LOADING DATA

design_load = HL93

Strength_limit := 1

wearing_surface := 6in

BRIDGE GEOMETRY

design_span := 30ft

brg_lgt := 12in

$N_L := 2$ (number of lanes)

$b_w := 10.5in$

design_width := 24ft

t := 16.5in

WHEEL LOAD DISTRIBUTION :

Load distribution E : LRFD 4.6.2.3

Single Lane Check

$$E_s := \frac{\left[10ft + \left(5\sqrt{design\_span \cdot design\_width}\right)\right]}{12} = 144.16 \cdot in$$

Multi Lane Check

$$E_{m1} := \frac{\left(84 \cdot ft + 1.44\sqrt{design\_span \cdot design\_width}\right)}{12} = 122.64 \cdot in$$

$$E_{m2} := \frac{12 \cdot design\_width}{N_L} \cdot \frac{1}{12} = 144 \cdot in$$

$$E_{w1} := \begin{cases} E_{m1} & \text{if } E_{m1} \le E_{m2} \\ E_{m2} & \text{otherwise} \end{cases} = 122.64 \cdot in$$

$$E_w := \begin{cases} E_s & \text{if } E_s \le E_{w1} \\ E_{w1} & \text{otherwise} \end{cases}$$

$E_w = 122.64 \cdot in$

DECK PROPERTIES & DESIGN VALUES:

Glulam Comb. 24F-V3, Species SP (AASHTO 8.4.1.2.3-1)

$$S_x := \frac{E_w \cdot t^2}{6}$$

$S_x = 5564.76 \cdot in^3$

$$I_x := \frac{E_w \cdot t^3}{12}$$

$I_x = 45909.24 \cdot in^4$

$F_{bo} := 2400psi$

$F_{cpo} := 740psi$

$E_o := 1800000psi$

WOOD ADJUSTMENT FACTORS - LRFD 8.4.4.1

Moisture Content Factor : LRFD Table 8.4.4.3-2

$C_{m\_b} := .8$ $\quad C_{m\_cp} := .53$ $\quad C_{m\_E} := .833$

$$C_{v1} := \left[\left(\frac{12in}{t}\right) \cdot \left(\frac{5.125in}{b_w}\right) \cdot \left(\frac{21ft}{design\_span}\right)\right]^{\frac{1}{20}}$$

$C_v := \begin{cases} 1 & \text{if } C_{v1} > 1 \\ C_{v1} & \text{otherwise} \end{cases}$

$C_v = 0.93$

Time Effect Factor : LRFD 8.4.4.9 $C_\lambda := 0.8$

Bearing Factor ; LRFD Table 8.8.3-1 $C_b := 1$

ADJUSTED DESIGN VALUES - LRFD 8.4.4.1

Resistance factors - LRFD Table 8.5.2.2 $\phi_m := 0.85$ $\phi_v := 0.75$ $\phi_{cp} := 0.9$

Conversion Factors : LRFD Table 8.4.4.2 $C_{KFb} := \frac{2.5}{\phi_m}$ $C_{KFv} := \frac{2.5}{\phi_v}$ $C_{KF\_CP} := \frac{2.1}{\phi_{cp}}$

$Fb := F_{bo} \cdot C_{KFb} \cdot C_{m\_b} \cdot C_v \cdot C_\lambda$ $Fb = 4.21 \cdot ksi$

$Fcp := F_{cpo} \cdot C_{KF\_CP} \cdot C_{m\_cp} \cdot C_\lambda$ $Fcp = 0.73 \cdot ksi$

$E := E_o \cdot C_{m\_E}$ $E = 1499.4 \cdot ksi$

FACTORED RESISTANCE

Flexure

$M_n := Fb \cdot S_x$ $M_n = 1954.08 \cdot ft \cdot kip$

$M_r := \phi_m \cdot M_n$ $M_r = 1660.97 \cdot ft \cdot kip$

Compression

$A_b := brg\_lgt \cdot E_w$

$P_n := Fcp \cdot A_b \cdot C_b$ $P_n = 1077.42 \cdot kip$

$P_r := \phi_{cp} \cdot P_n$ $P_r = 969.68 \cdot kip$

DECK DESIGN :

LRFD Table 3.5.1-1 $WT_{wood} := 50pcf$ $WT_{asphalt} := 140pcf$

Dead load and Moments for Components (deck, rods, dia & misc DL, rail)

$Deck_{dl} := E_w \cdot t \cdot WT_{wood}$ $Deck_{dl} = 0.7 \cdot klf$

$Misc_{dl} := .2klf$

$DC := Deck_{dl} + Misc_{dl}$ $\qquad DC = 0.9 \cdot klf$

$$M_{DC} := \frac{DC \cdot design\_span^2}{8} \qquad M_{DC} = 101.54 \cdot ft \cdot kip$$

Dead load and Moments for Asphalt Wearing Surface

$DW := E_w \cdot wearing\_surface \cdot WT_{asphalt}$ $\qquad DW = 0.72 \cdot klf$

$$M_{DW} := \frac{DW \cdot design\_span^2}{8} \qquad M_{DW} = 80.48 \cdot ft \cdot kip$$

Maximim HL93 Vehicle Moment : LRFD 3.6.1.2.2

$$M_{C1}(a_s, b_s) := \left(\frac{a_s \cdot ft \cdot b_s \cdot ft}{design\_span}\right)\left(8kip + 32kip \text{ if}\left(a_s > 14, \frac{a_s - 14}{a_s}, 0\right) + 32kip \text{ if}\left(a_s > 28, \frac{a_s - 28}{a_s}, 0\right)\right)$$

$$M_{C2}(a_s, b_s) := \left(\frac{a_s \cdot ft \cdot b_s \cdot ft}{design\_span}\right)\left(8kip \text{ if}\left(b_s > 14, \frac{b_s - 14}{b_s}, 0\right) + 32kip + 32kip \text{ if}\left(a_s > 14, \frac{a_s - 14}{a_s}, 0\right)\right)$$

$$M_{C3}(a_s, b_s) := \left(\frac{a_s \cdot ft \cdot b_s \cdot ft}{design\_span}\right)\left(25kip + 25kip \text{ if}\left(a_s > 4, \frac{a_s - 4}{a_s}, 0\right)\right)$$

$$M_{max}(a_s) := \max\left(M_{C1}\left(a_s, \frac{design\_span}{ft} - a_s\right), M_{C2}\left(a_s, \frac{design\_span}{ft} - a_s\right), M_{C3}\left(a_s, \frac{design\_span}{ft} - a_s\right)\right)$$

$$MMax_{LL} := \text{for } I \in 0, .1 .. \frac{design\_span}{ft}$$

$$MMax \leftarrow M_{max}(I) \text{ if } M_{max}(I - .1) < M_{max}(I)$$

$MMax_{LL} = 326.67 \cdot ft \cdot kip$

$$M_{laneload} := .64 \frac{kip}{ft} \frac{design\_span^2}{8} \qquad M_{laneload} = 72 \cdot ft \cdot kip$$

$M\_HL93 := MMax_{LL} + M_{laneload}$

$M\_HL93 = 398.67 \cdot ft \cdot kip$

Strength Limit States LRFD Table 3.4.1-1 $\qquad \gamma_{DC} := 1.25 \qquad \gamma_{DW} := 1.5 \qquad \gamma_{LL} := 1.75$

LRFD 1.3.3 Ductility $\eta_D := 1.0$

LRFD 1.3.4 Redundancy $\eta_R := 1.0$

LRFD 1.3.5 Operational Importance $\eta_I := 1.0$

LRFD 1.3.2.1-2

$$\eta_i := \begin{cases} (\eta_D \cdot \eta_R \cdot \eta_I) & \text{if } \eta_D \cdot \eta_R \cdot \eta_I \geq 0.95 \\ 0.95 & \text{otherwise} \end{cases}$$

$\eta_i = 1$

FLEXURE CHECK

$$Q_{flexure} := \eta_i \cdot (\gamma_{DC} \cdot M_{DC} + \gamma_{DW} \cdot M_{DW} + \gamma_{LL} \cdot M\_HL93)$$

$Q_{flexure} = 945.32 \cdot ft \cdot kip$

$$Flexure\_check := \begin{cases} \text{"OK"} & \text{if } M_r \geq Q_{flexure} \\ \text{"RE-RUN"} & \text{otherwise} \end{cases}$$

Flexure_check = "OK"

DECK DEFLECTION :

Live Load Deflection limited to L/425 LRFD 2.5.2.6.2

Live Load Deflection Criteria LRFD 3.6.1.3.2

$$P_{EQ} := \frac{4 \cdot MMax_{LL}}{design\_span}$$

$$\Delta_{truck} := \frac{P_{EQ} \cdot design\_span^3}{48 \cdot E \cdot I_x}$$

$\Delta_{truck} = 0.62 \cdot in$

$$\Delta_{tandem} := \frac{25kip}{24 \cdot E \cdot I_x} \cdot \left(\frac{design\_span - 4ft}{2}\right) \cdot \left[3 \cdot design\_span^2 - 4\left(\frac{design\_span - 4ft}{2}\right)^2\right]$$

$\Delta_{tandem} = 0.69 \cdot in$

$$\Delta_{lane\_load} := \frac{5 \cdot .64 \frac{kip}{ft} \cdot design\_span^4}{384 \cdot E \cdot I_x}$$

$\Delta_{lane\_load} = 0.17 \cdot in$

$$\Delta_{tr} := \begin{cases} (\Delta_{truck}) & \text{if } \Delta_{truck} \geq \Delta_{tandem} \\ (\Delta_{tandem}) & \text{otherwise} \end{cases}$$

$\Delta_{tr} = 0.69 \cdot in$

$$\Delta_{LL} := \begin{cases} (.25 \cdot \Delta_{tr} + \Delta_{lane\_load}) & \text{if } (.25 \cdot \Delta_{tr} + \Delta_{lane\_load}) > \Delta_{tr} \\ \Delta_{tr} & \text{otherwise} \end{cases}$$

$\Delta_{LL} = 0.69 \cdot in$

$$\Delta_{LL\_allow} := \frac{design\_span}{425}$$

$\Delta_{LL\_allow} = 0.85 \cdot in$

$$\Delta_{ratio} := \frac{design\_span}{\Delta_{LL}}$$

$\Delta_{ratio} = 523.23$

$$Deflection\_Check := \begin{cases} \text{"Deflection is good"} & \text{if } \Delta_{LL\_allow} \geq \Delta_{LL} \\ \text{"excessive deflction re-run"} & \text{otherwise} \end{cases}$$

Deflection_Check = "Deflection is good"

CAMBER REQUIRED:

Camber Timber Stringers three times dead load deflection LRFD 8.12.3

$$\Delta_{DLc} := 3\left[\frac{5 \cdot (DW + DC) \cdot design\_span^4}{384 \cdot E \cdot I_x}\right]$$

$\Delta_{DLc} = 1.285 \cdot in$

$$Radius := \frac{design\_span^2 + 4\Delta_{DLc}^{\;2}}{8\Delta_{DLc}}$$

$Radius = 1050.51 \cdot ft$

BEARING CHECK :

$$V_{C1}(a_s, b_s) := \left(1 - \frac{a_s \cdot ft}{design\_span}\right)\left(32kip + 32kip\ \text{if}\left(b_s > 14, \frac{b_s - 14}{b_s}, 0\right) + 8kip\ \text{if}\left(b_s > 28, \frac{b_s - 28}{b_s}, 0\right)\right)$$

$$V_{C2}(a_s, b_s) := \left(1 - \frac{a_s \cdot ft}{design\_span}\right)\left(25kip + 25kip\ \text{if}\left(b_s > 4, \frac{b_s - 4}{b_s}, 0\right)\right)$$

$$V_{max}(a_s) := \max\left(V_{C1}\left(a_s, \frac{design\_span}{ft} - a_s\right), V_{C2}\left(a_s, \frac{design\_span}{ft} - a_s\right)\right)$$

Maximum Shear reaction at abutment

$$V\_LaneLoad1 := .64\frac{kip}{ft} \cdot \left(\frac{design\_span}{2}\right)$$

$V_{br} := \left(V_{max}\left(\frac{0}{ft}\right)\right) + V\_LaneLoad1 = 59.2 \cdot kip$

$$Q_{cpo} := \eta_i\left[\left(\gamma_{DC} \cdot \frac{DC \cdot design\_span}{2} + \gamma_{DW} \cdot \frac{DW \cdot design\_span}{2}\right) + \gamma_{LL} \cdot V_{br}\right]$$

$Q_{cpo} = 136.62 \cdot kip$

$$Bearing\_Check := \begin{cases} \text{"Bearing Check - OK"} & \text{if } P_r \geq Q_{cpo} \\ \text{"no good Re-Run"} & \text{otherwise} \end{cases}$$

Bearing_Check = "Bearing Check - OK"

PRESTRESSING DESIGN LRFD 9.9.5.6.3

Stressing rod spacing $sp := 41in$

Area of stress bar $A_s := .85in^2$ 1" A722 HS COIL RODS

Steel to wood ratio $R_{sw} := \frac{A_s}{sp \cdot t}$ $(R_{sw} \le 0.0016)$ $R_{sw} = 0.0013$

Bearing plate size $S_w := 16in$ $S_d := 16in$

Anchor plate size $L_w := 6in$ $L_d := 4in$

Note : Anchor Plate thickness determined by standardized thickness of 1 1/4"thickness for 1"dia. bars from bar manufacturers

$S_{area} := S_w \cdot S_d$ $S_{area} = 256 \cdot in^2$ $F := .375ksi$ LRFD Table 9.9.5.6.3-1

Prestressing Force KIPS : LRFD 9.9.5.6.3-2 $P_{pt} := .1 \frac{kip}{in^2} \cdot t \cdot sp$ $P_{pt} = 67.65 \cdot kip$

Factored Compressive Bulkhead Resistance: LRFD 9.9.5.6.3-3

$P_{BU} := F \cdot \phi_{cp} \cdot S_{area}$ $P_{BU} = 86.4 \cdot kip$

$$Bulkhead\_resistance := \begin{cases} \text{"Bulkhead ok"} & \text{if } P_{BU} \cdot .8 \ge P_{pt} \\ \text{"Resize bulkhead"} & \text{otherwise} \end{cases}$$

Bulkhead_resistance = "Bulkhead ok"

Determine Bearing Plate Thickness :
formula 9-23 USDA Forest Servive Timber Bridge Manual

$$k := \left(\begin{cases} \frac{S_d - L_d}{2} & \text{if } \frac{S_d - L_d}{2} > \frac{S_w - L_w}{2} \\ \frac{S_w - L_w}{2} & \text{otherwise} \end{cases} \right)$$

$k = 6 \cdot in$

$$t_p := \sqrt{\frac{3 \cdot \frac{P_{pt}}{S_{area}} \cdot k^2}{(.55 \cdot 36000psi)}}$$

$t_p = 1.2 \cdot in$