AASHTO LRFD Loadings
Single-span, Multi -Lane
DF Longitudinal Bridge Design

LOADING DATA

design_load = HL93

Strength_limit := 1

wearing_surface := 6in

BRIDGE GEOMETRY

design_span := 19ft

design_width := 24ft

brg_lgt := 12in

t := 12.25in

$N_L := 2$
(number of lanes)

WHEEL LOAD DISTRIBUTION :

Load distribution Ew : LRFD 4.6.2.3

Single Lane Check

$$E_s := \frac{\left\lceil 10ft + \left(5\sqrt{design\_span \cdot design\_width}\right)\right\rceil}{12} = 116.77 \cdot in$$

Multi Lane Check

$$E_{m1} := \frac{\left(84 \cdot ft + 1.44\sqrt{design\_span \cdot design\_width}\right)}{12} = 114.75 \cdot in$$

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

$$E_{w1} := \begin{cases} E_{m1} & \text{if } E_{m1} \le E_{m2} \\ E_{m2} & \text{otherwise} \end{cases} = 114.75 \cdot in$$

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

$E_w = 114.75 \cdot in$

DECK PROPERTIES & DESIGN VALUES:

Glulam Identifcation No. 2, Species DF (AASHTO Table 8.4.1.2.3-2)

$$stag\_layup := \begin{cases} .5 & \text{if } t > 10.75in \\ 1 & \text{otherwise} \end{cases}$$

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

$S_x = 2869.94 \cdot in^3$

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

$I_x = 17578.41 \cdot in^4$

$F_{bo} := 1800psi$

$F_{cpo} := 560psi$

$E_o := 1600000psi$

$F_{vo} := stag\_layup \cdot .72 \cdot 230psi$

WOOD ADJUSTMENT FACTORS - LRFD 8.4.4.1

Moisture Content Factor : LRFD Table 8.4.4.3-2

$C_{m\_b} := .8$ $C_{m\_v} := .875$ $C_{m\_cp} := .53$ $C_{m\_E} := .833$

Flat Use Factor : LRFD 8.4.4.6

$C_{fu} := 1$

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 $\phi_b := 0.85$ $\phi_v := 0.75$ $\phi_{cp} := 0.9$

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

$Fb := F_{bo} \cdot C_{KFb} \cdot C_{m\_b} \cdot C_{fu} \cdot C_\lambda$ $Fb = 3.39 \cdot ksi$

$Fv := F_{vo} \cdot C_{KFv} \cdot C_{m\_v} \cdot C_\lambda$ $Fv = 0.193 \cdot ksi$

$Fcp := F_{cpo} \cdot C_{KF\_CP} \cdot C_{m\_cp} \cdot C_\lambda$ $Fcp = 0.55 \cdot ksi$

$E := E_o \cdot C_{m\_E}$ $E = 1332.8 \cdot ksi$

FACTORED RESISTANCE

Flexure

$M_n := Fb \cdot S_x$ $M_n = 810.34 \cdot ft{\cdot}kip$

$M_r := \phi_b \cdot M_n$ $M_r = 688.79 \cdot ft \cdot kip$

Shear

$V_n := \frac{Fv \cdot (E_w \cdot t)}{1.5}$ $V_n = 181.05 \cdot kip$

$V_r := \phi_v \cdot V_n$ $V_r = 135.79 \cdot kip$

Compression

$A_b := brg\_lgt \cdot E_w$ $A_b = 1377 \cdot in^2$

$P_n := Fcp \cdot A_b \cdot C_b$ $P_n = 762.89 \cdot kip$

$P_r := \phi_{cp} \cdot P_n$ $P_r = 686.61 \cdot kip$

DECK DESIGN :

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

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

$Deck_{dl} := E_w \cdot t \cdot WT_{wood}$ → $Deck_{dl} = 0.49 \cdot klf$

$Misc_{dl} := 0.2klf$

$DC := Deck_{dl} + Misc_{dl}$ → $DC = 0.69 \cdot klf$

$M_{DC} := \frac{DC \cdot design\_span^2}{8}$ → $M_{DC} = 31.05 \cdot ft \cdot kip$

$V_{DC} := DC\left(\frac{design\_span}{2} - t\right)$ → $V_{DC} = 5.83 \cdot kip$

Dead load and Moments for Asphalt Wearing Surface

$DW := E_w \cdot wearing\_surface \cdot WT_{asphalt}$ → $DW = 0.67 \cdot klf$

$M_{DW} := \frac{DW \cdot design\_span^2}{8}$ → $M_{DW} = 30.21 \cdot ft \cdot kip$

$V_{DW} := DW\left(\frac{design\_span}{2} - t\right)$ → $V_{DW} = 5.68 \cdot kip$

Maximim HL93 Vehicle Moment : LRFD 3.6.1.2.2

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

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

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

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

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

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

→ $MMax_{LL} = 190.13 \cdot ft \cdot kip$

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

$M_{laneload} = 28.88 \cdot ft \cdot kip$

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

$M\_HL93 = 219.01 \cdot ft \cdot kip$

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

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

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

$Q_{flexure} = 467.39 \cdot ft \cdot kip$

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

Flexure_check = "OK"

SHEAR CHECK

Critical Section location for Live Load Shear : LRFD 8.7 from support

$t = 12.25 \cdot in$

Maximum Shear Live Load placement

$Dist := \text{if}\left(3 \cdot t < \frac{1}{4} \cdot design\_span, 3 \cdot t, \frac{1}{4} \cdot design\_span\right)$

$Dist = 3.06 \cdot ft$

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

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

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

$$V_{max\_LL} := V_{max}\left(\frac{Dist}{ft}\right) \qquad V_{max\_LL} = 36.68 \cdot kip$$

$$V\_LaneLoad := .64\frac{kip}{ft} \cdot \left(\frac{design\_span}{2} - t\right) \qquad V\_LaneLoad = 5.43 \cdot kip$$

$$V\_HL93 := V_{max\_LL} + V\_LaneLoad \qquad V\_HL93 = 42.1 \cdot kip$$

$$Q_{shear} := \eta_i\left(\gamma_{DC} \cdot V_{DC} + \gamma_{DW} \cdot V_{DW} + \gamma_{LL} \cdot V\_HL93\right) \qquad Q_{shear} = 89.49 \cdot kip$$

$$Shear\_Check := \begin{cases} \text{"OK"} & \text{if } V_r \geq Q_{shear} \\ \text{"no good Re-run"} & \text{otherwise} \end{cases} \qquad Shear\_Check = \text{"OK"}$$

DECK DEFLECTION :

Live Load Deflection limited to L/425 LRFD 2.5.2.6.2

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

$$\Delta_{truck} := \frac{P_{EQ} \cdot design\_span^3}{48 \cdot E \cdot I_x} \qquad \Delta_{truck} = 0.42 \cdot in$$

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

$$\Delta_{tandem} = 0.49 \cdot in$$

$$\Delta_{lane\_load} := \frac{5 \cdot .64\frac{kip}{ft} \cdot design\_span^4}{384 \cdot E \cdot I_x} \qquad \Delta_{lane\_load} = 0.08 \cdot in$$

$$\Delta_{tr} := \begin{cases} \left(\Delta_{truck}\right) & \text{if } \Delta_{truck} \geq \Delta_{tandem} \\ \left(\Delta_{tandem}\right) & \text{otherwise} \end{cases} \qquad \Delta_{tr} = 0.49 \cdot in$$

$$\Delta_{LL} := \begin{cases} \left(.25 \cdot \Delta_{tr} + \Delta_{lane\_load}\right) & \text{if } \left(.25 \cdot \Delta_{tr} + \Delta_{lane\_load}\right) > \Delta_{tr} \\ \Delta_{tr} & \text{otherwise} \end{cases} \qquad \Delta_{LL} = 0.49 \cdot in$$

$\Delta_{LL\_allow} := \frac{design\_span}{425}$ $\Delta_{LL\_allow} = 0.54 \cdot in$

$\Delta_{ratio} := \frac{design\_span}{\Delta_{LL}}$ $\Delta_{ratio} = 461.17$

Deflection_Check := "Deflection is good" if $\Delta_{LL\_allow} \geq \Delta_{LL}$
"excessive deflction re-run" otherwise

Deflection_Check = "Deflection is good"

BEARING CHECK :

Maximum Shear reaction at abutment

$V\_LaneLoad1 := .64 \frac{kip}{ft} \cdot \left(\frac{design\_span}{2} \right)$ $V_{br} := \left(V_{max}\left(\frac{0}{ft} \right) \right) + V\_LaneLoad1 = 50.82 \cdot kip$

$Q_{cpo} := \eta_i \left[\left(\gamma_{DC} \cdot \frac{DC \cdot design\_span}{2} + \gamma_{DW} \cdot \frac{DW \cdot design\_span}{2} \right) + \gamma_{LL} \cdot V_{br} \right]$ $Q_{cpo} = 106.64 \cdot kip$

Bearing_Check := "Bearing Check - OK" if $P_r \geq Q_{cpo}$
"no good Re-Run" otherwise

Bearing_Check = "Bearing Check - OK"

STIFFENERS LRFD 9.9.4.3

Maximum stiffener spacing = 8'

$Stiff\_qty := \left[ceil\left[\frac{\left(\frac{design\_span}{2} \right)}{8 \cdot ft} \right] 2 \right] - 1 = 3$

$Stiff\_spacing := \left(\frac{design\_span}{Stiff\_qty + 1} \right) = 4.75 \cdot ft$

Stiffener_size = 6 3/4" x 4 1/2" Identification No. 2 DF Dry Stress Values apply Min EI Req'd = 80,000 kip-in^2

$I := \frac{6.75in \cdot (4.5in)^3}{12} = 51.26 \cdot in^4$ $E_o = 1600000 \cdot psi$ $E_o \cdot I = 82012.5 \cdot kip \cdot in^2$