon x.ps}$
0.00	3.78	44.36	5.33	4.30	260.9	119.24	33.56	3.68	50.82	49.90	28.00	0.34	0.05
10.44	3.78	44.56	5.33	4.30	261.0	119.27	91.95	3.68	50.82	49.90	28.00	0.94	0.14
20.88	3.78	44.77	5.33	4.30	261.0	119.30	150.33	3.68	50.82	49.90	28.00	1.00	0.23
31.32	3.78	44.98	5.33	4.30	261.0	119.33	175.44	3.68	50.82	49.90	28.00	1.00	0.31
41.75	3.78	45.19	5.34	4.30	261.1	119.37	186.33	3.68	50.82	49.90	28.00	1.00	0.40
48.54	3.78	45.33	5.34	4.30	261.1	119.39	193.41	3.68	50.82	49.90	28.00	1.00	0.46
52.19	3.78	45.40	5.34	4.30	261.1	119.40	197.23	3.68	50.82	49.90	28.00	1.00	0.49
55.85	3.78	45.47	5.34	4.30	261.1	119.41	201.05	3.68	50.82	49.90	28.00	1.00	0.52
62.63	3.78	45.61	5.34	4.30	261.2	119.43	208.13	3.68	50.82	49.90	28.00	1.00	0.57
73.07	3.78	45.82	5.14	4.14	261.5	119.73	219.06	3.68	50.82	50.00	28.00	1.00	0.66
83.51	3.78	46.03	4.85	3.90	262.0	120.14	230.02	3.68	50.82	54.50	28.00	1.00	0.75
93.95	3.78	46.24	4.85	3.90	262.1	120.17	240.93	3.68	50.82	54.50	28.00	1.00	0.83
104.39	3.78	46.44	4.85	3.91	262.1	120.19	251.85	5.20	49.30	54.50	30.00	1.00	0.92

x_{dist} (in)	$A_{ps.bot}$ (in^2)	d_e (in)	ε_s	d_v (in)	v_u	$A_{s.bot.\varepsilon x}$ (in^2)	$A_{ps.bot.\varepsilon x}$ (in^2)	ε_x	θ (rad)	β	$MinReinfCheck$
0.00	4.28	50.36	0.03	48.22	0.250	0.70	0.22	0.0232	0.6231	1.50	OK
10.44	4.28	50.58	0.03	48.43	0.109	1.92	0.59	0.0030	0.6424	2.16	OK
20.88	4.28	50.65	0.03	48.51	0.093	2.04	0.97	0.0016	0.6390	2.19	OK
31.32	4.28	50.67	0.03	48.53	0.072	2.04	1.34	0.0007	0.5734	2.44	OK
41.75	4.28	50.68	0.03	48.53	0.078	2.04	1.71	0.0005	0.5344	2.57	OK
48.54	4.28	50.69	0.03	48.54	0.080	2.04	1.96	0.0005	0.5201	2.64	OK
52.19	4.28	50.69	0.03	48.54	0.081	2.04	2.09	0.0004	0.5167	2.65	OK
55.85	4.28	50.69	0.03	48.54	0.082	2.04	2.22	0.0004	0.5136	2.66	OK
62.63	4.28	50.69	0.03	48.55	0.082	2.04	2.46	0.0004	0.5082	2.69	OK
73.07	4.28	50.75	0.03	48.69	0.082	1.20	2.83	0.0004	0.5087	2.68	OK

83.51	4.28	50.82	0.03	48.87	0.082	0.00	3.19	0.0004	0.5130	2.67	OK
93.95	4.28	50.82	0.03	48.87	0.083	0.00	3.56	0.0004	0.5056	2.70	OK
104.39	4.59	49.30	0.03	47.35	0.088	0.00	4.22	0.0003	0.4789	2.80	OK

Final Results for Shear Strength

x_{dist} (in)	V_c (kip)	V_s (kip)	V_{n1} (kip)	V_{n2} (kip)	V_n (kip)
0.00	47.6	749.4	800.5	751.1	751.1
10.44	68.9	258.1	336.6	760.4	336.6
20.88	70.1	208.3	294.0	767.6	294.0
31.32	77.8	139.9	235.1	769.8	235.1
41.75	82.2	152.6	252.2	769.9	252.2
48.54	84.2	157.7	259.3	769.9	259.3
52.19	84.7	159.0	261.1	770.0	261.1
55.85	85.1	160.2	262.7	770.0	262.7
62.63	85.8	162.2	265.4	770.1	265.4
73.07	86.0	162.5	265.9	772.2	265.9
83.51	85.8	161.5	264.6	775.1	264.6
93.95	86.8	164.3	268.4	775.1	268.4
104.39	87.2	169.7	274.4	751.5	274.4

Beam BT.8N.Typ.2

Inputs

γ_c (pcf)	150
f_c' (psi)	8570
f_{ci}' (psi)	6183
$f_{c.deck}$ (psi)	4990
$\gamma_{c.deck}$ (pcf)	127
E_{beam} (ksi)	4950
$E_{beam.i}$ (ksi)	4670
E_{slab} (ksi)	3110
h (in)	45
A_{beam} (in^2)	746.7
I_{beam} (in^4)	207300
L_{beam} (ft)	58.875
b_v (in)	7
y_b (in)	22.23
y_t (in)	22.77
S (ft)	7
t_{haunch} (in)	1

t_{struct} (in)	8.5
A_{ct} (in^2)	423.25
h_{flange} (in)	8.5
Num_{strand}	34
$Num_{straight}$	28
$Num_{straight.bot}$	28
Num_{harp}	6
$cg_{straight}$ (in)	3.68
$cg_{harp.end}$ (in)	41
$cg_{harp.ms}$ (in)	4.25
$cg_{straight.bot}$ (in)	3.68
A_{strand} (in^2)	0.15
φ (in)	0.5
f_{pu} (ksi)	270
f_{pe} (ksi)	167.8
E_p (ksi)	28500
$HarpDist$ (ft)	26.5

f_y (ksi)	69.8
f_{yv} (ksi)	69.8
E_s (ksi)	29000
α	1.57
$A_{s.top}$ (in^2)	0
d_{top} (in)	9.5
$d_{long.rebar}$	5
IsLongSteelEpoxyCoated	No
LongSteelClearSpacing (in)	3.75
LongSteelCover (in)	2
IsTopBarEffectApplicable	No
$A_{long.rebar}$ (in2)	0.31
ShearSpan (in)	152.62
$x_{bearing}$ (in)	6
$x_{bearing.roller}$ (in)	113
$x_{critical.assume}$ (in)	49.12

x_{dist} (in)	A_{ct} (in^2)	$cg_{s.bot}$ (in)	cg_s (in)	$s_{v.design}$ (in)	A_v (in^2)	P_{assume} (kip)	θ_{assume} (rad)
0	2.04	4.6	4.6	2.5	0.4	250	0.62
15.26	2.04	4.6	4.6	8.75	0.4	250	0.64
30.52	2.04	4.6	4.6	15	0.4	250	0.5800
45.78	2.04	4.6	4.6	15	0.4	250	0.52
48.58	2.04	4.6	4.6	15	0.4	250	0.52
61.05	2.04	4.6	4.6	15	0.4	250	0.51
76.31	2.04	4.6	4.6	15	0.4	250	0.5
91.57	0	0	0	15	0.4	250	0.51
104.04	0	0	0	18	0.4	250	0.45
106.83	0	0	0	18	0.4	250	0.45
122.09	0	0	0	18	0.4	250	0.4400
137.35	0	0	0	18	0.4	250	0.45
152.62	0	0	0	18	0.4	250	0.47

Basic Geometry and Material Calculations

x_{dist} (in)	d_s (in)	$A_{ps.bot}$ (in^2)	cg_{harp} (in)
0.00	49.90	4.28	40.32
15.26	49.90	4.28	38.59
30.52	49.90	4.28	36.86
45.78	49.90	4.28	35.13
48.58	49.90	4.28	34.81
61.05	49.90	4.28	33.40
76.31	49.90	4.28	31.66
91.57	54.50	4.28	29.93
104.04	54.50	4.59	28.52
106.83	54.50	4.59	28.20
122.09	54.50	4.90	26.47
137.35	54.50	5.20	24.74
152.62	54.50	5.20	23.01

h_c (in)	L_{span} (ft)	A_{ps} (in^2)	Ψ_{harp} (rad)	f_{po} (ksi)	$f_{r.V}$ (psi)	β_1
54.5	48.9583	5.202	0.1129	189	585.5	0.8005

Load Effect Calculations

x_{dist} (in)	V_{LL} (kip)	M_{LL} (ft-kip)	V_{DC1} (kip)	M_{DC1} (ft-kip)	V_{assume} (kip)	$M_{assume1}$ (ft-kip)	M_{assume} (ft-kip)	V_p (kip)
0.0	693.0	0.0	34.2	-0.2	727.2	-0.2	2910.2	3.5
15.3	256.9	326.7	32.3	42.1	289.2	368.8	1119.5	12.3
30.5	202.5	515.0	30.5	82.0	232.9	597.0	872.5	17.4
45.8	228.4	871.3	28.6	119.6	257.0	990.9	990.9	17.4
48.6	230.1	931.5	28.3	126.2	258.4	1057.7	1057.7	17.4
61.0	237.0	1205.7	26.8	154.9	263.8	1360.6	1360.6	17.4
76.3	244.2	1552.7	24.9	187.8	269.1	1740.5	1740.5	17.4
91.6	243.6	1859.2	23.1	218.3	266.7	2077.5	2077.5	17.4
104.0	239.4	2075.2	21.6	241.5	261.0	2316.7	2316.7	17.4
106.8	240.6	2142.2	21.3	246.5	261.9	2388.8	2388.8	17.4
122.1	241.2	2453.6	19.4	272.4	260.6	2726.0	2726.0	17.4
137.4	234.1	2679.6	17.6	295.9	251.7	2975.5	2975.5	17.4
152.6	225.4	2866.5	15.7	317.1	241.1	3183.6	3183.6	17.4

Calculations for β and θ

x_{dist} (in)	cg_{ps} (in)	d_p (in)	c (in)	a (in)	$f_{ps.max}$ (ksi)	$l_{d.ps}$ (in)	f_{ps} (ksi)	$cg_{ps.bot}$ (in)	$d_{p.bot}$ (in)	$d_{s.bot}$ (in)	$Num_{strand.bot}$	$RedFactor_{\varepsilon x.s}$	$RedFactor_{\varepsilon x.ps}$
0.00	3.78	44.36	5.26	4.21	261.0	119.33	33.56	3.68	50.82	49.90	28.00	0.34	0.05
15.26	3.78	44.66	5.26	4.21	261.1	119.38	118.92	3.68	50.82	49.90	28.00	1.00	0.18
30.52	3.78	44.97	5.26	4.21	261.2	119.43	174.61	3.68	50.82	49.90	28.00	1.00	0.31
45.78	3.78	45.27	5.26	4.21	261.2	119.47	190.54	3.68	50.82	49.90	28.00	1.00	0.43
48.58	3.78	45.33	5.26	4.21	261.2	119.48	193.46	3.68	50.82	49.90	28.00	1.00	0.46
61.05	3.78	45.58	5.26	4.21	261.3	119.52	206.48	3.68	50.82	49.90	28.00	1.00	0.56
76.31	3.78	45.88	5.27	4.22	261.3	119.57	222.42	3.68	50.82	49.90	28.00	1.00	0.69
91.57	3.78	46.19	4.78	3.83	262.2	120.25	238.46	3.68	50.82	54.50	28.00	1.00	0.81
104.04	3.78	46.44	4.78	3.83	262.2	120.28	251.50	5.20	49.30	54.50	30.00	1.00	0.91
106.83	3.78	46.49	4.78	3.83	262.2	120.29	254.43	5.18	49.32	54.50	30.00	1.00	0.94
122.09	3.78	46.80	4.78	3.83	262.3	120.32	262.27	6.40	48.10	54.50	32.00	1.00	1.00
137.35	3.78	47.10	4.78	3.83	262.3	120.36	262.32	7.40	47.10	54.50	34.00	1.00	1.00
152.62	3.78	47.41	4.79	3.83	262.4	120.40	262.37	7.09	47.41	54.50	34.00	1.00	1.00

x_{dist} (in)	$A_{ps.bot}$ (in²)	d_e (in)	ε_s	d_v (in)	v_u	$A_{s.bot.\varepsilon x}$ (in²)	$A_{ps.bot.\varepsilon x}$ (in²)	ε_x	θ (rad)	β	$MinReinfCheck$
0.00	4.28	50.36	0.03	48.26	0.250	0.70	0.22	0.0224	0.6231	1.50	OK
15.26	4.28	50.62	0.03	48.51	0.095	2.04	0.76	0.0020	0.6395	2.19	OK
30.52	4.28	50.67	0.03	48.57	0.074	2.04	1.31	0.0007	0.5758	2.43	OK
45.78	4.28	50.68	0.03	48.58	0.082	2.04	1.86	0.0005	0.5220	2.62	OK
48.58	4.28	50.69	0.03	48.58	0.083	2.04	1.96	0.0004	0.5192	2.63	OK
61.05	4.28	50.69	0.03	48.59	0.085	2.04	2.40	0.0004	0.5085	2.68	OK
76.31	4.28	50.70	0.03	48.59	0.086	2.04	2.95	0.0004	0.4982	2.72	OK
91.57	4.28	50.82	0.03	48.91	0.085	0.00	3.48	0.0004	0.5059	2.69	OK
104.04	4.59	49.30	0.03	47.38	0.086	0.00	4.20	0.0002	0.4493	2.97	OK
106.83	4.59	49.32	0.03	47.41	0.086	0.00	4.31	0.0002	0.4477	2.98	OK

122.09	4.90	48.10	0.03	46.18	0.088	0.00	4.90	0.0002	0.4381	3.02	OK
137.35	5.20	47.10	0.03	45.19	0.086	0.00	5.20	0.0002	0.4453	2.99	OK
152.62	5.20	47.41	0.03	45.49	0.082	0.00	5.20	0.0003	0.4694	2.87	OK

Final Results for Shear Strength

x_{dist} (in)	V_c (kip)	V_s (kip)	V_{n1} (kip)	V_{n2} (kip)	V_n (kip)
0.00	46.9	750.0	800.4	727.2	727.2
15.26	68.8	208.1	289.2	739.9	289.2
30.52	76.3	139.3	232.9	745.8	232.9
45.78	82.4	157.2	257.0	745.9	257.0
48.58	82.8	158.2	258.4	745.9	258.4
61.05	84.2	162.3	263.8	746.0	263.8
76.31	85.5	166.3	269.1	746.2	269.1
91.57	85.1	164.3	266.8	750.9	266.8
104.04	91.2	152.4	261.0	728.0	261.0
106.83	91.5	153.1	261.9	728.3	261.9
122.09	90.3	152.9	260.6	710.0	260.6
137.35	87.5	146.9	251.8	695.1	251.8
152.62	84.7	139.1	241.2	699.7	241.2

Beam BT.8.Typ.1

Inputs

γ_c (pcf)	125.8
f_c' (psi)	9080
f_{ci}' (psi)	6330
$f_{c.deck}$ (psi)	5580
$\gamma_{c.deck}$ (pcf)	128.4
E_{beam} (ksi)	3590
$E_{beam.i}$ (ksi)	3790
E_{slab} (ksi)	3600
h (in)	45
A_{beam} (in^2)	746.7
I_{beam} (in^4)	207300
L_{beam} (ft)	59
b_v (in)	7
y_b (in)	22.23
y_t (in)	22.77
S (ft)	7
t_{haunch} (in)	1

t_{struct} (in)	8.5
A_{ct} (in^2)	423.25
h_{flange} (in)	8.5
Num_{strand}	34
$Num_{straight}$	28
$Num_{straight.bot}$	28
Num_{harp}	6
$cg_{straight}$ (in)	3.68
$cg_{harp.end}$ (in)	41
$cg_{harp.ms}$ (in)	4.25
$cg_{straight.bot}$ (in)	3.68
A_{strand} (in^2)	0.15
φ (in)	0.5
f_{pu} (ksi)	270
f_{pe} (ksi)	175.09
E_p (ksi)	28500
$HarpDist$ (ft)	26.5

f_y (ksi)	67.3
f_{yv} (ksi)	67.3
E_s (ksi)	29000
α	1.57
$A_{s.top}$ (in^2)	0
d_{top} (in)	9.5
$d_{long.rebar}$	5
$IsLongSteelEpoxyCoated$	No
$LongSteelClearSpacing$ (in)	3.75
$LongSteelCover$ (in)	2
$IsTopBarEffectApplicable$	No
$A_{long.rebar}$ (in2)	0.31
$ShearSpan$ (in)	102.10
$x_{bearing}$ (in)	6
$x_{bearing.roller}$ (in)	6
$x_{critical.assume}$ (in)	44.15

x_{dist} (in)	A_{ct} (in^2)	$cg_{s.bot}$ (in)	cg_s (in)	$s_{v.design}$ (in)	A_v (in^2)	P_{assume} (kip)	θ_{assume} (rad)
0	2.48	4.5	4.5	2.5	0.4	250	0.62
10.21	2.48	4.5	4.5	5.75	0.4	250	0.64
20.42	2.48	4.5	4.5	9	0.4	250	0.6400
30.63	2.48	4.5	4.5	9	0.4	250	0.63
40.84	2.48	4.5	4.5	9	0.4	250	0.59
48.77	2.48	4.5	4.5	9	0.4	250	0.58
51.05	2.48	4.5	4.5	9	0.4	250	0.57
53.33	2.48	4.5	4.5	9	0.4	250	0.57
61.26	2.48	4.5	4.5	9	0.4	250	0.57
71.47	2.48	4.5	4.5	9	0.4	250	0.56
81.68	0	0	0	9	0.4	250	0.5900
91.89	0	0	0	9	0.4	250	0.59
102.10	0	0	0	10	0.4	250	0.54

Basic Geometry and Material Calculations

x_{dist} (in)	d_s (in)	$A_{ps.bot}$ (in^2)	cg_{harp} (in)
0.00	50.00	4.28	40.32
10.21	50.00	4.28	39.16
20.42	50.00	4.28	38.00
30.63	50.00	4.28	36.85
40.84	50.00	4.28	35.69
48.77	50.00	4.28	34.79
51.05	50.00	4.28	34.53
53.33	50.00	4.28	34.27
61.26	50.00	4.28	33.37
71.47	50.00	4.28	32.21
81.68	54.50	4.28	31.05
91.89	54.50	4.28	29.90
102.10	54.50	4.59	28.74

h_c (in)	L_{span} (ft)	A_{ps} (in^2)	Ψ_{harp} (rad)	f_{po} (ksi)	$f_{r.V}$ (psi)	β_1
54.5	58	5.202	0.1129	189	602.7	0.771

Load Effect Calculations

x_{dist} (in)	V_{LL} (kip)	M_{LL} (ft-kip)	V_{DC1} (kip)	M_{DC1} (ft-kip)	V_{assume} (kip)	$M_{assume1}$ (ft-kip)	M_{assume} (ft-kip)	V_p (kip)
0.0	735.2	0.0	38.6	-0.2	773.8	-0.2	3110.9	3.6
10.2	344.7	293.3	37.5	32.2	382.1	325.4	1510.0	9.8
20.4	248.0	422.1	36.3	63.6	284.4	485.6	1090.1	16.0
30.6	257.1	656.1	35.2	94.0	292.3	750.2	1113.9	18.1
40.8	276.4	940.8	34.1	123.5	310.5	1064.3	1188.2	18.1
48.8	287.3	1167.8	33.2	145.7	320.5	1313.5	1313.5	18.1
51.0	288.4	1226.9	32.9	152.0	321.3	1378.9	1378.9	18.1
53.3	289.4	1286.3	32.7	158.2	322.1	1444.5	1444.5	18.1
61.3	292.8	1494.9	31.8	179.5	324.6	1674.4	1674.4	18.1
71.5	296.8	1767.4	30.7	206.1	327.4	1973.5	1973.5	18.1
81.7	283.0	1926.3	29.5	231.7	312.5	2158.0	2158.0	18.1
91.9	288.0	2205.1	28.4	256.4	316.4	2461.4	2461.4	18.1
102.1	284.3	2418.8	27.3	280.0	311.6	2698.8	2698.8	18.1

Calculations for β and θ

x_{dist} (in)	cg_{ps} (in)	d_p (in)	c (in)	a (in)	$f_{ps.max}$ (ksi)	$l_{d.ps}$ (in)	f_{ps} (ksi)	$cg_{ps.bot}$ (in)	$d_{p.bot}$ (in)	$d_{s.bot}$ (in)	$Num_{strand.bot}$	$RedFactor_{\varepsilon x.s}$	$RedFactor_{\varepsilon x.ps}$
0.00	3.78	44.36	4.97	3.83	261.5	115.84	35.02	3.68	50.82	50.00	28.00	0.36	0.05
10.21	3.78	44.56	4.97	3.83	261.6	115.87	94.61	3.68	50.82	50.00	28.00	0.96	0.14
20.42	3.78	44.76	4.97	3.83	261.6	115.90	154.20	3.68	50.82	50.00	28.00	1.00	0.23
30.63	3.78	44.97	4.97	3.84	261.6	115.93	181.77	3.68	50.82	50.00	28.00	1.00	0.32
40.84	3.78	45.17	4.97	3.84	261.7	115.96	192.05	3.68	50.82	50.00	28.00	1.00	0.40
48.77	3.78	45.33	4.98	3.84	261.7	115.98	200.04	3.68	50.82	50.00	28.00	1.00	0.47
51.05	3.78	45.38	4.98	3.84	261.7	115.99	202.34	3.68	50.82	50.00	28.00	1.00	0.49
53.33	3.78	45.42	4.98	3.84	261.7	115.99	204.64	3.68	50.82	50.00	28.00	1.00	0.51
61.26	3.78	45.58	4.98	3.84	261.7	116.02	212.63	3.68	50.82	50.00	28.00	1.00	0.58
71.47	3.78	45.79	4.98	3.84	261.8	116.04	222.92	3.68	50.82	50.00	28.00	1.00	0.67
81.68	3.78	45.99	4.45	3.43	262.7	116.77	233.32	3.68	50.82	54.50	28.00	1.00	0.75
91.89	3.78	46.19	4.45	3.43	262.7	116.79	243.63	3.68	50.82	54.50	28.00	1.00	0.84
102.10	3.78	46.40	4.45	3.43	262.8	116.82	253.95	5.22	49.28	54.50	30.00	1.00	0.93

x_{dist} (in)	$A_{ps.bot}$ (in^2)	d_e (in)	ε_s	d_v (in)	v_u	$A_{s.bot.\varepsilon x}$ (in^2)	$A_{ps.bot.\varepsilon x}$ (in^2)	ε_x	θ (rad)	β	$MinReinfCheck$
0.00	4.28	50.39	0.03	48.47	0.250	0.88	0.22	0.0198	0.6231	1.50	OK
10.21	4.28	50.58	0.03	48.66	0.120	2.39	0.60	0.0029	0.6448	2.14	OK
20.42	4.28	50.66	0.03	48.74	0.087	2.48	0.98	0.0013	0.6377	2.21	OK
30.63	4.28	50.68	0.03	48.76	0.089	2.48	1.35	0.0009	0.6267	2.24	OK
40.84	4.28	50.68	0.03	48.77	0.094	2.48	1.73	0.0008	0.5927	2.33	OK
48.77	4.28	50.69	0.03	48.77	0.098	2.48	2.02	0.0007	0.5753	2.38	OK
51.05	4.28	50.69	0.03	48.77	0.098	2.48	2.11	0.0007	0.5740	2.39	OK
53.33	4.28	50.69	0.03	48.77	0.098	2.48	2.19	0.0007	0.5726	2.39	OK
61.26	4.28	50.69	0.03	48.78	0.099	2.48	2.48	0.0006	0.5684	2.40	OK
71.47	4.28	50.70	0.03	48.78	0.100	2.48	2.86	0.0006	0.5638	2.42	OK

81.68	4.28	50.82	0.03	49.11	0.094	0.00	3.22	0.0008	0.5927	2.33	OK
91.89	4.28	50.82	0.03	49.11	0.096	0.00	3.59	0.0007	0.5860	2.35	OK
102.10	4.59	49.28	0.03	47.57	0.097	0.00	4.25	0.0005	0.5391	2.50	OK

Final Results for Shear Strength

x_{dist} (in)	V_c (kip)	V_s (kip)	V_{n1} (kip)	V_{n2} (kip)	V_n (kip)
0.00	48.5	726.4	778.5	773.8	773.8
10.21	69.4	303.0	382.1	783.1	382.1
20.42	71.7	196.7	284.4	790.4	284.4
30.63	72.7	201.4	292.3	792.9	292.3
40.84	75.8	216.6	310.5	793.0	310.5
48.77	77.5	224.9	320.5	793.1	320.5
51.05	77.6	225.6	321.3	793.1	321.3
53.33	77.7	226.3	322.1	793.1	322.1
61.26	78.1	228.4	324.6	793.2	324.6
71.47	78.6	230.8	327.4	793.2	327.4
81.68	76.3	218.1	312.6	798.4	312.6
91.89	77.0	221.3	316.4	798.4	316.4
102.10	79.4	214.1	311.6	774.0	311.6

Beam BT.8.Typ.2

Inputs

γ_c (pcf)	125.8
f_c' (psi)	9080
f_{ci}' (psi)	6330
$f_{c.deck}$ (psi)	6690
$\gamma_{c.deck}$ (pcf)	135.8
E_{beam} (ksi)	3590
$E_{beam.i}$ (ksi)	3790
E_{slab} (ksi)	4050
h (in)	45
A_{beam} (in^2)	746.7
I_{beam} (in^4)	207300
L_{beam} (ft)	59
b_v (in)	7
y_b (in)	22.23
y_t (in)	22.77
S (ft)	7
t_{haunch} (in)	1

t_{struct} (in)	8.5
A_{ct} (in^2)	423.25
h_{flange} (in)	8.5
Num_{strand}	34
$Num_{straight}$	28
$Num_{straight.bot}$	28
Num_{harp}	6
$cg_{straight}$ (in)	3.68
$cg_{harp.end}$ (in)	41
$cg_{harp.ms}$ (in)	4.25
$cg_{straight.bot}$ (in)	3.68
A_{strand} (in^2)	0.15
φ (in)	0.5
f_{pu} (ksi)	270
f_{pe} (ksi)	175.09
E_p (ksi)	28500
$HarpDist$ (ft)	26.5

f_y (ksi)	67.3
f_{yv} (ksi)	67.3
E_s (ksi)	29000
α	1.57
$A_{s.top}$ (in^2)	0
d_{top} (in)	9.5
$d_{long.rebar}$	5
$IsLongSteelEpoxyCoated$	No
$LongSteelClearSpacing$ (in)	3.75
$LongSteelCover$ (in)	2
$IsTopBarEffectApplicable$	No
$A_{long.rebar}$ (in2)	0.31
$ShearSpan$ (in)	153.28
$x_{bearing}$ (in)	6
$x_{bearing.roller}$ (in)	108.5
$x_{critical.assume}$ (in)	44.35

x_{dist} (in)	A_{ct} (in^2)	$cg_{s.bot}$ (in)	cg_s (in)	$s_{v.design}$ (in)	A_v (in^2)	P_{assume} (kip)	θ_{assume} (rad)
0	2.48	4.5	4.5	2.5	0.4	250	0.62
15.33	2.48	4.5	4.5	5.75	0.4	250	0.64
30.66	2.48	4.5	4.5	9	0.4	250	0.6200
45.98	2.48	4.5	4.5	9	0.4	250	0.57
49.08	2.48	4.5	4.5	9	0.4	250	0.57
61.31	2.48	4.5	4.5	9	0.4	250	0.56
76.64	0	0	0	9	0.4	250	0.59
91.97	0	0	0	10	0.4	250	0.56
104.19	0	0	0	10	0.4	250	0.53
107.29	0	0	0	10	0.4	250	0.53
122.62	0	0	0	10	0.4	250	0.5300
137.95	0	0	0	10	0.4	250	0.54
153.28	0	0	0	10	0.4	250	0.56

Basic Geometry and Material Calculations

x_{dist} (in)	d_s (in)	$A_{ps.bot}$ (in^2)	cg_{harp} (in)
0.00	50.00	4.28	40.32
15.33	50.00	4.28	38.58
30.66	50.00	4.28	36.84
45.98	50.00	4.28	35.10
49.08	50.00	4.28	34.75
61.31	50.00	4.28	33.37
76.64	54.50	4.28	31.63
91.97	54.50	4.28	29.89
104.19	54.50	4.59	28.50
107.29	54.50	4.59	28.15
122.62	54.50	4.90	26.41
137.95	54.50	5.20	24.67
153.28	54.50	5.20	22.93

h_c (in)	L_{span} (ft)	A_{ps} (in^2)	Ψ_{harp} (rad)	f_{po} (ksi)	$f_{r.V}$ (psi)	β_1
54.5	49.4583	5.202	0.1129	189	602.7	0.7155

Load Effect Calculations

x_{dist} (in)	V_{LL} (kip)	M_{LL} (ft-kip)	V_{DC1} (kip)	M_{DC1} (ft-kip)	V_{assume} (kip)	$M_{assume1}$ (ft-kip)	M_{assume} (ft-kip)	V_p (kip)
0.0	743.4	0.0	32.7	-0.2	776.2	-0.2	3140.8	3.6
15.3	347.1	443.3	31.0	40.5	378.1	483.8	1491.8	12.9
30.7	256.9	656.4	29.3	79.0	286.2	735.4	1096.3	18.1
46.0	286.0	1096.1	27.5	115.3	313.5	1211.4	1211.4	18.1
49.1	287.6	1176.4	27.1	122.3	314.8	1298.7	1298.7	18.1
61.3	293.2	1497.8	25.8	149.3	318.9	1647.0	1647.0	18.1
76.6	281.5	1797.7	24.0	181.0	305.5	1978.8	1978.8	18.1
92.0	278.5	2134.3	22.3	210.6	300.7	2344.9	2344.9	18.1
104.2	286.7	2489.5	20.9	232.5	307.6	2722.1	2722.1	18.1
107.3	288.1	2576.4	20.5	237.9	308.6	2814.3	2814.3	18.1
122.6	282.8	2890.2	18.8	263.0	301.6	3153.2	3153.2	18.1
137.9	273.6	3145.2	17.0	285.8	290.6	3431.0	3431.0	18.1
153.3	263.6	3366.5	15.3	306.4	278.8	3672.9	3672.9	18.1

Calculations for β and θ

x_{dist} (in)	cg_{ps} (in)	d_p (in)	c (in)	a (in)	$f_{ps.max}$ (ksi)	$l_{d.ps}$ (in)	f_{ps} (ksi)	$cg_{ps.bot}$ (in)	$d_{p.bot}$ (in)	$d_{s.bot}$ (in)	$Num_{strand.bot}$	$RedFactor_{\varepsilon x.s}$	$RedFactor_{\varepsilon x.ps}$
0.00	3.78	44.36	4.48	3.21	262.4	116.51	35.02	3.68	50.82	50.00	28.00	0.30	0.05
15.33	3.78	44.66	4.48	3.21	262.4	116.55	124.48	3.68	50.82	50.00	28.00	1.00	0.18
30.66	3.78	44.97	4.48	3.21	262.5	116.59	181.81	3.68	50.82	50.00	28.00	1.00	0.31
45.98	3.78	45.28	4.48	3.21	262.5	116.63	197.27	3.68	50.82	50.00	28.00	1.00	0.45
49.08	3.78	45.34	4.48	3.21	262.5	116.64	200.40	3.68	50.82	50.00	28.00	1.00	0.47
61.31	3.78	45.58	4.48	3.21	262.6	116.67	212.75	3.68	50.82	50.00	28.00	1.00	0.58
76.64	3.78	45.89	4.01	2.87	263.4	117.33	228.31	3.68	50.82	54.50	28.00	1.00	0.70
91.97	3.78	46.20	4.01	2.87	263.4	117.37	243.82	3.68	50.82	54.50	28.00	1.00	0.83
104.19	3.78	46.44	4.01	2.87	263.5	117.40	256.19	5.20	49.30	54.50	30.00	1.00	0.94
107.29	3.78	46.50	4.01	2.87	263.5	117.40	259.32	5.18	49.32	54.50	30.00	1.00	0.97
122.62	3.78	46.81	4.01	2.87	263.5	117.44	263.52	6.40	48.10	54.50	32.00	1.00	1.00
137.95	3.78	47.12	4.01	2.87	263.6	117.47	263.56	7.38	47.12	54.50	34.00	1.00	1.00
153.28	3.78	47.42	4.01	2.87	263.6	117.50	263.60	7.08	47.42	54.50	34.00	1.00	1.00

x_{dist} (in)	$A_{ps.bot}$ (in^2)	d_e (in)	ε_s	d_v (in)	v_u	$A_{s.bot.\varepsilon x}$ (in^2)	$A_{ps.bot.\varepsilon x}$ (in^2)	ε_x	θ (rad)	β	$MinReinfCheck$
0.00	4.28	50.39	0.03	48.79	0.249	0.74	0.22	0.0229	0.6231	1.50	OK
15.33	4.28	50.63	0.03	49.02	0.117	2.48	0.78	0.0024	0.6441	2.15	OK
30.66	4.28	50.68	0.03	49.07	0.086	2.48	1.35	0.0009	0.6208	2.26	OK
45.98	4.28	50.69	0.03	49.08	0.095	2.48	1.91	0.0007	0.5709	2.40	OK
49.08	4.28	50.69	0.03	49.08	0.095	2.48	2.02	0.0006	0.5689	2.41	OK
61.31	4.28	50.69	0.03	49.09	0.096	2.48	2.47	0.0006	0.5619	2.43	OK
76.64	4.28	50.82	0.04	49.39	0.092	0.00	3.02	0.0007	0.5879	2.35	OK
91.97	4.28	50.82	0.04	49.39	0.090	0.00	3.58	0.0006	0.5565	2.46	OK
104.19	4.59	49.30	0.03	47.87	0.095	0.00	4.31	0.0005	0.5290	2.55	OK
107.29	4.59	49.32	0.03	47.89	0.096	0.00	4.43	0.0005	0.5275	2.55	OK

122.62	4.90	48.10	0.03	46.67	0.096	0.00	4.90	0.0005	0.5269	2.56	OK
137.95	5.20	47.12	0.03	45.68	0.094	0.00	5.20	0.0005	0.5357	2.52	OK
153.28	5.20	47.42	0.03	45.99	0.089	0.00	5.20	0.0006	0.5612	2.45	OK

Final Results for Shear Strength

x_{dist} (in)	V_c (kip)	V_s (kip)	V_{n1} (kip)	V_{n2} (kip)	V_n (kip)
0.00	41.6	731.1	776.3	778.8	776.3
15.33	59.6	305.6	378.1	791.8	378.1
30.66	62.8	205.3	286.2	797.9	286.2
45.98	66.9	228.6	313.6	798.0	313.6
49.08	67.0	229.6	314.8	798.1	314.8
61.31	67.6	233.2	318.9	798.2	318.9
76.64	65.8	221.6	305.6	802.9	305.6
91.97	68.9	213.7	300.8	802.9	300.8
104.19	69.1	220.4	307.6	778.7	307.6
107.29	69.3	221.3	308.7	779.1	308.7
122.62	67.6	216.0	301.7	759.7	301.7
137.95	65.3	207.2	290.6	744.0	290.6
153.28	63.8	197.0	278.9	748.9	278.9

Beam BT.10.Typ.1

Inputs

γ_c (pcf)	124.6
f_c' (psi)	8890
f_{ci}' (psi)	6120
$f_{c.deck}$ (psi)	4130
$\gamma_{c.deck}$ (pcf)	126.6
E_{beam} (ksi)	3910
$E_{beam.i}$ (ksi)	4230
E_{slab} (ksi)	3160
h (in)	45
A_{beam} (in^2)	746.7
I_{beam} (in^4)	207300
L_{beam} (ft)	58.9375
b_v (in)	7
y_b (in)	22.23
y_t (in)	22.77
S (ft)	7
t_{haunch} (in)	1

t_{struct} (in)	8.5
A_{ct} (in^2)	423.25
h_{flange} (in)	8.5
Num_{strand}	34
$Num_{straight}$	28
$Num_{straight.bot}$	28
Num_{harp}	6
$cg_{straight}$ (in)	3.68
$cg_{harp.end}$ (in)	41
$cg_{harp.ms}$ (in)	4.25
$cg_{straight.bot}$ (in)	3.68
A_{strand} (in^2)	0.15
φ (in)	0.5
f_{pu} (ksi)	270
f_{pe} (ksi)	173.34
E_p (ksi)	28500
$HarpDist$ (ft)	26.5

f_y (ksi)	67.3
f_{yv} (ksi)	67.3
E_s (ksi)	29000
α	1.57
$A_{s.top}$ (in^2)	0
d_{top} (in)	9.5
$d_{long.rebar}$	6
$IsLongSteelEpoxyCoated$	No
$LongSteelClearSpacing$ (in)	1
$LongSteelCover$ (in)	2
$IsTopBarEffectApplicable$	No
$A_{long.rebar}$ (in2)	0.31
$ShearSpan$ (in)	98.39
$x_{bearing}$ (in)	6
$x_{bearing.roller}$ (in)	6
$x_{critical.assume}$ (in)	44.18

x_{dist} (in)	A_{ct} (in^2)	$cg_{s.bot}$ (in)	cg_s (in)	$s_{v.design}$ (in)	A_v (in^2)	P_{assume} (kip)	θ_{assume} (rad)
0	3	4.95	4.95	2.5	0.4	250	0.62
9.84	3	4.95	4.95	7.75	0.4	250	0.64
19.68	3	4.95	4.95	10	0.4	250	0.6300
29.52	3	4.95	4.95	10	0.4	250	0.59
39.36	3	4.95	4.95	10	0.4	250	0.56
47.94	3	4.95	4.95	10	0.4	250	0.54
49.19	3	4.95	4.95	10	0.4	250	0.54
50.44	3	4.95	4.95	10	0.4	250	0.54
59.03	3	4.95	4.95	10	0.4	250	0.54
68.87	3	4.95	4.95	10	0.4	250	0.53
78.71	3	4.95	4.95	10	0.4	250	0.5300
88.55	1.76	5	5	10	0.4	250	0.54
98.39	0	0	0	12	0.4	250	0.49

Basic Geometry and Material Calculations

x_{dist} (in)	d_s (in)	$A_{ps.bot}$ (in^2)	cg_{harp} (in)
0.00	49.55	4.28	40.32
9.84	49.55	4.28	39.20
19.68	49.55	4.28	38.09
29.52	49.55	4.28	36.97
39.36	49.55	4.28	35.86
47.94	49.55	4.28	34.88
49.19	49.55	4.28	34.74
50.44	49.55	4.28	34.60
59.03	49.55	4.28	33.62
68.87	49.55	4.28	32.51
78.71	49.55	4.28	31.39
88.55	49.50	4.28	30.28
98.39	54.50	4.59	29.16

h_c (in)	L_{span} (ft)	A_{ps} (in^2)	Ψ_{harp} (rad)	f_{po} (ksi)	$f_{r.V}$ (psi)	β_1
54.5	57.9375	5.202	0.1129	189	596.3	0.8435

Load Effect Calculations

x_{dist} (in)	V_{LL} (kip)	M_{LL} (ft-kip)	V_{DC1} (kip)	M_{DC1} (ft-kip)	V_{assume} (kip)	$M_{assume1}$ (ft-kip)	M_{assume} (ft-kip)	V_p (kip)
0.0	703.7	0.0	38.1	-0.2	741.8	-0.2	2919.7	3.6
9.8	254.2	208.4	37.0	30.6	291.2	239.0	1121.2	9.5
19.7	216.7	355.4	35.9	60.5	252.7	416.0	947.0	15.4
29.5	237.0	582.9	34.9	89.6	271.8	672.5	1014.1	17.9
39.4	254.8	835.6	33.8	117.7	288.6	953.3	1081.1	17.9
47.9	265.6	1061.2	32.8	141.6	298.5	1202.8	1202.8	17.9
49.2	266.2	1091.2	32.7	145.0	298.9	1236.2	1236.2	17.9
50.4	266.8	1121.4	32.6	148.4	299.3	1269.8	1269.8	17.9
59.0	270.4	1330.4	31.6	171.3	302.1	1501.8	1501.8	17.9
68.9	274.5	1575.2	30.6	196.8	305.0	1772.0	1772.0	17.9
78.7	278.1	1824.2	29.5	221.4	307.6	2045.6	2045.6	17.9
88.6	276.3	2038.8	28.4	245.2	304.7	2284.0	2284.0	17.9
98.4	257.9	2114.3	27.3	268.0	285.2	2382.3	2382.3	17.9

Calculations for β and θ

x_{dist} (in)	cg_{ps} (in)	d_p (in)	c (in)	a (in)	$f_{ps.max}$ (ksi)	$l_{d.ps}$ (in)	f_{ps} (ksi)	$cg_{ps.bot}$ (in)	$d_{p.bot}$ (in)	$d_{s.bot}$ (in)	$Num_{strand.bot}$	$RedFactor_{\varepsilon x.s}$	$RedFactor_{\varepsilon x.ps}$
0.00	3.78	44.36	6.24	5.26	259.4	115.05	34.67	3.68	50.82	49.55	28.00	0.25	0.05
9.84	3.78	44.55	6.24	5.26	259.4	115.09	91.52	3.68	50.82	49.55	28.00	0.65	0.14
19.68	3.78	44.75	6.24	5.26	259.5	115.12	148.37	3.68	50.82	49.55	28.00	1.00	0.22
29.52	3.78	44.95	6.24	5.26	259.5	115.16	178.92	3.68	50.82	49.55	28.00	1.00	0.31
39.36	3.78	45.14	6.24	5.26	259.6	115.19	188.88	3.68	50.82	49.55	28.00	1.00	0.39
47.94	3.78	45.32	6.24	5.26	259.6	115.22	197.57	3.68	50.82	49.55	28.00	1.00	0.47
49.19	3.78	45.34	6.24	5.26	259.6	115.23	198.84	3.68	50.82	49.55	28.00	1.00	0.48
50.44	3.78	45.37	6.24	5.26	259.6	115.23	200.10	3.68	50.82	49.55	28.00	1.00	0.49
59.03	3.78	45.54	6.24	5.26	259.6	115.26	208.80	3.68	50.82	49.55	28.00	1.00	0.56
68.87	3.78	45.73	6.24	5.27	259.7	115.30	218.76	3.68	50.82	49.55	28.00	1.00	0.65
78.71	3.78	45.93	6.24	5.27	259.7	115.33	228.73	3.68	50.82	49.55	28.00	1.00	0.73
88.55	3.78	46.13	5.92	4.99	260.3	115.79	238.77	3.68	50.82	49.50	28.00	1.00	0.82
98.39	3.78	46.32	5.46	4.61	261.1	116.42	248.87	5.24	49.26	54.50	30.00	1.00	0.90

x_{dist} (in)	$A_{ps.bot}$ (in^2)	d_e (in)	ε_s	d_v (in)	v_u	$A_{s.bot.\varepsilon x}$ (in^2)	$A_{ps.bot.\varepsilon x}$ (in^2)	ε_x	θ (rad)	β	$MinReinfCheck$
0.00	4.28	50.09	0.02	47.46	0.250	0.74	0.22	0.0217	0.6231	1.50	OK
9.84	4.28	50.39	0.02	47.76	0.095	1.96	0.59	0.0024	0.6394	2.19	OK
19.68	4.28	50.51	0.02	47.88	0.080	3.00	0.96	0.0010	0.6291	2.24	OK
29.52	4.28	50.56	0.02	47.93	0.085	3.00	1.32	0.0008	0.5942	2.34	OK
39.36	4.28	50.57	0.02	47.94	0.091	3.00	1.69	0.0006	0.5618	2.44	OK
47.94	4.28	50.58	0.02	47.94	0.094	3.00	2.01	0.0005	0.5439	2.50	OK
49.19	4.28	50.58	0.02	47.95	0.094	3.00	2.05	0.0005	0.5431	2.50	OK
50.44	4.28	50.58	0.02	47.95	0.094	3.00	2.10	0.0005	0.5423	2.50	OK
59.03	4.28	50.59	0.02	47.95	0.095	3.00	2.42	0.0005	0.5376	2.51	OK
68.87	4.28	50.60	0.02	47.96	0.096	3.00	2.78	0.0005	0.5327	2.53	OK

78.71	4.28	50.60	0.02	47.97	0.097	3.00	3.15	0.0005	0.5284	2.55	OK
88.55	4.28	50.68	0.02	48.19	0.096	1.76	3.50	0.0005	0.5354	2.52	OK
98.39	4.59	49.26	0.02	46.95	0.092	0.00	4.12	0.0003	0.4934	2.71	OK

Final Results for Shear Strength

x_{dist} (in)	V_c (kip)	V_s (kip)	V_{n1} (kip)	V_{n2} (kip)	V_n (kip)
0.00	39.9	711.2	754.7	741.9	741.9
9.84	58.6	223.1	291.2	752.5	291.2
19.68	60.2	177.1	252.7	760.3	252.7
29.52	63.0	191.0	271.9	763.5	271.9
39.36	65.7	205.0	288.6	763.7	288.6
47.94	67.1	213.4	298.5	763.8	298.5
49.19	67.2	213.8	298.9	763.8	298.9
50.44	67.2	214.2	299.3	763.9	299.3
59.03	67.6	216.6	302.1	764.0	302.1
68.87	68.0	219.0	305.0	764.1	305.0
78.71	68.4	221.2	307.6	764.2	307.6
88.55	68.1	218.7	304.7	767.6	304.7
98.39	71.4	195.9	285.2	748.4	285.2

Beam BT.10.Typ.2

Inputs

γ_c (pcf)	129
f_c' (psi)	9730
f_{ci}' (psi)	6123
$f_{c.deck}$ (psi)	4930
$\gamma_{c.deck}$ (pcf)	129
E_{beam} (ksi)	4060
$E_{beam.i}$ (ksi)	4230
E_{slab} (ksi)	3270
h (in)	45
A_{beam} (in^2)	746.7
I_{beam} (in^4)	207300
L_{beam} (ft)	58.9375
b_v (in)	7
y_b (in)	22.23
y_t (in)	22.77
S (ft)	7
t_{haunch} (in)	1

t_{struct} (in)	8.5
A_{ct} (in^2)	423.25
h_{flange} (in)	8.5
Num_{strand}	34
$Num_{straight}$	28
$Num_{straight.bot}$	28
Num_{harp}	6
$cg_{straight}$ (in)	3.68
$cg_{harp.end}$ (in)	41
$cg_{harp.ms}$ (in)	4.25
$cg_{straight.bot}$ (in)	3.68
A_{strand} (in^2)	0.15
φ (in)	0.5
f_{pu} (ksi)	270
f_{pe} (ksi)	173.34
E_p (ksi)	28500
$HarpDist$ (ft)	26.5

f_y (ksi)	67.3
f_{yv} (ksi)	67.3
E_s (ksi)	29000
α	1.57
$A_{s.top}$ (in^2)	0
d_{top} (in)	9.5
$d_{long.rebar}$	6
$IsLongSteelEpoxyCoated$	No
$LongSteelClearSpacing$ (in)	1
$LongSteelCover$ (in)	2
$IsTopBarEffectApplicable$	No
$A_{long.rebar}$ (in2)	0.31
$ShearSpan$ (in)	146.21
$x_{bearing}$ (in)	6
$x_{bearing.roller}$ (in)	107.89
$x_{critical.assume}$ (in)	44.23

x_{dist} (in)	A_{ct} (in^2)	$cg_{s.bot}$ (in)	cg_s (in)	$s_{v.design}$ (in)	A_v (in^2)	P_{assume} (kip)	θ_{assume} (rad)
0	3	4.95	4.95	2.5	0.4	250	0.62
14.62	3	4.95	4.95	7.75	0.4	250	0.64
29.24	3	4.95	4.95	10	0.4	250	0.6000
43.86	3	4.95	4.95	10	0.4	250	0.55
48.36	3	4.95	4.95	10	0.4	250	0.55
58.48	3	4.95	4.95	10	0.4	250	0.54
73.11	3	4.95	4.95	10	0.4	250	0.53
87.73	0	0	0	12	0.4	250	0.53
97.85	0	0	0	12	0.4	250	0.5
102.35	0	0	0	12	0.4	250	0.5
116.97	0	0	0	12	0.4	250	0.4800
131.59	0	0	0	12	0.4	250	0.51
146.21	0	0	0	12	0.4	250	0.52

Basic Geometry and Material Calculations

x_{dist} (in)	d_s (in)	$A_{ps.bot}$ (in^2)	cg_{harp} (in)
0.00	49.55	4.28	40.32
14.62	49.55	4.28	38.66
29.24	49.55	4.28	37.00
43.86	49.55	4.28	35.34
48.36	49.55	4.28	34.83
58.48	49.55	4.28	33.69
73.11	49.55	4.28	32.03
87.73	54.50	4.28	30.37
97.85	54.50	4.59	29.22
102.35	54.50	4.59	28.71
116.97	54.50	4.90	27.05
131.59	54.50	4.90	25.39
146.21	54.50	5.20	23.74

h_c (in)	L_{span} (ft)	A_{ps} (in^2)	Ψ_{harp} (rad)	f_{po} (ksi)	$f_{r.V}$ (psi)	β_1
54.5	49.447	5.202	0.1129	189	623.9	0.8035

Load Effect Calculations

x_{dist} (in)	V_{LL} (kip)	M_{LL} (ft-kip)	V_{DC1} (kip)	M_{DC1} (ft-kip)	V_{assume} (kip)	$M_{assume1}$ (ft-kip)	M_{assume} (ft-kip)	V_p (kip)
0.0	733.3	0.0	32.3	-0.2	765.6	-0.2	3040.3	3.6
14.6	270.1	329.1	30.6	38.2	300.7	367.3	1159.6	12.3
29.2	245.9	599.3	29.0	74.5	274.9	673.8	1035.3	17.9
43.9	272.1	994.7	27.4	108.8	299.5	1103.5	1134.6	17.9
48.4	275.8	1111.6	26.8	119.0	302.7	1230.6	1230.6	17.9
58.5	280.2	1365.7	25.7	141.2	305.9	1506.9	1506.9	17.9
73.1	285.8	1741.1	24.1	171.5	309.9	1912.6	1912.6	17.9
87.7	258.9	1892.7	22.4	199.8	281.3	2092.5	2092.5	17.9
97.8	266.6	2174.1	21.3	218.2	287.9	2392.3	2392.3	17.9
102.3	268.8	2292.3	20.8	226.1	289.5	2518.4	2518.4	17.9
117.0	270.7	2639.0	19.1	250.4	289.9	2889.5	2889.5	17.9
131.6	259.2	2842.9	17.5	272.7	276.7	3115.6	3115.6	17.9
146.2	252.2	3073.1	15.8	293.0	268.1	3366.1	3366.1	17.9

Calculations for β ***and*** θ

x_{dist} (in)	cg_{ps} (in)	d_p (in)	c (in)	a (in)	$f_{ps.max}$ (ksi)	$l_{d.ps}$ (in)	f_{ps} (ksi)	$cg_{ps.bot}$ (in)	$d_{p.bot}$ (in)	$d_{s.bot}$ (in)	$Num_{strand.bot}$	$RedFactor_{\varepsilon x.s}$	$RedFactor_{\varepsilon x.ps}$
0.00	3.78	44.36	5.51	4.43	260.6	116.04	34.67	3.68	50.82	49.55	28.00	0.25	0.05
14.62	3.78	44.65	5.51	4.43	260.7	116.09	119.15	3.68	50.82	49.55	28.00	0.85	0.18
29.24	3.78	44.94	5.51	4.43	260.7	116.14	178.66	3.68	50.82	49.55	28.00	1.00	0.30
43.86	3.78	45.23	5.51	4.43	260.8	116.18	193.50	3.68	50.82	49.55	28.00	1.00	0.43
48.36	3.78	45.32	5.51	4.43	260.8	116.20	198.06	3.68	50.82	49.55	28.00	1.00	0.47
58.48	3.78	45.53	5.51	4.43	260.8	116.23	208.34	3.68	50.82	49.55	28.00	1.00	0.55
73.11	3.78	45.82	5.51	4.43	260.9	116.28	223.18	3.68	50.82	49.55	28.00	1.00	0.68
87.73	3.78	46.11	4.82	3.87	262.1	117.23	238.18	3.68	50.82	54.50	28.00	1.00	0.80
97.85	3.78	46.31	4.82	3.87	262.1	117.26	248.49	5.25	49.25	54.50	30.00	1.00	0.89
102.35	3.78	46.40	4.82	3.87	262.1	117.27	253.07	5.21	49.29	54.50	30.00	1.00	0.92
116.97	3.78	46.70	4.82	3.87	262.2	117.31	262.19	6.48	48.02	54.50	32.00	1.00	1.00
131.59	3.78	46.99	4.82	3.88	262.2	117.34	262.24	6.27	48.23	54.50	32.00	1.00	1.00
146.21	3.78	47.28	4.82	3.88	262.3	117.38	262.29	7.22	47.28	54.50	34.00	1.00	1.00

x_{dist} (in)	$A_{ps.bot}$ (in^2)	d_e (in)	ε_s	d_v (in)	v_u	$A_{s.bot.\varepsilon x}$ (in^2)	$A_{ps.bot.\varepsilon x}$ (in^2)	ε_x	θ (rad)	β	$MinReinfCheck$
0.00	4.28	50.09	0.02	47.88	0.234	0.74	0.22	0.0224	0.6231	1.59	OK
14.62	4.28	50.46	0.02	48.25	0.088	2.55	0.76	0.0018	0.6380	2.20	OK
29.24	4.28	50.56	0.02	48.34	0.078	3.00	1.30	0.0008	0.5990	2.34	OK
43.86	4.28	50.57	0.02	48.36	0.086	3.00	1.84	0.0006	0.5528	2.49	OK
48.36	4.28	50.58	0.02	48.36	0.086	3.00	2.00	0.0006	0.5472	2.51	OK
58.48	4.28	50.59	0.02	48.37	0.087	3.00	2.38	0.0005	0.5416	2.52	OK
73.11	4.28	50.60	0.02	48.39	0.089	3.00	2.91	0.0005	0.5350	2.54	OK
87.73	4.28	50.82	0.03	48.88	0.079	0.00	3.43	0.0005	0.5266	2.61	OK
97.85	4.59	49.25	0.03	47.32	0.084	0.00	4.07	0.0004	0.4995	2.72	OK
102.35	4.59	49.29	0.03	47.35	0.084	0.00	4.24	0.0004	0.4970	2.73	OK

116.97	4.90	48.02	0.03	46.09	0.087	0.00	4.90	0.0003	0.4836	2.78	OK
131.59	4.90	48.23	0.03	46.29	0.082	0.00	4.90	0.0004	0.5092	2.68	OK
146.21	5.20	47.28	0.03	45.34	0.081	0.00	5.20	0.0004	0.5155	2.66	OK

Final Results for Shear Strength

x_{dist} (in)	V_c (kip)	V_s (kip)	V_{n1} (kip)	V_{n2} (kip)	V_n (kip)
0.00	44.7	717.4	765.7	818.8	765.7
14.62	62.4	226.0	300.8	833.9	300.8
29.24	66.4	190.6	274.9	841.1	274.9
43.86	70.6	211.0	299.5	841.4	299.5
48.36	71.1	213.7	302.7	841.4	302.7
58.48	71.6	216.5	305.9	841.6	305.9
73.11	72.1	219.8	309.9	841.8	309.9
87.73	74.8	188.6	281.3	850.3	281.3
97.85	75.5	194.5	288.0	823.6	288.0
102.35	75.9	195.8	289.6	824.2	289.6
116.97	75.2	196.8	290.0	802.7	290.0
131.59	72.8	186.0	276.8	806.2	276.8
146.21	70.6	179.5	268.1	790.0	268.1

Beam BT.10.Min.1

Inputs

γ_c (pcf)	129
f_c' (psi)	9730
f_{ci}' (psi)	6120
$f_{c.deck}$ (psi)	5170
$\gamma_{c.deck}$ (pcf)	126.6
E_{beam} (ksi)	4060
$E_{beam.i}$ (ksi)	4230
E_{slab} (ksi)	3200
h (in)	45
A_{beam} (in^2)	746.7
I_{beam} (in^4)	207300
L_{beam} (ft)	59
b_v (in)	7
y_b (in)	22.23
y_t (in)	22.77
S (ft)	7
t_{haunch} (in)	1

t_{struct} (in)	8.5
A_{ct} (in^2)	423.25
h_{flange} (in)	8.5
Num_{strand}	34
$Num_{straight}$	28
$Num_{straight.bot}$	28
Num_{harp}	6
$cg_{straight}$ (in)	3.68
$cg_{harp.end}$ (in)	41
$cg_{harp.ms}$ (in)	4.25
$cg_{straight.bot}$ (in)	3.68
A_{strand} (in^2)	0.15
φ (in)	0.5
f_{pu} (ksi)	270
f_{pe} (ksi)	179.11
E_p (ksi)	28500
$HarpDist$ (ft)	26.5

f_y (ksi)	67.3
f_{yv} (ksi)	67.3
E_s (ksi)	29000
α	1.57
$A_{s.top}$ (in^2)	0
d_{top} (in)	9.5
$d_{long.rebar}$	6
$IsLongSteelEpoxyCoated$	No
$LongSteelClearSpacing$ (in)	1
$LongSteelCover$ (in)	2
$IsTopBarEffectApplicable$	No
$A_{long.rebar}$ (in2)	0.31
$ShearSpan$ (in)	105.00
$x_{bearing}$ (in)	6
$x_{bearing.roller}$ (in)	6
$x_{critical.assume}$ (in)	55.66

x_{dist} (in)	A_{ct} (in^2)	$cg_{s.bot}$ (in)	cg_s (in)	$s_{v.design}$ (in)	A_v (in^2)	P_{assume} (kip)	θ_{assume} (rad)
0	3	4.95	4.95	2.5	0.4	250	0.62
10.50	3	4.95	4.95	15	0.4	250	0.64
21.00	3	4.95	4.95	15.75	0.4	250	0.5700
31.50	3	4.95	4.95	15.75	0.4	250	0.53
42.00	3	4.95	4.95	24	0.4	250	0.45
51.85	3	4.95	4.95	24	0.4	250	0.44
52.50	3	4.95	4.95	24	0.4	250	0.44
53.15	3	4.95	4.95	24	0.4	250	0.44
63.00	3	4.95	4.95	24	0.4	250	0.43
73.50	3	4.95	4.95	24	0.4	250	0.42
84.00	0	0	0	24	0.4	250	0.4200
94.50	0	0	0	24	0.4	250	0.41
105.00	0	0	0	24	0.4	250	0.39

Basic Geometry and Material Calculations

x_{dist} (in)	d_s (in)	$A_{ps.bot}$ (in^2)	cg_{harp} (in)
0.00	49.55	4.28	40.32
10.50	49.55	4.28	39.13
21.00	49.55	4.28	37.94
31.50	49.55	4.28	36.75
42.00	49.55	4.28	35.56
51.85	49.55	4.28	34.44
52.50	49.55	4.28	34.36
53.15	49.55	4.28	34.29
63.00	49.55	4.28	33.17
73.50	49.55	4.28	31.98
84.00	54.50	4.28	30.79
94.50	54.50	4.28	29.60
105.00	54.50	4.59	28.41

h_c (in)	L_{span} (ft)	A_{ps} (in^2)	Ψ_{harp} (rad)	f_{po} (ksi)	$f_{r.V}$ (psi)	β_1
54.5	58	5.202	0.1129	189	623.9	0.7915

Load Effect Calculations

x_{dist} (in)	V_{LL} (kip)	M_{LL} (ft-kip)	V_{DC1} (kip)	M_{DC1} (ft-kip)	V_{assume} (kip)	$M_{assume1}$ (ft-kip)	M_{assume} (ft-kip)	V_p (kip)
0.0	728.7	0.0	38.8	-0.2	767.5	-0.2	3054.4	3.7
10.5	153.3	134.1	37.6	33.3	190.9	167.4	727.4	10.2
21.0	177.9	311.2	36.5	65.7	214.3	376.9	797.5	16.7
31.5	197.3	517.9	35.3	97.1	232.6	615.0	864.4	18.5
42.0	182.4	638.5	34.1	127.4	216.6	766.0	799.7	18.5
51.8	191.1	825.8	33.0	155.0	224.1	980.8	980.8	18.5
52.5	191.6	838.0	32.9	156.8	224.5	994.8	994.8	18.5
53.1	192.0	850.2	32.9	158.6	224.8	1008.8	1008.8	18.5
63.0	198.0	1039.4	31.8	185.1	229.8	1224.5	1224.5	18.5
73.5	204.2	1250.4	30.6	212.4	234.8	1462.8	1462.8	18.5
84.0	207.1	1450.0	29.4	238.7	236.6	1688.6	1688.6	18.5
94.5	213.1	1678.0	28.3	263.9	241.4	1941.9	1941.9	18.5
105.0	222.8	1949.5	27.1	288.1	249.9	2237.6	2237.6	18.5

***Calculations for* β *and* θ**

x_{dist} (in)	cg_{ps} (in)	d_p (in)	c (in)	a (in)	$f_{ps.max}$ (ksi)	$l_{d.ps}$ (in)	f_{ps} (ksi)	$cg_{ps.bot}$ (in)	$d_{p.bot}$ (in)	$d_{s.bot}$ (in)	$Num_{strand.bot}$	$RedFactor_{\varepsilon x.s}$	$RedFactor_{\varepsilon x.ps}$
0.00	3.78	44.36	5.34	4.22	260.9	113.20	35.82	3.68	50.82	49.55	28.00	0.25	0.05
10.50	3.78	44.57	5.34	4.22	260.9	113.23	98.51	3.68	50.82	49.55	28.00	0.68	0.15
21.00	3.78	44.78	5.34	4.22	261.0	113.26	161.19	3.68	50.82	49.55	28.00	1.00	0.24
31.50	3.78	44.99	5.34	4.23	261.0	113.30	186.48	3.68	50.82	49.55	28.00	1.00	0.33
42.00	3.78	45.20	5.34	4.23	261.1	113.33	196.81	3.68	50.82	49.55	28.00	1.00	0.42
51.85	3.78	45.39	5.34	4.23	261.1	113.36	206.50	3.68	50.82	49.55	28.00	1.00	0.51
52.50	3.78	45.41	5.34	4.23	261.1	113.36	207.14	3.68	50.82	49.55	28.00	1.00	0.52
53.15	3.78	45.42	5.34	4.23	261.1	113.36	207.78	3.68	50.82	49.55	28.00	1.00	0.52
63.00	3.78	45.62	5.34	4.23	261.1	113.39	217.47	3.68	50.82	49.55	28.00	1.00	0.61
73.50	3.78	45.83	5.34	4.23	261.2	113.43	227.81	3.68	50.82	49.55	28.00	1.00	0.70
84.00	3.78	46.04	4.67	3.70	262.3	114.34	238.31	3.68	50.82	54.50	28.00	1.00	0.79
94.50	3.78	46.25	4.67	3.70	262.4	114.37	248.68	3.68	50.82	54.50	28.00	1.00	0.88
105.00	3.78	46.46	4.67	3.70	262.4	114.39	259.05	5.19	49.31	54.50	30.00	1.00	0.97

x_{dist} (in)	$A_{ps.bot}$ (in²)	d_e (in)	ε_s	d_v (in)	v_u	$A_{s.bot.\varepsilon x}$ (in²)	$A_{ps.bot.\varepsilon x}$ (in²)	ε_x	θ (rad)	β	$MinReinfCheck$
0.00	4.28	50.10	0.03	47.99	0.234	0.74	0.23	0.0224	0.6231	1.59	OK
10.50	4.28	50.41	0.03	48.30	0.055	2.04	0.62	0.0012	0.6353	2.23	OK
21.00	4.28	50.53	0.03	48.42	0.060	3.00	1.02	0.0007	0.5726	2.44	OK
31.50	4.28	50.56	0.03	48.45	0.065	3.00	1.42	0.0005	0.5326	2.59	OK
42.00	4.28	50.58	0.03	48.46	0.060	3.00	1.81	0.0002	0.4522	3.03	OK
51.85	4.28	50.59	0.03	48.47	0.062	3.00	2.19	0.0002	0.4373	3.14	OK
52.50	4.28	50.59	0.03	48.47	0.062	3.00	2.21	0.0002	0.4366	3.15	OK
53.15	4.28	50.59	0.03	48.47	0.063	3.00	2.24	0.0002	0.4359	3.15	OK
63.00	4.28	50.60	0.03	48.48	0.064	3.00	2.61	0.0001	0.4266	3.22	OK
73.50	4.28	50.60	0.03	48.49	0.066	3.00	3.00	0.0001	0.4185	3.31	OK

84.00	4.28	50.82	0.03	48.97	0.065	0.00	3.37	0.0001	0.4190	3.30	OK
94.50	4.28	50.82	0.03	48.97	0.067	0.00	3.76	0.0001	0.4119	3.38	OK
105.00	4.59	49.31	0.03	47.46	0.072	0.00	4.45	0.0000	0.3891	3.65	OK

Final Results for Shear Strength

x_{dist} (in)	V_c (kip)	V_s (kip)	V_{n1} (kip)	V_{n2} (kip)	V_n (kip)
0.00	44.8	719.1	767.6	820.8	767.6
10.50	63.2	117.6	190.9	832.6	190.9
21.00	69.3	128.4	214.3	841.2	214.3
31.50	73.6	140.5	232.6	843.6	232.6
42.00	86.1	111.9	216.6	843.7	216.6
51.85	89.3	116.3	224.2	843.9	224.2
52.50	89.5	116.5	224.5	843.9	224.5
53.15	89.6	116.7	224.9	843.9	224.9
63.00	91.6	119.7	229.8	844.0	229.8
73.50	94.0	122.3	234.8	844.2	234.8
84.00	94.8	123.3	236.6	852.4	236.6
94.50	97.1	125.7	241.4	852.4	241.4
105.00	101.6	129.8	250.0	826.6	250.0

Beam BT.10.Min.2

Inputs

γ_c (pcf)	130.6
f_c' (psi)	10315
f_{ci}' (psi)	8940
$f_{c.deck}$ (psi)	5860
$\gamma_{c.deck}$ (pcf)	127.8
E_{beam} (ksi)	4140
$E_{beam.i}$ (ksi)	4230
E_{slab} (ksi)	3410
h (in)	45
A_{beam} (in^2)	746.7
I_{beam} (in^4)	207300
L_{beam} (ft)	59
b_v (in)	7
y_b (in)	22.23
y_t (in)	22.77
S (ft)	7
t_{haunch} (in)	1

t_{struct} (in)	8.5
A_{ct} (in^2)	423.25
h_{flange} (in)	8.5
Num_{strand}	34
$Num_{straight}$	28
$Num_{straight.bot}$	28
Num_{harp}	6
$cg_{straight}$ (in)	3.68
$cg_{harp.end}$ (in)	41
$cg_{harp.ms}$ (in)	4.25
$cg_{straight.bot}$ (in)	3.68
A_{strand} (in^2)	0.15
φ (in)	0.5
f_{pu} (ksi)	270
f_{pe} (ksi)	179.11
E_p (ksi)	28500
$HarpDist$ (ft)	26.5

f_y (ksi)	67.3
f_{yv} (ksi)	67.3
E_s (ksi)	29000
α	1.57
$A_{s.top}$ (in^2)	0
d_{top} (in)	9.5
$d_{long.rebar}$	6
IsLongSteelEpoxyCoated	No
LongSteelClearSpacing (in)	1
LongSteelCover (in)	2
IsTopBarEffectApplicable	No
$A_{long.rebar}$ (in2)	0.31
ShearSpan (in)	151.80
$x_{bearing}$ (in)	6
$x_{bearing.roller}$ (in)	108.25
$x_{critical.assume}$ (in)	55.82

x_{dist} (in)	A_{ct} (in^2)	$cg_{s.bot}$ (in)	cg_s (in)	$s_{v.design}$ (in)	A_v (in^2)	P_{assume} (kip)	θ_{assume} (rad)
0	3	4.95	4.95	2.5	0.4	250	0.62
15.18	3	4.95	4.95	15	0.4	250	0.61
30.36	3	4.95	4.95	15.75	0.4	250	0.5400
45.54	3	4.95	4.95	24	0.4	250	0.45
51.63	3	4.95	4.95	24	0.4	250	0.44
60.72	3	4.95	4.95	24	0.4	250	0.43
75.90	3	4.95	4.95	24	0.4	250	0.42
91.08	3	0	0	24	0.4	250	0.41
100.17	3	0	0	24	0.4	250	0.39
106.26	3	0	0	24	0.4	250	0.39
121.44	0	0	0	24	0.4	250	0.3900
136.62	0	0	0	24	0.4	250	0.4
151.80	0	0	0	24	0.4	250	0.42

Basic Geometry and Material Calculations

x_{dist} (in)	d_s (in)	$A_{ps.bot}$ (in^2)	cg_{harp} (in)
0.00	49.55	4.28	40.32
15.18	49.55	4.28	38.60
30.36	49.55	4.28	36.88
45.54	49.55	4.28	35.15
51.63	49.55	4.28	34.46
60.72	49.55	4.28	33.43
75.90	49.55	4.28	31.71
91.08	54.50	4.28	29.99
100.17	54.50	4.59	28.96
106.26	54.50	4.59	28.27
121.44	54.50	4.90	26.54
136.62	54.50	5.20	24.82
151.80	54.50	5.20	23.10

h_c (in)	L_{span} (ft)	A_{ps} (in^2)	Ψ_{harp} (rad)	f_{po} (ksi)	$f_{r.V}$ (psi)	β_1
54.5	49.4792	5.202	0.1129	189	642.3	0.757

Load Effect Calculations

x_{dist} (in)	V_{LL} (kip)	M_{LL} (ft-kip)	V_{DC1} (kip)	M_{DC1} (ft-kip)	V_{assume} (kip)	$M_{assume1}$ (ft-kip)	M_{assume} (ft-kip)	V_p (kip)
0.0	740.8	0.0	32.4	-0.2	773.1	-0.2	3092.6	3.7
15.2	173.5	219.5	30.6	39.7	204.1	259.1	773.8	13.1
30.4	203.8	515.7	28.9	77.4	232.8	593.1	869.4	18.5
45.5	195.3	741.0	27.2	112.9	222.5	853.9	853.9	18.5
51.6	199.4	858.0	26.5	126.5	226.0	984.6	984.6	18.5
60.7	205.1	1037.9	25.5	146.2	230.6	1184.2	1184.2	18.5
75.9	213.7	1352.0	23.8	177.4	237.5	1529.4	1529.4	18.5
91.1	224.7	1705.4	22.1	206.4	246.8	1911.8	1911.8	18.5
100.2	232.6	1941.6	21.1	222.8	253.6	2164.3	2164.3	18.5
106.3	235.5	2085.0	20.4	233.3	255.8	2318.3	2318.3	18.5
121.4	227.1	2297.9	18.7	258.0	245.7	2555.9	2555.9	18.5
136.6	220.5	2510.3	17.0	280.5	237.4	2790.8	2790.8	18.5
151.8	211.1	2670.5	15.2	300.9	226.3	2971.4	2971.4	18.5

***Calculations for* β *and* θ**

x_{dist} (in)	cg_{ps} (in)	d_p (in)	c (in)	a (in)	$f_{ps.max}$ (ksi)	$l_{d.ps}$ (in)	f_{ps} (ksi)	$cg_{ps.bot}$ (in)	$d_{p.bot}$ (in)	$d_{s.bot}$ (in)	$Num_{strand.bot}$	$RedFactor_{\varepsilon x.s}$	$RedFactor_{\varepsilon x.ps}$
0.00	3.78	44.36	4.93	3.73	261.6	113.75	35.82	3.68	50.82	49.55	28.00	0.25	0.05
15.18	3.78	44.66	4.93	3.74	261.6	113.79	126.45	3.68	50.82	49.55	28.00	0.87	0.19
30.36	3.78	44.96	4.94	3.74	261.7	113.84	185.38	3.68	50.82	49.55	28.00	1.00	0.32
45.54	3.78	45.27	4.94	3.74	261.8	113.88	200.33	3.68	50.82	49.55	28.00	1.00	0.45
51.63	3.78	45.39	4.94	3.74	261.8	113.90	206.33	3.68	50.82	49.55	28.00	1.00	0.51
60.72	3.78	45.57	4.94	3.74	261.8	113.92	215.30	3.68	50.82	49.55	28.00	1.00	0.59
75.90	3.78	45.87	4.94	3.74	261.9	113.96	230.26	3.68	50.82	49.55	28.00	1.00	0.72
91.08	3.78	46.18	4.94	3.74	261.9	114.01	245.23	3.68	50.82	54.50	28.00	1.00	0.85
100.17	3.78	46.36	4.94	3.74	261.9	114.03	254.20	5.23	49.27	54.50	30.00	1.00	0.93
106.26	3.78	46.48	4.94	3.74	262.0	114.05	260.21	5.18	49.32	54.50	30.00	1.00	0.98
121.44	3.78	46.79	4.32	3.27	263.0	114.89	263.02	6.41	48.09	54.50	32.00	1.00	1.00
136.62	3.78	47.09	4.32	3.27	263.1	114.93	263.06	7.41	47.09	54.50	34.00	1.00	1.00
151.80	3.78	47.39	4.32	3.27	263.1	114.96	263.11	7.11	47.39	54.50	34.00	1.00	1.00

x_{dist} (in)	$A_{ps.bot}$ (in^2)	d_e (in)	ε_s	d_v (in)	v_u	$A_{s.bot.\varepsilon x}$ (in^2)	$A_{ps.bot.\varepsilon x}$ (in^2)	ε_x	θ (rad)	β	$MinReinfCheck$
0.00	4.28	50.10	0.03	48.23	0.221	0.74	0.23	0.0225	0.6242	1.66	OK
15.18	4.28	50.48	0.03	48.61	0.054	2.62	0.80	0.0009	0.6144	2.30	OK
30.36	4.28	50.56	0.03	48.70	0.061	3.00	1.37	0.0005	0.5398	2.56	OK
45.54	4.28	50.58	0.03	48.71	0.058	3.00	1.94	0.0002	0.4476	3.06	OK
51.63	4.28	50.59	0.03	48.72	0.059	3.00	2.17	0.0002	0.4408	3.12	OK
60.72	4.28	50.59	0.03	48.72	0.060	3.00	2.51	0.0001	0.4320	3.18	OK
75.90	4.28	50.61	0.03	48.74	0.062	3.00	3.08	0.0001	0.4202	3.29	OK
91.08	4.28	51.41	0.03	49.55	0.064	3.00	3.65	0.0001	0.4121	3.38	OK
100.17	4.59	50.04	0.03	48.17	0.068	3.00	4.27	0.0000	0.3930	3.60	OK
106.26	4.59	50.07	0.03	48.20	0.068	3.00	4.52	0.0000	0.3901	3.64	OK

121.44	4.90	48.09	0.03	46.45	0.068	0.00	4.90	0.0000	0.3923	3.61	OK
136.62	5.20	47.09	0.03	45.45	0.067	0.00	5.20	0.0000	0.3974	3.55	OK
151.80	5.20	47.39	0.03	45.76	0.063	0.00	5.20	0.0001	0.4167	3.33	OK

Final Results for Shear Strength

x_{dist} (in)	V_c (kip)	V_s (kip)	V_{n1} (kip)	V_{n2} (kip)	V_n (kip)
0.00	48.5	721.0	773.2	874.3	773.2
15.18	67.4	123.6	204.1	890.5	204.1
30.36	75.3	138.9	232.8	897.5	232.8
45.54	90.1	113.8	222.5	897.8	222.5
51.63	91.6	115.8	226.0	897.9	226.0
60.72	93.6	118.5	230.7	898.1	230.7
75.90	96.7	122.3	237.6	898.3	237.6
91.08	101.1	127.1	246.8	912.9	246.8
100.17	104.8	130.3	253.7	888.1	253.7
106.26	105.9	131.5	255.9	888.5	255.9
121.44	101.3	125.9	245.8	857.1	245.8
136.62	97.5	121.5	237.5	839.0	237.5
151.80	91.9	115.9	226.4	844.5	226.4

Beam Example Following the Simplified Procedure for Prestressed and Nonprestressed Sections

Additional Inputs and Basic Calculations

The same scenario provided in Section 0 is used for example calculations following Article 5.8.3.4.3 in the AASHTO LRFD Bridge Specifications. The same information and calculations presented previously apply here, with the exception that the values in P_{assume} are:

$$P_{assume1} = (325.48\ \ 229.2\ \ 270.06\ \ 226.13\ \ 238.59\ \ 242.5\ \ 234.72\ \ 236.2\ \ 236.68\ \ 238.51\ \ 231.75\ \ 233.55)\text{kip}$$

Additional required inputs and basic calculations for using this procedure include:

$$h_{top.flange} = 30\,\text{in}$$

$$S_b = \frac{I_{beam}}{y_b}$$

$$S_b = \frac{50979\text{in}^4}{15.83\text{in}}$$

$$S_b = 3220.4\,\text{in}^3$$

Load Effects

Since the amount of assumed live load changed from the original example, the shear and moment due to that assumed live load are calculated as:

$$V_{LL_i} = \frac{P_{assume_i}}{L_{span}}\cdot\left[2\left(L_{span} - \text{ShearSpan}\right) - \text{LoadSpacing}\right]$$

$$V_{LL_2} = \frac{229.2\text{kip}}{40\text{ft}}\cdot[2\cdot(40\text{ft} - 57.34\text{in}) - 14.52\text{ft}]$$

$$V_{LL.2} = 320.5\text{kip}$$

$$V_{LL}{}^T = (455.1\ \ 320.5\ \ 377.6\ \ 316.2\ \ 333.6\ \ 339.1\ \ 328.2\ \ 330.3\ \ 330.9\ \ 333.5\ \ 324\ \ 326.5)\,\text{kip}$$

$$M_{LL_i} = \frac{P_{assume_i}}{L_{span}} \cdot \left[2\left(L_{span} - ShearSpan\right) - LoadSpacing\right] \cdot x_{dist_i}$$

$$M_{LL_2} = \frac{229.2kip}{40ft} \cdot [2(40ft - 57.34in) - 14.52ft]\ 5.73in$$

$$M_{LL_2} = 153.ft \cdot kip$$

$$M_{LL}^T = (1000000\ \ 153.1\ \ 360.8\ \ 453.2\ \ 637.6\ \ 810\ \ 940.9\ \ 1064.7\ \ 1106.8\ \ 1274.7\ \ 1393.4\ \ 1560.3)\ ft \cdot kip$$

Using the dead load calculations from previously, the total shear and moment assumed to be in the beam are calculated as:

$$V_{assume} = V_{LL} + V_{DC1}$$

$$V_{assume_2} = 320.47kip + 18.22kip$$

$$V_{assume_2} = 338.7kip$$

$$V_{assume}^T = (473.8\ \ 338.7\ \ 395.4\ \ 333.5\ \ 350.5\ \ 355.5\ \ 344.2\ \ 345.9\ \ 346.5\ \ 348.6\ \ 338.7\ \ 340.8)\ kip$$

$$M_{assume} = M_{LL} + M_{DC1}$$

$$M_{assume_2} = 153.12ft \cdot kip + 8.7ft \cdot kip$$

$$M_{assume_2} = 161.8 \cdot ft \cdot kip$$

$$M_{assume}^T = (999999.9\ \ 161.8\ \ 378.1\ \ 478.9\ \ 671.4\ \ 851.9\ \ 990.4\ \ 1120\ \ 1163.9\ \ 1339.2\ \ 1465\ \ 1638.7)\ ft \cdot kip$$

Additionally, the maximum shear and moment due to externally applied loads, V_i and M_{max} are:

$$V_i = V_{assume} - V_d$$

$$V_{i_2} = V_{assume_2} - V_{d_2}$$

$$V_{i_2} = 338.69kip - 18.22kip$$

$$V_{i_2} = 320.47\ kip$$

$$V_i^T = (455.08\ \ 320.47\ \ 377.6\ \ 316.17\ \ 333.6\ \ 339.06\ \ 328.18\ \ 330.25\ \ 330.92\ \ 333.48\ \ 324.03\ \ 326.55)\ kip$$

$$M_{max} = M_{assume} - M_d$$

$$M_{max_2} = M_{assume_2} - M_{d_2}$$

$$M_{max_2} = 161.82 ft \cdot kip - 8.7 ft \cdot kip$$

$$M_{max_2} = 153.12 ft \cdot kip$$

$$M_{max}^T = (1000000 \quad 153.12 \quad 360.84 \quad 453.21 \quad 637.58 \quad 810.03 \quad 940.86 \quad 1064.74 \quad 1106.83 \quad 1274.73 \quad 1393.43 \quad 1560.28)\ ft \cdot kip$$

where, in the case of this example, the terms V_d and M_d are equivalent to V_{DC1} and M_{DC1}.

Calculate the Shear Resistance

Determine the Concrete Contribution to the Shear Resistance

Calculate V_{ci}

Calculate f_{cpe}, the Compressive Stress in the Concrete Due to Effective Prestress Forces

$$P_{f.cpe_i} = \begin{cases} f_{pe} \cdot A_{strand} \cdot Num_{strand} \cdot \dfrac{x_{dist_i} + x_{bearing}}{l_t} & \text{if } x_{dist_i} + x_{bearing} < l_t \\ f_{pe} \cdot A_{strand} \cdot Num_{strand} & \text{if } x_{dist_i} + x_{bearing} \geq l_t \\ \text{"error"} & \text{otherwise} \end{cases}$$

$$P_{f.cpe_2} = f_{pe} \cdot A_{strand} \cdot Num_{strand} \cdot \frac{x_{dist_2} + x_{bearing}}{l_t} \quad \text{if } x_{dist_2} < l_t$$

$$P_{f.cpe_2} = 164.96 ksi \cdot 0.153 in^2 \cdot 24 \cdot \frac{5.73 in + 6 in}{30 in} \quad \text{if } 5.73 in < 30 in$$

$$P_{f.cpe_2} = 236.84 kip$$

$$P_{f.cpe}^T = (121.1 \quad 236.8 \quad 352.7 \quad 468.4 \quad 584.1 \quad 605.7 \quad 605.7 \quad 605.7 \quad 605.7 \quad 605.7 \quad 605.7 \quad 605.7)\ kip$$

$$e_{strand_i} = y_b - cg_{ps_i}$$

$$e_{strand_2} = y_b - cg_{ps_2}$$

$$e_{strand_2} = 15.83in - 12.16in$$

$$e_{strand_2} = 3.67\,in$$

$$e_{strand}^T = (3.5 \quad 3.67 \quad 3.84 \quad 4 \quad 4.17 \quad 4.33 \quad 4.5 \quad 4.62 \quad 4.67 \quad 4.83 \quad 5 \quad 5.16)\,in$$

$$f_{cpe_i} = \frac{P_{f.cpe_i}}{A_{beam}} + \frac{P_{f.cpe_i} \cdot e_{strand_i}}{S_b}$$

$$f_{cpe_2} = \frac{236.84kip}{369in^2} + \frac{236.84kip \cdot 3.67in}{3220.4in^3}$$

$$f_{cpe_2} = 0.91\,ksi$$

$$f_{cpe}^T = (0.46 \quad 0.91 \quad 1.38 \quad 1.85 \quad 2.34 \quad 2.46 \quad 2.49 \quad 2.51 \quad 2.52 \quad 2.55 \quad 2.58 \quad 2.61)\,ksi$$

Calculate the Moment Due to Externally Applied Loads Causing Cracking, M_{cre}

In the case of this example, M_{dnc}, the total unfactored dead load moment acting on the noncomposite section is simply M_{DC1}.

$$M_{cre_i} = S_{bc} \cdot \left(f_{r.V} + f_{cpe_i} - \frac{M_{dnc_i}}{S_b} \right)$$

$$M_{cre_2} = 6510.03in^3 \cdot \left(0.595ksi + 0.912ksi - \frac{8.697ft \cdot kip}{3220.4in^3} \right)$$

$$M_{cre_2} = 800.08\,ft \cdot kip$$

$$M_{cre}^T = (572.9 \quad 800.1 \quad 1034.6 \quad 1275.6 \quad 1523.4 \quad 1571.2 \quad 1572.5 \quad 1573.6 \quad 1574.2 \quad 1576.3 \quad 1578.8 \quad 1581.9)\,ft \cdot kip$$

Calculate V_{ci}

$$V_{ci_i} = \max\left(0.02\alpha_v \cdot \sqrt{\frac{f_{c'}}{ksi}} \cdot ksi \cdot b_v \cdot d_{v_i} + V_{d_i} + \frac{V_{i_i} \cdot M_{cre_i}}{M_{max_i}}, 0.06 \cdot \alpha_v \sqrt{\frac{f_{c'}}{ksi}} \cdot ksi \cdot b_v \cdot d_{v_i}\right)$$

$$V_{ci_2} = \max\left(0.02\alpha_v \cdot \sqrt{\frac{f_{c'}}{ksi}} \cdot ksi \cdot b_v \cdot d_{v_2} + V_{d_2} + \frac{V_{i_2} \cdot M_{cre_2}}{M_{max_2}}, 0.06 \cdot \alpha_v \sqrt{\frac{f_{c'}}{ksi}} \cdot ksi \cdot b_v \cdot d_{v_2}\right)$$

$$V_{ci_2} = \max\left[0.02(1) \cdot \sqrt{8.87} ksi \cdot 6in \cdot 40.13in + 18.22kip + \frac{320.47kip \cdot 800.08ft \cdot kip}{153.12ft \cdot kip}, 0.06(1) \cdot \sqrt{8.87} ksi \cdot 6in \cdot 40.13in\right]$$

$$V_{ci_2} = \max(1707.08kip, 43.03kip)$$

$$V_{ci_2} = 1707.03\,kip$$

$$V_{ci}^T = (42.9\ \ 1707.03\ \ 1114.78\ \ 921.58\ \ 828.36\ \ 688.5\ \ 578.31\ \ 517.27\ \ 500.04\ \ 441.33\ \ 395.19\ \ 358.69)\,kip$$

Calculate V_{cw}

Determine the Compressive Stress at the Composite Centroid, f_{pc}

$$P_{f.pc_i} = f_{ps_i} \cdot A_{strand} \cdot Num_{strand}$$

$$P_{f.pc_2} = f_{ps_2} \cdot A_{strand} \cdot Num_{strand}$$

$$P_{f.pc_2} = 64.5ksi \cdot 0.153in^2 \cdot 24$$

$$P_{f.pc_2} = 236.84\,kip$$

$$P_{f.pc}^T = (121.15\ \ 236.84\ \ 352.74\ \ 468.43\ \ 584.13\ \ 623.9\ \ 646.2\ \ 662.89\ \ 668.54\ \ 690.84\ \ 713.14\ \ 735.49)\,kip$$

$$f_{pc_i} = \begin{cases} \dfrac{P_{f.pc_i}}{A_{beam}} + \dfrac{P_{f.pc_i} \cdot e_{strand_i} \cdot (y_b - y_{bc})}{I_{beam}} - \dfrac{M_{DC1_i} \cdot (y_b - y_{bc})}{I_{beam}} & \text{if } y_{bc} \le h_{top.flange} \\ \dfrac{P_{f.pc_i}}{A_{beam}} + \dfrac{P_{f.pc_i} \cdot e_{strand_i} \cdot (y_b - h_{top.flange})}{I_{beam}} - \dfrac{M_{DC1_i} \cdot (y_b - h_{top.flange})}{I_{beam}} & \text{if } y_{bc} > h_{top.flange} \end{cases}$$

$$f_{pc_2} = \frac{P_{f.pc_2}}{A_{beam}} + \frac{P_{f.pc_2} \cdot e_{strand_2} \cdot (y_b - h_{top.flange})}{I_{beam}} - \frac{M_{DC1_2} \cdot (y_b - h_{top.flange})}{I_{beam}} \quad \text{if } y_{bc} > h_{top.flange}$$

$$f_{pc_2} = \frac{236.84\text{kip}}{369\text{in}^2} + \frac{236.84\text{kip} \cdot 3.67\text{in} \cdot (15.83\text{in} - 30\text{in})}{50979\text{in}^4} - \frac{8.7\text{ft} \cdot \text{kip} \cdot (15.83\text{in} - 30\text{in})}{50979\text{in}^4} \quad \text{if } 32.57\text{in} > 30\text{in}$$

$$f_{pc_2} = 0.43\text{ksi} \quad \text{if } 32.57\text{in} > 30\text{in}$$

$$f_{pc_2} = 0.43\,\text{ksi}$$

$$f_{pc}^{T} = (0.21 \;\; 0.43 \;\; 0.64 \;\; 0.83 \;\; 1.02 \;\; 1.08 \;\; 1.11 \;\; 1.13 \;\; 1.14 \;\; 1.16 \;\; 1.18 \;\; 1.2)\,\text{ksi}$$

Determine *V_{cw}*

$$V_{cw_i} = \left(0.06 \cdot \alpha_v \cdot \sqrt{\frac{f_{c'}}{\text{ksi}}} \cdot \text{ksi} + 0.30 \cdot f_{pc_i}\right) \cdot b_v \cdot d_{v_i} + V_{p_i}$$

$$V_{cw_2} = \left(0.06 \cdot \alpha_v \cdot \sqrt{\frac{f_{c'}}{\text{ksi}}} \cdot \text{ksi} + 0.30 \cdot f_{pc_2}\right) \cdot b_v \cdot d_{v_2} + V_{p_2}$$

$$V_{cw_2} = \left[0.06 \cdot (1) \cdot \sqrt{8.87}\text{ksi} + 0.30 \cdot 0.429\text{ksi}\right] \cdot 6\text{in} \cdot 40.13\text{in} + 6.81\text{kip}$$

$$V_{cw_2} = 80.82\,\text{kip}$$

$$V_{cw}^{T} = (61.5 \;\; 80.8 \;\; 99.3 \;\; 117 \;\; 133.8 \;\; 138.8 \;\; 136 \;\; 137.6 \;\; 138.1 \;\; 139.9 \;\; 137.1 \;\; 138.7)\,\text{kip}$$

Calculate V_c

$$V_{c_i} = \min\left(V_{ci_i}, V_{cw_i}\right)$$

$$V_{c_2} = \min\left(V_{ci_2}, V_{cw_2}\right)$$

$$V_{c_2} = \min(1707.03kip, 80.82kip)$$

$$V_{c_2} = 80.82\,kip$$

$$V_c^T = (42.9 \quad 80.82 \quad 99.34 \quad 116.99 \quad 133.81 \quad 138.77 \quad 136.04 \quad 137.57 \quad 138.06 \quad 139.9 \quad 137.15 \quad 138.7)\,kip$$

Calculate the Steel Contribution to the Shear Resistance

Determine $cot\theta$

$$\cot\theta_i = \begin{cases} 1 & \text{if } V_{ci_i} < V_{cw_i} \\ \min\left(1 + 3\cdot\dfrac{f_{pc_i}}{\alpha_v\cdot\sqrt{f_c'\cdot ksi}}, 1.8\right) & \text{if } V_{ci_i} \ge V_{cw_i} \end{cases}$$

$$\cot\theta_2 = \min\left(1 + 3\cdot\frac{f_{pc_2}}{\alpha_v\cdot\sqrt{f_c'}\cdot ksi}, 1.8\right) \quad \text{if } 1707.03kip \ge 80.82kip$$

$$\cot\theta_2 = \min\left[1 + 3\cdot\frac{0.429ksi}{(1)\cdot\sqrt{8.87}\cdot ksi}, 1.8\right] \quad \text{if } 1707.03kip \ge 80.82kip$$

$$\cot\theta_2 = \min(1.43, 1.8) \quad \text{if } 1707.03kip \ge 80.82kip$$

$$\cot\theta_2 = 1.433$$

$$\cot\theta^T = (1.00 \quad 1.43 \quad 1.64 \quad 1.80 \quad 1.80 \quad 1.80 \quad 1.80 \quad 1.80 \quad 1.80 \quad 1.80 \quad 1.80 \quad 1.80)$$

Find V_s

$$V_{s_i} = \frac{A_{v_i} \cdot f_{yv} \cdot d_{v_i} \cdot \left(\cot\theta_i + \cot(\alpha)\right) \cdot \sin(\alpha)}{s_{v.design_i}}$$

$$V_{s_2} = \frac{A_{v_2} \cdot f_{yv} \cdot d_{v_2} \cdot \left(\cot\theta_2 + \cot(\alpha)\right) \cdot \sin(\alpha)}{s_{v.design_2}}$$

$$V_{s_2} = \frac{0.4in^2 \cdot 67.3ksi \cdot 40.13in \cdot \left(1.433 + \cot\left(\frac{\pi}{2}\right) \cdot \sin\left(\frac{\pi}{2}\right)\right)}{6in}$$

$$V_{s_2} = 257.91\,kip$$

$$V_s^T = (430.9 \;\; 257.9 \;\; 296.2 \;\; 216.6 \;\; 216.8 \;\; 216.8 \;\; 208.2 \;\; 208.4 \;\; 208.5 \;\; 208.8 \;\; 201.6 \;\; 202.1)\,kip$$

Determine the Nominal Shear Resistance

$$V_{n1} = V_c + V_s$$

$$V_{n1_2} = V_{c_2} + V_{s_2}$$

$$V_{n1_2} = 80.82kip + 257.91kip + 6.81kip$$

$$V_{n1_2} = 338.7\,kip$$

$$V_{n1}^T = (473.8 \;\; 338.7 \;\; 395.5 \;\; 333.6 \;\; 350.6 \;\; 355.6 \;\; 344.3 \;\; 346 \;\; 346.6 \;\; 348.7 \;\; 338.8 \;\; 340.8)\,kip$$

Note that for V_{n1}, V_p is taken as zero. Since V_{n2} is the same as what was calculated previously, the nominal shear resistance is calculated as:

$$V_{n_i} = \min\left(V_{n1_i}, V_{n2_i}\right)$$

$$V_{n_2} = \min\left(V_{n1_2}, V_{n2_2}\right)$$

$$V_{n_2} = \min(345.5\text{kip}, 540.39\text{kip})$$

$$V_{n_2} = 338.7\,\text{kip}$$

$$V_n^T = (473.8\ \ 338.7\ \ 395.5\ \ 333.6\ \ 350.6\ \ 355.6\ \ 344.3\ \ 346\ \ 346.6\ \ 348.7\ \ 338.8\ \ 340.8)\,\text{kip}$$

Although not nearly as iterative as the General Procedure for finding the shear strength, the Simplified approach may require one or two refinements of $P_{asssume}$ before the results for V_n converge. If necessary, the same process as outlined earlier can be done to refine the values for P_{assume}. However, in the case of this example, such refinement is not necessary because the assumed live loads leading to shear failure were correctly chosen.

The critical section in this example is determined in a similar fashion as for the General Procedure, with the exception that the term $cot\theta$ may be different, in which case, $x_{critical}$ is calculated as:

$$x_{critical} = \max\left(d_{v.critical}, \frac{1}{2} \cdot d_{v.critical} \cdot \cot\theta_{critical}\right)$$

$$x_{critical} = \max\left(38.69\text{in}, \frac{1}{2} 38.69\text{in} \cdot 1.8\right)$$

$$x_{critical} = \max(38.69\text{in}, 34.82\text{in})$$

$$x_{critical} = 38.69\,\text{in}$$

where as in the previous example, the assume critical section was at 38.69 in from the support. This distance corresponded to the eighth element in the parameter $cot\theta$, whose value is 1.8. Note that although the parameter $cot\theta$ may be different than that used in the earlier example, the critical section is the same since $d_{v.critical}$ was the controlling parameter.

In any event, the corresponding shear strength at the critical section is the eighth element of V_n above, which is 346.0 kip. However, the calculated shear strength at the section located 51.6 in. from the support was 338.8 kip. Since this location is further from the support than the critical section, the corresponding value is taken as the predicted shear strength, or 339 kip after rounding to the nearest kip.

Inputs and Detailed Results for Shear Calculations Following the Simplified Procedure (Article 5.8.4.3.3)

Many of the inputs and basic calculations detailed earlier apply to calculating the shear strength when following the Simplified Procedure. Additional information and intermediate calculations that are required for the Simplified Procedure are provided for each beam test in the subsections on the following pages.

Beam T2.8.Typ.1

Additional Input and Basic Calculation

$h_{top.flange}$ (in)	30
S_b (in^3)	3220.4

Load Effects

x_{dist} (in)	V_{LL} (kip)	M_{LL} (ft-kip)	V_{DC1} (kip)	M_{DC1} (ft-kip)	V_{assume} (kip)	M_{assume} (ft-kip)
0.00	455.1	100000	18.7	-0.1	473.7	100000
5.73	320.5	153.1	18.2	8.7	338.7	161.8
11.47	377.6	360.9	17.8	17.3	395.4	378.2
17.20	316.2	453.2	17.3	25.7	333.5	478.9
22.94	333.6	637.6	16.9	33.9	350.5	671.5
28.67	339.0	810.0	16.4	41.8	355.5	851.8
34.40	328.2	940.9	16.0	49.6	344.2	990.5
38.71	330.3	1065.5	15.7	55.3	345.9	1120.7
40.14	330.9	1106.9	15.5	57.1	346.5	1164.0
45.87	333.5	1274.8	15.1	64.4	348.6	1339.2
51.60	324.0	1393.5	14.7	71.5	338.7	1465.0
57.34	326.6	1560.3	14.2	78.4	340.8	1638.7

Nominal Shear Strength Calculations

x_{dist} (in)	$P_{f.cpe}$ (kip)	e_{strand} (in)	f_{cpe} (ksi)	M_{cre} (ft-kip)	$P_{f.pc}$ (kip)	f_{pc} (ksi)	$cot\theta$
0.00	121.1	3.50	0.46	572.9	121.1	0.21	1.00
5.73	236.9	3.67	0.91	800.2	236.9	0.43	1.43
11.47	352.7	3.84	1.38	1034.5	352.7	0.64	1.64
17.20	468.5	4.00	1.85	1275.6	468.5	0.83	1.80
22.94	584.2	4.17	2.34	1523.7	584.2	1.02	1.80
28.67	605.7	4.33	2.46	1571.2	623.9	1.08	1.80
34.40	605.7	4.50	2.49	1572.5	646.2	1.11	1.80
38.71	605.7	4.62	2.51	1573.7	663.0	1.13	1.80
40.14	605.7	4.67	2.52	1574.2	668.5	1.14	1.80
45.87	605.7	4.83	2.55	1576.3	690.8	1.16	1.80
51.60	605.7	5.00	2.58	1578.9	713.2	1.18	1.80
57.34	605.7	5.16	2.61	1581.8	735.5	1.20	1.80

Final Shear Strength Results

x_{dist} (in)	V_{ci} (kip)	V_{cw} (kip)	V_c (kip)	V_s (kip)	V_{n1} (kip)	V_{n2} (kip)	V_n (kip)
0.0	42.9	61.5	42.9	430.9	473.8	535.6	473.8
5.7	1707.4	80.8	80.8	257.9	338.8	540.4	338.8
11.5	1114.7	99.3	99.3	296.1	395.5	544.6	395.5
17.2	922	117.0	117.0	216.6	333.6	548.4	333.6
22.9	828	133.8	133.8	216.8	350.6	552.1	350.6
28.7	689	138.8	138.8	216.8	355.6	552.9	355.6
34.4	578	136.0	136.0	208.2	344.3	531.7	344.3
38.7	517	137.6	137.6	208.4	346.0	532.2	346.0
40.1	500	138.1	138.1	208.5	346.6	532.4	346.6
45.9	441	139.9	139.9	208.8	348.7	533.0	348.7
51.6	395	137.2	137.2	201.6	338.8	515.4	338.8
57.3	359	138.7	138.7	202.1	340.8	516.7	340.8

Beam T2.8.Typ.2

Additional Input and Basic Calculation

$h_{top.flange}$ (in)	30
S_b (in^3)	3220.4

Load Effects

x_{dist} (in)	V_{LL} (kip)	M_{LL} (ft-kip)	V_{DC1} (kip)	M_{DC1} (ft-kip)	V_{assume} (kip)	M_{assume} (ft-kip)
0.00	458.4	100000	16.0	-0.1	474.5	100000
11.88	382.4	378.5	15.1	15.3	397.5	393.8
23.75	337.9	668.9	14.2	29.8	352.1	698.6
35.63	330.1	980.2	13.2	43.3	343.4	1023.5
38.77	331.5	1070.9	13.0	46.7	344.5	1117.7
47.50	334.9	1325.8	12.3	56.0	347.2	1381.8
59.38	327.6	1621.2	11.4	67.7	339.0	1688.9
71.26	317.5	1885.1	10.5	78.5	327.9	1963.6
79.99	301.3	2008.4	9.8	85.9	311.1	2094.3
83.13	302.4	2094.8	9.5	88.4	311.9	2183.2
95.01	306.0	2422.7	8.6	97.4	314.6	2520.1
106.88	308.8	2750.6	7.7	105.5	316.5	2856.1
118.76	310.5	3072.4	6.8	112.7	317.2	3185.1

Nominal Shear Strength Calculations

x_{dist} (in)	$P_{f.cpe}$ (kip)	e_{strand} (in)	f_{cpe} (ksi)	M_{cre} (ft-kip)	$P_{f.pc}$ (kip)	f_{pc} (ksi)	$cot\theta$
0.00	121.1	3.50	0.46	567.4	121.1	0.21	1.00
11.88	360.9	3.85	1.41	1046.1	360.9	0.64	1.65
23.75	600.7	4.19	2.41	1554.2	600.7	1.03	1.80
35.63	605.7	4.54	2.49	1572.6	651.0	1.09	1.80
38.77	605.7	4.63	2.51	1574.9	663.2	1.10	1.80
47.50	605.7	4.88	2.56	1582.0	697.2	1.13	1.80
59.38	605.7	5.22	2.62	1593.2	743.5	1.16	1.80
71.26	605.7	5.57	2.69	1606.3	790.0	1.18	1.80
79.99	605.7	5.82	2.74	1617.0	824.0	1.19	1.80
83.13	605.7	5.91	2.75	1621.1	836.3	1.19	1.80

95.01	605.7	6.25	2.82	1637.9	882.6	1.18	1.80
106.88	605.7	6.60	2.88	1656.4	929.0	1.17	1.80
118.76	605.7	6.94	2.95	1676.8	968.8	1.13	1.80

Final Shear Strength Results

x_{dist} (in)	V_{ci} (kip)	V_{cw} (kip)	V_c (kip)	V_s (kip)	V_{n1} (kip)	V_{n2} (kip)	V_n (kip)
0.0	43.0	61.6	43.0	431.5	474.5	537.9	474.5
11.9	1086.6	100.2	100.2	297.4	397.6	547.1	397.6
23.8	813.8	135.1	135.1	217.1	352.2	554.9	352.2
35.6	556.8	134.9	134.9	208.6	343.5	534.0	343.5
38.8	514	135.8	135.8	208.7	344.6	534.4	344.6
47.5	426	138.2	138.2	209.2	347.3	535.4	347.3
59.4	347	136.5	136.5	202.6	339.1	519.3	339.1
71.3	294	133.2	133.2	194.8	328.0	500.0	328.0
80.0	265	134.5	134.5	176.7	311.2	503.7	311.2
83.1	257	134.8	134.8	177.2	312.0	505.0	312.0
95.0	229	135.7	135.7	179.0	314.7	510.0	314.7
106.9	207	135.8	135.8	180.8	316.6	515.0	316.6
118.8	190	134.7	134.7	182.6	317.3	520.0	317.3

Beam T2.8.Min.1

Additional Input and Basic Calculation

$h_{top.flange}$ (in)	30
S_b (in^3)	3220.4

Load Effects

x_{dist} (in)	V_{LL} (kip)	M_{LL} (ft-kip)	V_{DC1} (kip)	M_{DC1} (ft-kip)	V_{assume} (kip)	M_{assume} (ft-kip)
0.00	449.9	100000	18.1	-0.1	468.0	100000
5.80	231.3	111.8	17.7	8.5	248.9	120.3
11.60	226.3	218.8	17.2	17.0	243.6	235.7
17.40	258.9	375.3	16.8	25.2	275.7	400.5
23.20	276.0	533.5	16.4	33.2	292.3	566.7
29.00	280.7	678.2	15.9	41.0	296.6	719.2
34.80	272.0	788.7	15.5	48.6	287.5	837.4
38.22	273.6	871.5	15.2	53.0	288.8	924.5
40.60	274.7	929.3	15.0	56.0	289.7	985.2
46.40	277.1	1071.5	14.6	63.1	291.7	1134.7
52.20	269.5	1172.2	14.2	70.1	283.7	1242.3
58.00	271.8	1313.8	13.7	76.8	285.6	1390.7

Nominal Shear Strength Calculations

x_{dist} (in)	$P_{f.cpe}$ (kip)	e_{strand} (in)	f_{cpe} (ksi)	M_{cre} (ft-kip)	$P_{f.pc}$ (kip)	f_{pc} (ksi)	$cot\theta$
0.00	119.4	3.50	0.45	557.1	119.4	0.21	1.00
5.80	234.9	3.67	0.90	779.0	234.9	0.43	1.43
11.60	350.4	3.84	1.37	1007.8	350.4	0.63	1.64
17.40	465.8	4.01	1.84	1243.3	465.8	0.83	1.80
23.20	581.3	4.18	2.33	1485.7	581.3	1.01	1.80
29.00	597.2	4.34	2.42	1520.6	616.8	1.06	1.80
34.80	597.2	4.51	2.46	1522.1	639.6	1.09	1.80
38.22	597.2	4.61	2.47	1523.2	653.1	1.11	1.80
40.60	597.2	4.68	2.49	1524.1	662.4	1.12	1.80
46.40	597.2	4.85	2.52	1526.4	685.2	1.15	1.80
52.20	597.2	5.01	2.55	1529.2	708.0	1.17	1.80
58.00	597.2	5.18	2.58	1532.3	730.8	1.18	1.80

Final Shear Strength Results

x_{dist} (in)	V_{ci} (kip)	V_{cw} (kip)	V_c (kip)	V_s (kip)	V_{n1} (kip)	V_{n2} (kip)	V_n (kip)
0.0	42.4	60.6	42.4	425.7	468.1	530.6	468.1
5.8	1643.7	79.6	79.6	169.3	248.9	535.3	248.9
11.6	1074.0	97.9	97.9	145.7	243.6	539.5	243.6
17.4	889	115.3	115.3	160.5	275.7	543.3	275.7
23.2	799	131.8	131.8	160.6	292.4	547.0	292.4
29.0	659	136.0	136.0	160.6	296.7	547.6	296.7
34.8	554	133.4	133.4	154.2	287.6	526.5	287.6
38.2	507	134.6	134.6	154.4	288.9	526.9	288.9
40.6	479	135.4	135.4	154.4	289.8	527.2	289.8
46.4	423	137.2	137.2	154.6	291.8	527.8	291.8
52.2	379	134.4	134.4	149.3	283.8	510.2	283.8
58.0	344	136.0	136.0	149.7	285.7	511.5	285.7

T2.8.Min.2

Additional Input and Basic Calculation

$h_{top.flange}$ (in)	30
S_b (in^3)	3220.4

Load Effects

x_{dist} (in)	V_{LL} (kip)	M_{LL} (ft-kip)	V_{DC1} (kip)	M_{DC1} (ft-kip)	V_{assume} (kip)	M_{assume} (ft-kip)
0.00	456.5	100000	15.9	-0.1	472.4	100000
11.63	278.5	269.8	15.0	14.9	293.5	284.7
23.25	279.9	542.3	14.1	29.0	294.0	571.3
34.88	275.5	800.6	13.2	42.2	288.7	842.8
38.60	277.0	891.2	12.9	46.2	289.9	937.4
46.50	280.1	1085.5	12.3	54.5	292.4	1140.0
58.13	274.5	1329.6	11.4	65.9	285.8	1395.5
69.75	266.3	1548.0	10.4	76.5	276.8	1624.5
77.65	269.2	1742.1	9.8	83.2	279.0	1825.2
81.38	270.5	1834.1	9.5	86.2	280.0	1920.3
93.00	273.9	2122.5	8.6	94.9	282.5	2217.5
104.63	276.5	2410.8	7.7	102.9	284.2	2513.6
116.25	278.3	2696.4	6.8	109.9	285.1	2806.3

Nominal Shear Strength Calculations

x_{dist} (in)	$P_{f.cpe}$ (kip)	e_{strand} (in)	f_{cpe} (ksi)	M_{cre} (ft-kip)	$P_{f.pc}$ (kip)	f_{pc} (ksi)	$cot\theta$
0.00	119.4	3.50	0.45	564.4	119.4	0.21	1.00
11.63	350.9	3.84	1.37	1026.4	350.9	0.63	1.63
23.25	582.3	4.18	2.33	1516.2	582.3	1.00	1.80
34.88	597.2	4.51	2.46	1555.4	639.9	1.07	1.80
38.60	597.2	4.62	2.48	1558.0	654.6	1.09	1.80
46.50	597.2	4.85	2.52	1564.2	685.6	1.12	1.80
58.13	597.2	5.19	2.58	1574.8	731.3	1.15	1.80
69.75	597.2	5.52	2.64	1587.2	777.2	1.17	1.80
77.65	597.2	5.75	2.69	1596.6	808.3	1.18	1.80
81.38	597.2	5.86	2.71	1601.3	823.0	1.18	1.80
93.00	597.2	6.20	2.77	1617.3	868.8	1.18	1.80
104.63	597.2	6.53	2.83	1635.0	914.6	1.16	1.80
116.25	597.2	6.87	2.89	1654.4	960.4	1.14	1.80

Final Shear Strength Results

x_{dist} (in)	V_{ci} (kip)	V_{cw} (kip)	V_c (kip)	V_s (kip)	V_{n1} (kip)	V_{n2} (kip)	V_n (kip)
0.0	42.8	61.1	42.8	429.7	472.5	535.6	472.5
11.6	1088.9	98.3	98.3	195.4	293.6	544.5	293.6
23.3	811.0	132.0	132.0	162.1	294.1	552.1	294.1
34.9	562	133.0	133.0	155.7	288.8	531.5	288.8
38.6	511	134.2	134.2	155.9	290.0	531.9	290.0
46.5	430	136.3	136.3	156.2	292.5	532.8	292.5
58.1	350	134.7	134.7	151.2	285.9	516.5	285.9
69.8	296	131.5	131.5	145.3	276.8	497.1	276.8
77.7	270	132.8	132.8	146.3	279.1	500.5	279.1
81.4	259	133.3	133.3	146.8	280.1	502.0	280.1
93.0	230	134.3	134.3	148.3	282.6	506.9	282.6
104.6	209	134.5	134.5	149.8	284.3	511.8	284.3
116.3	191	134.0	134.0	151.3	285.2	516.7	285.2

Beam BT.8.Typ.1

Additional Input and Basic Calculation

$h_{top.flange}$ (in)	41
S_b (in^3)	9325.24

Load Effects

x_{dist} (in)	V_{LL} (kip)	M_{LL} (ft-kip)	V_{DC1} (kip)	M_{DC1} (ft-kip)	V_{assume} (kip)	M_{assume} (ft-kip)
0.00	549.2	100000	38.6	-0.2	587.8	100000
10.21	352.7	300.1	37.5	32.2	390.1	332.2
20.42	298.0	507.1	36.3	63.6	334.4	570.7
30.63	321.9	821.6	35.2	94.0	357.1	915.7
40.84	332.0	1129.7	34.1	123.5	366.0	1253.2
48.77	339.4	1379.2	33.2	145.7	372.6	1524.9
51.05	341.4	1452.5	32.9	152.0	374.4	1604.5
53.33	343.5	1526.5	32.7	158.2	376.2	1684.7
61.26	350.4	1788.6	31.8	179.5	382.2	1968.1
71.47	358.7	2136.5	30.7	206.1	389.4	2342.6
81.68	369.1	2512.1	29.5	231.7	398.6	2743.9
91.89	376.3	2881.8	28.4	256.4	404.7	3138.2
102.10	346.1	2944.9	27.3	280.0	373.4	3224.9

Nominal Shear Strength Calculations

x_{dist} (in)	$P_{f.cpe}$ (kip)	e_{strand} (in)	f_{cpe} (ksi)	M_{cre} (ft-kip)	$P_{f.pc}$ (kip)	f_{pc} (ksi)	$cot\theta$
0.00	182.2	12.09	0.48	1251.8	182.2	0.10	1.00
10.21	492.1	12.29	1.31	2160.4	492.1	0.28	1.28
20.42	802.1	12.49	2.15	3086.1	802.1	0.45	1.45
30.63	910.8	12.70	2.46	3400.5	945.6	0.53	1.53
40.84	910.8	12.90	2.48	3379.8	999.1	0.57	1.56
48.77	910.8	13.06	2.50	3364.6	1040.6	0.59	1.59
51.05	910.8	13.11	2.50	3360.4	1052.6	0.60	1.60
53.33	910.8	13.15	2.50	3356.3	1064.5	0.61	1.61
61.26	910.8	13.31	2.52	3342.5	1106.1	0.63	1.63
71.47	910.8	13.52	2.54	3326.1	1159.6	0.66	1.66
81.68	910.8	13.72	2.56	3311.1	1213.7	0.69	1.69
91.89	910.8	13.93	2.58	3297.5	1267.4	0.71	1.71
102.10	910.8	14.13	2.60	3285.3	1321.0	0.74	1.73

Final Shear Strength Results

x_{dist} (in)	V_{ci} (kip)	V_{cw} (kip)	V_c (kip)	V_s (kip)	V_{n1} (kip)	V_{n2} (kip)	V_n (kip)
0.0	65.9	74.6	65.9	522.0	587.9	773.8	587.9
10.2	2597.1	99.6	99.6	290.5	390.1	783.1	390.1
20.4	1870.5	123.5	123.5	210.9	334.4	790.4	334.4
30.6	1388	134.2	134.2	222.9	357.1	792.9	357.1
40.8	1048	137.9	137.9	228.2	366.0	793.0	366.0
48.8	882	140.6	140.6	232.0	372.6	793.1	372.6
51.1	843	141.3	141.3	233.1	374.4	793.1	374.4
53.3	808	142.1	142.1	234.1	376.2	793.1	376.2
61.3	707	144.5	144.5	237.6	382.2	793.2	382.2
71.5	610	147.5	147.5	241.9	389.4	793.2	389.4
81.7	537	151.2	151.2	247.4	398.6	798.4	398.6
91.9	480	153.7	153.7	251.0	404.7	798.4	404.7
102.1	433	151.7	151.7	221.7	373.4	774.0	373.4

Beam BT.8.Typ.2

Additional Input and Basic Calculation

$h_{top.flange}$ (in)	41
S_b (in^3)	9325.24

Load Effects

x_{dist} (in)	V_{LL} (kip)	M_{LL} (ft-kip)	V_{DC1} (kip)	M_{DC1} (ft-kip)	V_{assume} (kip)	M_{assume} (ft-kip)
0.00	554.2	100000	32.8	-0.2	587.0	100000
15.33	382.1	488.0	31.0	40.5	413.1	528.6
30.66	316.2	807.7	29.3	79.0	345.4	886.7
45.98	328.8	1259.8	27.5	115.3	356.3	1375.1
49.08	331.2	1354.5	27.1	122.3	358.3	1476.8
61.31	340.0	1737.2	25.8	149.3	365.8	1886.4
76.64	352.0	2248.2	24.0	181.0	376.0	2429.2
91.97	336.7	2580.4	22.3	210.6	359.0	2791.0
104.19	331.6	2879.3	20.9	232.5	352.5	3111.9
107.29	333.0	2977.6	20.5	237.9	353.5	3215.5
122.62	325.9	3330.1	18.8	263.0	344.6	3593.1
137.95	318.5	3660.9	17.0	285.8	335.5	3946.7
153.28	319.6	4082.5	15.3	306.4	334.9	4388.9

Nominal Shear Strength Calculations

x_{dist} (in)	$P_{f.cpe}$ (kip)	e_{strand} (in)	f_{cpe} (ksi)	M_{cre} (ft-kip)	$P_{f.pc}$ (kip)	f_{pc} (ksi)	$cot\theta$
0.00	182.2	12.09	0.48	1267.0	182.2	0.09	1.00
15.33	647.5	12.39	1.73	2665.3	647.5	0.33	1.33
30.66	910.8	12.70	2.46	3464.4	945.8	0.48	1.47
45.98	910.8	13.01	2.49	3444.9	1026.2	0.52	1.52
49.08	910.8	13.07	2.50	3441.3	1042.5	0.53	1.52
61.31	910.8	13.31	2.52	3428.7	1106.7	0.56	1.55
76.64	910.8	13.62	2.55	3415.9	1187.7	0.59	1.59
91.97	910.8	13.93	2.58	3406.5	1268.3	0.62	1.61
104.19	910.8	14.17	2.60	3401.4	1332.7	0.63	1.63
107.29	910.8	14.23	2.61	3400.5	1349.0	0.64	1.64
122.62	910.8	14.54	2.64	3397.8	1370.8	0.64	1.63
137.95	910.8	14.85	2.67	3398.5	1371.1	0.63	1.62
153.28	910.8	15.15	2.70	3402.5	1371.3	0.61	1.61

Final Shear Strength Results

x_{dist} (in)	V_{ci} (kip)	V_{cw} (kip)	V_c (kip)	V_s (kip)	V_{n1} (kip)	V_{n2} (kip)	V_n (kip)
0.0	61.7	74.2	61.7	525.3	587.1	778.8	587.1
15.3	2138.4	108.7	108.7	304.5	413.1	791.8	413.1
30.7	1406.1	129.2	129.2	216.2	345.4	797.9	345.4
46.0	947	133.7	133.7	222.6	356.3	798.0	356.3
49.1	889	134.5	134.5	223.8	358.3	798.1	358.3
61.3	718	137.6	137.6	228.2	365.8	798.2	365.8
76.6	580	141.7	141.7	234.3	376.0	802.9	376.0
92.0	488	144.5	144.5	214.5	359.0	802.9	359.0
104.2	433	142.4	142.4	210.1	352.5	778.7	352.5
107.3	421	142.8	142.8	210.7	353.5	779.1	353.5
122.6	371	139.5	139.5	205.2	344.7	759.7	344.7
138.0	332	135.9	135.9	199.5	335.5	744.0	335.5
153.3	301	135.5	135.5	199.4	334.9	748.9	334.9

Beam BT.8N.Typ.1

Additional Input and Basic Calculation

$h_{top.flange}$ (in)	41
S_b (in^3)	9325.24

Load Effects

x_{dist} (in)	V_{LL} (kip)	M_{LL} (ft-kip)	V_{DC1} (kip)	M_{DC1} (ft-kip)	V_{assume} (kip)	M_{assume} (ft-kip)
0.00	565.0	100000	41.9	-0.2	606.9	100000
10.44	329.6	286.7	40.7	35.7	370.2	322.4
20.88	343.6	597.8	39.4	70.6	383.0	668.3
31.32	263.7	688.1	38.1	104.3	301.8	792.4
41.76	274.4	954.6	36.9	136.9	311.2	1091.6
48.54	281.1	1137.0	36.1	157.6	317.2	1294.6
52.19	284.7	1238.2	35.6	168.5	320.3	1406.7
55.85	287.4	1337.4	35.2	179.3	322.5	1516.7
62.63	291.2	1519.6	34.4	198.9	325.5	1718.5
73.07	297.7	1812.8	33.1	228.3	330.8	2041.1
83.51	304.4	2118.3	31.8	256.5	336.2	2374.8
93.95	309.7	2424.5	30.6	283.7	340.3	2708.2
104.39	304.6	2649.9	29.3	309.7	333.9	2959.6

Nominal Shear Strength Calculations

x_{dist} (in)	$P_{f.cpe}$ (kip)	e_{strand} (in)	f_{cpe} (ksi)	M_{cre} (ft-kip)	$P_{f.pc}$ (kip)	f_{pc} (ksi)	$cot\theta$
0.00	174.6	12.09	0.46	1152.6	174.6	0.13	1.00
10.44	478.3	12.29	1.27	1987.8	478.3	0.36	1.36
20.88	782.0	12.50	2.10	2839.4	782.0	0.59	1.59
31.32	872.9	12.71	2.36	3079.3	912.6	0.69	1.70
41.76	872.9	12.92	2.38	3054.7	969.3	0.74	1.75
48.54	872.9	13.06	2.39	3039.7	1006.1	0.77	1.78
52.19	872.9	13.13	2.40	3031.8	1026.0	0.79	1.79
55.85	872.9	13.20	2.41	3024.1	1045.8	0.80	1.80
62.63	872.9	13.34	2.42	3010.4	1082.7	0.83	1.80
73.07	872.9	13.55	2.44	2990.5	1139.5	0.88	1.80
83.51	872.9	13.76	2.46	2972.1	1196.5	0.92	1.80
93.95	872.9	13.97	2.48	2955.3	1253.3	0.96	1.80
104.39	872.9	14.18	2.50	2940.1	1310.1	0.99	1.80

Final Shear Strength Results

x_{dist} (in)	V_{ci} (kip)	V_{cw} (kip)	V_c (kip)	V_s (kip)	V_{n1} (kip)	V_{n2} (kip)	V_n (kip)
0.00	68.5	76.5	68.5	538.5	607.0	751.1	607.0
10.44	2346.0	106.8	106.8	263.5	370.3	760.4	370.3
20.88	1691.7	136.3	136.3	246.8	383.0	767.6	383.0
31.32	1238	148.5	148.5	153.3	301.8	769.8	301.8
41.75	935	153.5	153.5	157.8	311.3	769.9	311.3
48.54	808	156.6	156.6	160.6	317.2	769.9	317.2
52.19	753	158.3	158.3	162.0	320.3	770.0	320.3
55.85	705	159.9	159.9	162.6	322.6	770.0	322.6
62.63	631	162.9	162.9	162.7	325.5	770.1	325.5
73.07	545	167.7	167.7	163.1	330.8	772.2	330.8
83.51	479	172.5	172.5	163.7	336.3	775.1	336.3
93.95	428	176.6	176.6	163.7	340.3	775.1	340.3
104.39	387	175.3	175.3	158.6	334.0	751.5	334.0

Beam BT.8N.Typ.2

Additional Input and Basic Calculation

$h_{top.flange}$ (in)	41
S_b (in^3)	9325.24

Load Effects

x_{dist} (in)	V_{LL} (kip)	M_{LL} (ft-kip)	V_{DC1} (kip)	M_{DC1} (ft-kip)	V_{assume} (kip)	M_{assume} (ft-kip)
0.00	565.1	100000	34.2	-0.2	599.3	100000
15.26	312.9	397.9	32.3	42.1	345.2	440.0
30.52	266.6	678.0	30.5	82.0	297.0	760.1
45.79	280.9	1071.7	28.6	119.6	309.5	1191.3
48.58	283.4	1147.4	28.3	126.2	311.7	1273.6
61.05	293.6	1493.7	26.8	154.9	320.4	1648.5
76.31	301.2	1915.2	24.9	187.8	326.1	2102.9
91.57	310.3	2368.0	23.1	218.3	333.4	2586.3
104.04	279.4	2422.5	21.6	241.5	301.0	2664.0
106.83	280.7	2499.2	21.3	246.5	302.0	2745.7
122.09	277.0	2818.8	19.4	272.4	296.5	3091.2
137.35	272.2	3115.9	17.6	295.9	289.8	3411.9
152.62	275.1	3499.0	15.7	317.1	290.9	3816.1

Nominal Shear Strength Calculations

x_{dist} (in)	$P_{f.cpe}$ (kip)	e_{strand} (in)	f_{cpe} (ksi)	M_{cre} (ft-kip)	$P_{f.pc}$ (kip)	f_{pc} (ksi)	$cot\theta$
0.00	174.6	12.09	0.46	1146.2	174.6	0.12	1.00
15.26	618.6	12.39	1.65	2391.2	618.6	0.46	1.47
30.52	872.9	12.70	2.36	3109.7	908.3	0.67	1.68
45.79	872.9	13.00	2.39	3088.1	991.2	0.73	1.75
48.58	872.9	13.06	2.39	3084.4	1006.4	0.74	1.76
61.05	872.9	13.31	2.42	3069.7	1074.1	0.79	1.80
76.31	872.9	13.61	2.44	3054.6	1157.0	0.85	1.80
91.57	872.9	13.92	2.47	3042.9	1240.5	0.90	1.80
104.04	872.9	14.17	2.50	3035.7	1308.3	0.94	1.80
106.83	872.9	14.22	2.50	3034.4	1323.5	0.94	1.80
122.09	872.9	14.53	2.53	3029.3	1364.3	0.96	1.80
137.35	872.9	14.84	2.56	3027.4	1364.6	0.96	1.80
152.62	872.9	15.14	2.59	3028.9	1364.8	0.95	1.80

Final Shear Strength Results

x_{dist} (in)	V_{ci} (kip)	V_{cw} (kip)	V_c (kip)	V_s (kip)	V_{n1} (kip)	V_{n2} (kip)	V_n (kip)
0.0	60.4	75.3	60.4	538.9	599.4	727.2	599.4
15.3	1932.4	118.3	118.3	226.9	345.2	739.9	345.2
30.5	1273.0	145.0	145.0	152.1	297.1	745.8	297.1
45.8	858	151.5	151.5	158.0	309.5	745.9	309.5
48.6	810	152.7	152.7	159.1	311.7	745.9	311.7
61.1	650	157.6	157.6	162.8	320.4	746.0	320.4
76.3	525	163.3	163.3	162.8	326.1	746.2	326.1
91.6	442	169.6	169.6	163.9	333.4	750.9	333.4
104.0	391	168.7	168.7	132.3	301.0	728.0	301.0
106.8	382	169.6	169.6	132.4	302.0	728.3	302.0
122.1	336	167.5	167.5	128.9	296.5	710.0	296.5
137.4	301	163.6	163.6	126.2	289.8	695.1	289.8
152.6	273	163.8	163.8	127.0	290.9	699.7	290.9

Beam BT.10.Typ.1

Additional Input and Basic Calculation

$h_{top.flange}$ (in)	41
S_b (in^3)	9325.24

Load Effects

x_{dist} (in)	V_{LL} (kip)	M_{LL} (ft-kip)	V_{DC1} (kip)	M_{DC1} (ft-kip)	V_{assume} (kip)	M_{assume} (ft-kip)
0.00	537.3	100000	38.1	-0.2	575.4	100000
9.84	280.1	229.6	37.0	30.6	317.1	260.3
19.68	282.4	463.1	35.9	60.5	318.3	523.6
29.52	310.1	762.7	34.9	89.6	344.9	852.2
39.36	320.1	1049.7	33.8	117.7	353.9	1167.4
47.95	328.4	1312.3	32.8	141.6	361.3	1453.8
49.20	329.6	1351.4	32.7	145.0	362.3	1496.4
50.45	330.8	1390.7	32.6	148.4	363.4	1539.1
59.03	338.8	1666.7	31.6	171.3	370.4	1838.0
68.87	347.5	1994.4	30.6	196.8	378.0	2191.2
78.71	355.8	2333.6	29.5	221.4	385.2	2555.0
88.55	364.5	2689.5	28.4	245.2	392.9	2934.6
98.39	320.7	2629.7	27.3	268.0	348.1	2897.7

Nominal Shear Strength Calculations

x_{dist} (in)	$P_{f.cpe}$ (kip)	e_{strand} (in)	f_{cpe} (ksi)	M_{cre} (ft-kip)	$P_{f.pc}$ (kip)	f_{pc} (ksi)	$cot\theta$
0.00	180.3	12.09	0.48	1210.1	180.3	0.11	1.00
9.84	476.1	12.28	1.27	2056.6	476.1	0.31	1.31
19.68	771.8	12.48	2.07	2918.4	771.8	0.50	1.50
29.52	901.7	12.68	2.43	3290.5	930.8	0.60	1.60
39.36	901.7	12.87	2.45	3271.1	982.6	0.64	1.64
47.95	901.7	13.05	2.47	3255.2	1027.8	0.67	1.67
49.20	901.7	13.07	2.47	3253.0	1034.4	0.67	1.68
50.45	901.7	13.10	2.47	3250.8	1040.9	0.68	1.68
59.03	901.7	13.27	2.49	3236.2	1086.2	0.71	1.71
68.87	901.7	13.46	2.51	3220.6	1138.0	0.74	1.75
78.71	901.7	13.66	2.53	3206.4	1189.8	0.77	1.78
88.55	901.7	13.86	2.55	3193.4	1242.1	0.80	1.80
98.39	901.7	14.06	2.57	3181.7	1294.6	0.83	1.80

Final Shear Strength Results

x_{dist} (in)	V_{ci} (kip)	V_{cw} (kip)	V_c (kip)	V_s (kip)	V_{n1} (kip)	V_{n2} (kip)	V_n (kip)
0.0	64.4	74.0	64.4	511.0	575.5	741.9	575.5
9.8	2565.2	100.0	100.0	217.1	317.1	752.5	317.1
19.7	1835.7	125.2	125.2	193.2	318.4	760.3	318.4
29.5	1393	138.2	138.2	206.7	344.9	763.5	344.9
39.4	1051	142.1	142.1	211.8	353.9	763.7	353.9
47.9	868	145.3	145.3	216.0	361.3	763.8	361.3
49.2	846	145.8	145.8	216.6	362.4	763.9	362.4
50.4	826	146.3	146.3	217.2	363.4	763.9	363.4
59.0	709	149.3	149.3	221.1	370.4	764.0	370.4
68.9	612	152.7	152.7	225.4	378.1	764.1	378.1
78.7	538	155.8	155.8	229.5	385.2	764.2	385.2
88.6	481	159.4	159.4	233.5	392.9	767.6	392.9
98.4	435	158.5	158.5	189.6	348.1	748.4	348.1

Beam BT.10.Typ.2

Additional Input and Basic Calculation

$h_{top.flange}$ (in)	41
S_b (in^3)	9325.24

Load Effects

x_{dist} (in)	V_{LL} (kip)	M_{LL} (ft-kip)	V_{DC1} (kip)	M_{DC1} (ft-kip)	V_{assume} (kip)	M_{assume} (ft-kip)
0.00	545.9	100000	32.3	-0.2	578.2	100000
14.62	316.2	385.3	30.6	38.2	346.8	423.4
29.24	315.8	769.6	29.0	74.5	344.8	844.1
43.86	329.2	1203.5	27.4	108.8	356.6	1312.3
48.36	333.2	1342.8	26.8	119.0	360.0	1461.8
58.49	341.7	1665.4	25.7	141.2	367.4	1806.6
73.11	353.2	2152.0	24.1	171.5	377.3	2323.5
87.73	329.4	2408.5	22.4	199.8	351.9	2608.3
97.85	324.8	2648.6	21.3	218.2	346.1	2866.9
102.35	327.6	2794.4	20.8	226.1	348.4	3020.6
116.97	323.7	3155.7	19.1	250.4	342.9	3406.1
131.59	325.3	3567.3	17.5	272.7	342.8	3840.0
146.21	318.5	3880.5	15.8	293.0	334.3	4173.5

Nominal Shear Strength Calculations

x_{dist} (in)	$P_{f.cpe}$ (kip)	e_{strand} (in)	f_{cpe} (ksi)	M_{cre} (ft-kip)	$P_{f.pc}$ (kip)	f_{pc} (ksi)	$cot\theta$
0.00	180.3	12.09	0.48	1240.7	180.3	0.11	1.00
14.62	619.8	12.38	1.65	2514.0	619.8	0.40	1.38
29.24	901.7	12.67	2.43	3341.5	929.4	0.59	1.57
43.86	901.7	12.96	2.46	3323.6	1006.6	0.64	1.62
48.36	901.7	13.05	2.47	3318.7	1030.3	0.66	1.63
58.49	901.7	13.26	2.49	3308.6	1083.8	0.69	1.66
73.11	901.7	13.55	2.52	3296.5	1161.0	0.73	1.70
87.73	901.7	13.84	2.55	3287.3	1239.0	0.77	1.74
97.85	901.7	14.04	2.57	3282.7	1292.6	0.79	1.76
102.35	901.7	14.13	2.57	3281.0	1316.5	0.81	1.77
116.97	901.7	14.43	2.60	3277.7	1363.9	0.82	1.79
131.59	901.7	14.72	2.63	3277.2	1364.2	0.81	1.78
146.21	901.7	15.01	2.66	3279.7	1364.4	0.80	1.77

Final Shear Strength Results

x_{dist} (in)	V_{ci} (kip)	V_{cw} (kip)	V_c (kip)	V_s (kip)	V_{n1} (kip)	V_{n2} (kip)	V_n (kip)
0.0	62.7	77.4	62.7	515.5	578.3	818.8	578.3
14.6	2115.0	115.6	115.6	231.3	346.8	833.9	346.8
29.2	1421.4	141.0	141.0	203.8	344.8	841.1	344.8
43.9	958	146.3	146.3	210.3	356.6	841.4	356.6
48.4	871	147.8	147.8	212.2	360.0	841.4	360.0
58.5	726	151.1	151.1	216.3	367.4	841.6	367.4
73.1	586	155.6	155.6	221.8	377.3	841.8	377.3
87.7	493	161.0	161.0	190.9	351.9	850.3	351.9
97.9	445	158.9	158.9	187.2	346.1	823.6	346.1
102.4	426	160.0	160.0	188.4	348.4	824.2	348.4
117.0	376	157.8	157.8	185.1	342.9	802.7	342.9
131.6	337	157.7	157.7	185.1	342.8	806.2	342.8
146.2	305	153.9	153.9	180.4	334.3	790.0	334.3

Beam BT.10.Min.1

Additional Input and Basic Calculation

$h_{top.flange}$ (in)	41
S_b (in^3)	9325.24

Load Effects

x_{dist} (in)	V_{LL} (kip)	M_{LL} (ft-kip)	V_{DC1} (kip)	M_{DC1} (ft-kip)	V_{assume} (kip)	M_{assume} (ft-kip)
0.00	544.4	100000	38.8	-0.2	583.2	100000
10.50	184.4	161.3	37.6	33.3	222.0	194.6
21.00	225.2	394.2	36.5	65.7	261.7	459.8
31.50	244.5	641.7	35.3	97.1	279.8	738.8
42.00	206.1	721.1	34.1	127.4	240.2	848.6
48.47	210.5	850.0	33.4	145.6	243.8	995.7
52.50	213.1	932.4	32.9	156.8	246.1	1089.2
56.53	215.8	1016.4	32.5	167.8	248.3	1184.1
63.00	219.9	1154.4	31.8	185.1	251.7	1339.5
73.50	226.3	1386.2	30.6	212.4	256.9	1598.6
84.00	234.9	1644.3	29.4	238.7	264.3	1882.9
94.50	240.1	1890.5	28.3	263.9	268.3	2154.4
105.00	236.3	2067.4	27.1	288.1	263.4	2355.5

Nominal Shear Strength Calculations

x_{dist} (in)	$P_{f.cpe}$ (kip)	e_{strand} (in)	f_{cpe} (ksi)	M_{cre} (ft-kip)	$P_{f.pc}$ (kip)	f_{pc} (ksi)	$cot\theta$
0.00	186.3	12.09	0.49	1255.4	186.3	0.12	1.00
10.50	512.4	12.30	1.36	2187.4	512.4	0.34	1.32
21.00	838.5	12.51	2.25	3137.5	838.5	0.55	1.52
31.50	931.7	12.72	2.52	3396.9	970.1	0.63	1.61
42.00	931.7	12.93	2.54	3376.5	1023.8	0.67	1.65
48.47	931.7	13.06	2.55	3364.7	1056.9	0.70	1.67
52.50	931.7	13.14	2.56	3357.7	1077.6	0.71	1.69
56.53	931.7	13.22	2.57	3350.8	1098.2	0.73	1.70
63.00	931.7	13.35	2.58	3340.3	1131.3	0.75	1.72
73.50	931.7	13.56	2.60	3324.4	1185.1	0.78	1.75
84.00	931.7	13.77	2.62	3310.0	1239.7	0.81	1.78
94.50	931.7	13.98	2.64	3297.0	1293.6	0.84	1.80
105.00	931.7	14.19	2.67	3285.6	1347.6	0.87	1.80

Final Shear Strength Results

x_{dist} (in)	V_{ci} (kip)	V_{cw} (kip)	V_c (kip)	V_s (kip)	V_{n1} (kip)	V_{n2} (kip)	V_n (kip)
0.0	66.6	78.2	66.6	516.7	583.3	820.8	583.3
10.5	2558.8	107.4	107.4	114.6	222.0	832.6	222.0
21.0	1850.5	135.6	135.6	126.2	261.7	841.2	261.7
31.5	1351	146.5	146.5	133.3	279.8	843.6	279.8
42.0	1020	150.6	150.6	89.6	240.2	843.7	240.2
48.5	888	153.0	153.0	90.8	243.9	843.8	243.9
52.5	822	154.5	154.5	91.6	246.1	843.9	246.1
56.5	765	155.9	155.9	92.3	248.3	844.0	248.3
63.0	689	158.2	158.2	93.5	251.7	844.1	251.7
73.5	595	161.7	161.7	95.3	256.9	844.2	256.9
84.0	524	166.4	166.4	97.9	264.4	852.4	264.4
94.5	468	169.5	169.5	98.9	268.4	852.4	268.4
105.0	423	167.6	167.6	95.8	263.4	826.6	263.4

Beam BT.10.Min.2

Additional Input and Basic Calculation

$h_{top.flange}$ (in)	41
S_b (in^3)	9325.24

Load Effects

x_{dist} (in)	V_{LL} (kip)	M_{LL} (ft-kip)	V_{DC1} (kip)	M_{DC1} (ft-kip)	V_{assume} (kip)	M_{assume} (ft-kip)
0.00	552.0	100000	32.4	-0.2	584.4	100000
15.18	211.0	266.9	30.6	39.7	241.6	306.6
30.36	246.7	624.1	28.9	77.4	275.6	701.5
45.54	211.6	802.9	27.2	112.9	238.8	915.8
48.71	213.5	866.6	26.9	120.0	240.3	986.6
60.72	220.4	1115.3	25.5	146.2	245.9	1261.5
75.90	228.6	1445.7	23.8	177.4	252.4	1623.1
91.08	240.0	1821.4	22.1	206.4	262.1	2027.8
103.09	238.6	2049.8	20.7	227.9	259.3	2277.7
106.26	240.0	2125.3	20.4	233.3	260.4	2358.6
121.44	232.9	2357.2	18.7	258.0	251.6	2615.2
136.62	228.4	2600.0	17.0	280.5	245.3	2880.6
151.80	230.1	2910.8	15.2	300.9	245.3	3211.7

Nominal Shear Strength Calculations

x_{dist} (in)	$P_{f.cpe}$ (kip)	e_{strand} (in)	f_{cpe} (ksi)	M_{cre} (ft-kip)	$P_{f.pc}$ (kip)	f_{pc} (ksi)	$cot\theta$
0.00	186.3	12.09	0.49	1282.7	186.3	0.11	1.00
15.18	657.8	12.39	1.76	2654.6	657.8	0.41	1.39
30.36	931.7	12.69	2.52	3460.9	964.3	0.60	1.56
45.54	931.7	13.00	2.55	3443.6	1042.1	0.65	1.61
48.71	931.7	13.06	2.55	3440.4	1058.4	0.66	1.62
60.72	931.7	13.30	2.58	3429.4	1120.0	0.70	1.65
75.90	931.7	13.61	2.61	3418.3	1197.8	0.74	1.69
91.08	931.7	13.91	2.64	3410.4	1275.7	0.78	1.73
103.09	931.7	14.15	2.66	3406.4	1337.3	0.80	1.75
106.26	931.7	14.21	2.67	3405.7	1353.6	0.81	1.76
121.44	931.7	14.52	2.70	3404.0	1368.2	0.81	1.76
136.62	931.7	14.82	2.73	3405.6	1368.5	0.80	1.75
151.80	931.7	15.12	2.76	3410.3	1368.7	0.79	1.74

Final Shear Strength Results

x_{dist} (in)	V_{ci} (kip)	V_{cw} (kip)	V_c (kip)	V_s (kip)	V_{n1} (kip)	V_{n2} (kip)	V_n (kip)
0.0	65.1	80.1	65.1	519.4	584.4	874.4	584.4
15.2	2151.0	120.8	120.8	120.9	241.6	890.5	241.6
30.4	1418.8	145.7	145.7	130.0	275.6	897.6	275.6
45.5	957	150.9	150.9	87.9	238.8	897.8	238.8
48.7	896	151.9	151.9	88.4	240.3	897.9	240.3
60.7	725	155.7	155.7	90.3	245.9	898.1	245.9
75.9	586	160.0	160.0	92.4	252.4	898.3	252.4
91.1	494	166.2	166.2	95.9	262.1	912.9	262.1
103.1	439	164.8	164.8	94.6	259.4	888.3	259.4
106.3	427	165.5	165.5	94.9	260.4	888.5	260.4
121.4	376	160.1	160.1	91.5	251.6	857.1	251.6
136.6	337	156.2	156.2	89.1	245.3	839.1	245.3
151.8	305	156.2	156.2	89.2	245.4	844.5	245.4