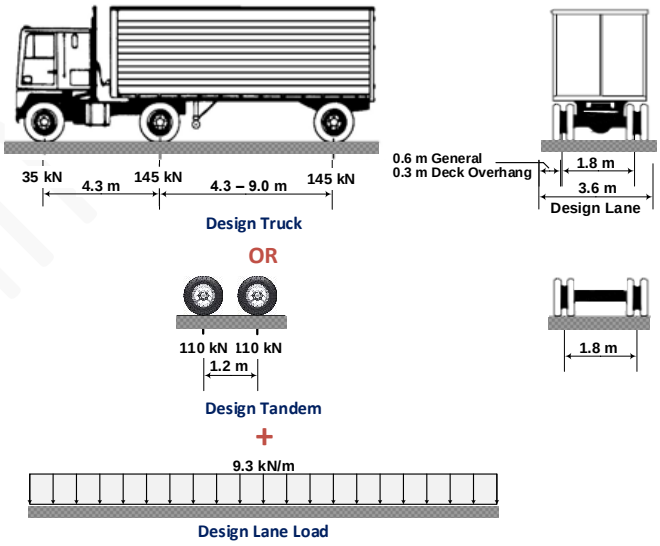
AASHTO Specifications

General

- L , S (mm) = center/center of supports
- h_{min} (mm) = $0.04(S+3000)$ **or** $0.033(S+3000)$ [simply supported **or** continuous slab bridge]
  = $0.07L$ [simple supported beam bridge]
- Υ_c (kN/m^3) = 24
- Υ_{as} (kN/m^3) = 22.5
- c_c (mm) = 25 **or** 50 [slab bottom **or** slab top and beam]
- $E_c = 0.043 K_1 {\Upsilon_c}^{1.5} \sqrt{f'_c}$
- $f_r = 0.63\sqrt{f'_c}$
- $M_{cr} = f_r . S_{nc}$
- $c = (A_{ps}.f_{pu} + A_s.f_s + A'_s.f'_s)/(0.85 f'_c.\beta_1.b + k.A_{ps}.f_{pu}/d_{ps})$
- $\beta_1 = 0.85 - 0.05(f'_c - 28)/7$ [$28 \le f'_c$ (MPa) ≤ 55]
- $a = \beta_1 . c$
- $M_n = A_{ps}.f_{ps}\left(d_{ps} - \frac{a}{2}\right) + A_s.f_s\left(d_s - \frac{a}{2}\right) - A'_s.f'_s\left(d'_s - \frac{a}{2}\right)$ [rectangular section]
- $M_n = A_{ps}.f_{ps}\left(d_{ps} - \frac{a}{2}\right) + A_s.f_s\left(d_s - \frac{a}{2}\right) - A'_s.f'_s\left(d'_s - \frac{a}{2}\right) + 0.85 f'_c (b - b_w) h_f \left(\frac{a}{2} - \frac{h_f}{2}\right)$ [T-section]

LRFD Specifications

- $R_r = \phi . R_n \ge Q_u$
- $Q_u = 1.25DC + 1.50DW + 1.75(LL + IM)$
- $LL + IM = DF[(1 + IM)Q_{Mo} + Q_{Ln})$
- ϕ_f = 0.9 **or** 1.0 [reinforced **or** prestressed]
- $\phi_v = 0.9$
- $M_r \ge M_u$
  $\ge 1.2 M_{cr}$
- $V_r \ge V_u$



Live Load

- IM = 0.33
- $N_L = INT(w/3.6)$
- m = 1.20, 1.00, 0.85 **or** 0.65 [N_L = 1, 2, 3 **or** > 3]

Equivalent Strip Widths for Slab Bridges

- L_1 (mm) = $S \le 18000$
- W_1 (mm) = $W \le 9000$ [$N_L = 1$] ≤ 18000 [$N_L \ge 2$]
- E_{si} (mm) = $250 + 0.42\sqrt{L_1 W_1}$ [$N_L = 1$]
- E_{mi} (mm) = $2100 + 0.12\sqrt{L_1 W_1} \le W/N_L$ [$N_L \ge 2$]
- E_{int} (mm) = $E_{mi} \ge E_{si}$
- E_{ext} (mm) = $E_{beam} = E_{edge} = W_e + 300 + E_{int}/4$
  $\le E_{int}/2$
  ≤ 1800

Main Reinforcement

- A_s (mm^2/m) = $1.25 M_u / f_y . d_s$
- $\varepsilon_t = 0.003[(d_t - c)/c] \ge 0.005$
- $M_r \ge 1.2 M_{cr} \le 1.33 M_u$

Distribution Reinforcement

- $A_{s,Dist}$ (mm^2/m) = $\%A_s$
- % = $17.5/\sqrt{S\ (\text{mm})} \le 0.50$ [$A_s \parallel$ traffic]
- % = $38.4/\sqrt{S\ (\text{mm})} \le 0.67$ [$A_s \perp$ traffic]

Shrinkage and Temperature Reinforcement

- $A_{s,S+T}$ (mm^2/m) $\geq 750b.h/2(b+h)f_y$
- $233 \leq A_{s,S+T} \leq 1270$

Reinforcing Bars Spacing

- s_{min} (mm) $= 1.5\emptyset_b \geq 1.5d_{agg.} \geq 38$ [reniforcing bars]
- s_{min} (mm) = Tablulated Value $\geq 1.33d_{ag}$ [prestressing steel]
- s_{min} (mm) $= 25 \geq \emptyset_b$ [mutilayers]
- s_{max} (mm) $= 1.5h \leq 3h\ [A_{s,S+T}] \leq 450$

$\emptyset_p$	s_{min}
14.29 - 15.24	51
11.11 - 12.70	44
9.53	38

Shear Reinforcement

- w_b(mm) $= 300$
- $x = d_v + 0.5w_b$
- $V_n = 0.25f_c'.b_v.d_v$
  $\geq V_c + V_s + V_p$
- $\phi_v.V_n \geq V_u$ [section is adequate]
- $V_c = 0.166\sqrt{f_c'}.b_v.d_v$
- $\phi_v.V_c \geq V_u \rightarrow s_{max}$ [mm] $= A_v.f_y/(0.083\sqrt{f_c'}.b_v)$
- $\phi_v.V_c < V_u \rightarrow s$ [mm] $= A_v.f_y.d_v/V_s$
- $v_u = V_u/\phi_v.b_v.d_v$
- s_{max} (mm) $= 0.8d_v \leq 600$ $[v_u < 0.125f_c']$
  $= 0.4d_v \leq 300$ $[v_u \geq 0.125f_c']$

Prestressed Girders

Stress Limits

- $f_{ci} = 0.6f_{ci}'$
- $f_{ti} = 0.63\sqrt{f_{ci}'}$ [with bonded reinforcement]
  $= 0.25\sqrt{f_{ci}'} \leq 1.38$ MPa [without bonded reinforcement]
- $f_c \leq 0.45f_c'$
- $f_t \leq 0.50\sqrt{f_c'}$
- $f_{pi} \leq 0.75f_{pu}$
- $f_{pe} \leq 0.80f_{py}$
- $f_{pe} = (1 - losses)f_{pi}$

Prestressing Required

- $f_{bot} = \frac{M_{DC1}}{S_{bg}} + \frac{M_{DC2}+M_{DW}+0.8M_{(LL+IM)}}{S_{bcg}}$
- $f_{c,pe} = f_{bot} - f_t = \frac{P_e}{A_g} + \frac{P_e.e_c}{S_{bg}}$
- $e_c = y_{bg} - y_{bp}$
- $y_{bp} = (0.05 \sim 0.15)h_g$
- $P_{i,p} = A_p.f_{pi}$

Check of Stresses

- $f_{i,top} = -\frac{P_i}{A_g} + \frac{P_i.e}{S_{tg}} - \frac{M_g}{S_{tg}}$
- $f_{i,bot} = -\frac{P_i}{A_g} - \frac{P_i.e}{S_{bg}} + \frac{M_g}{S_{bg}}$

- $f_{top} = -\frac{P_e}{A_g} + \frac{P_e.e}{S_{tg}} - \frac{M_{DC1}}{S_{tg}} - \frac{M_{DC2}+M_{DW}+0.8M_{(LL+IM)}}{S_{tcg}}$
- $f_{bot} = -\frac{P_e}{A_g} - \frac{P_e.e}{S_{bg}} + \frac{M_{DC1}}{S_{bg}} + \frac{M_{DC2}+M_{DW}+0.8M_{(LL+IM)}}{S_{bcg}}$

Section Strength

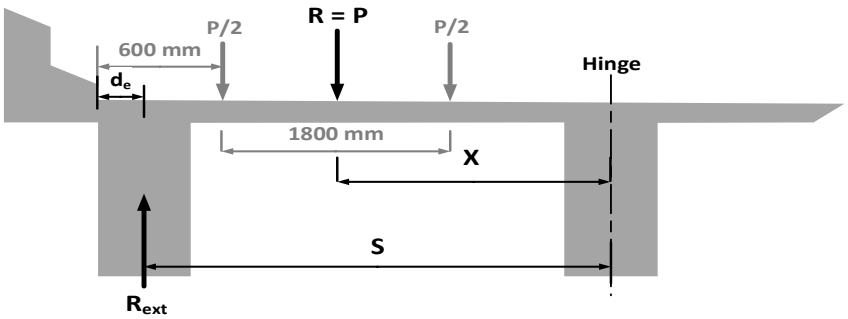
- $k = 2(1.04 - f_{py}/f_{pu})$
- $d_{ps} = h - y_{bp}$
- $f_{ps} = f_{pu}(1 - k.c/d_{ps})$
- $M_{cr} = (f_r + f_{c,pe} - M_{D,nc}/S_{bg})S_{bcg} \geq f_r.S_{bcg}$
- $d_e = (A_s.f_s.d_s + A_{ps}.f_{ps}.d_{ps})/(A_s.f_s + A_{ps}.f_{ps})$
- $d_v = d_e - a/2 \geq 0.9d_e \geq 0.72h_c$

Steel Girders

- $f_{top} = \frac{M_{DC1}}{S_{tg}} + \frac{M_{DC2}+M_{DW}}{S_{tcgA}} + \frac{M_{(LL+IM)}}{S_{tcgB}}$
- $f_{bot} = \frac{M_{DC1}}{S_{bg}} + \frac{M_{DC2}+M_{DW}}{S_{bcgA}} + \frac{M_{(LL+IM)}}{S_{bcgB}}$

Distribution of Live Load per Lane for Concrete Deck on Steel or Concrete Beams

Location	Action	Equation	Range of Applicability
Interior	Moment	***Single Lane Loaded*** $DFM_{si} = 0.06 + \left(\frac{S}{4300}\right)^{0.4}.\left(\frac{S}{L}\right)^{0.3}.\left(\frac{K_g}{L.h_s^3}\right)^{0.1}$	$N_g \geq 4$ $6x10^3 \leq L \leq 73x10^3$ mm $1.1x10^3 \leq S \leq 4.9x10^3$ mm $110 \leq h_s \leq 300$ mm $4x10^9 \leq K_g \leq 3x10^{12}$ mm^2
		Multiple Lanes Loaded $DFM_{mi} = 0.075 + \left(\frac{S}{2900}\right)^{0.6}.\left(\frac{S}{L}\right)^{0.2}.\left(\frac{K_g}{L.h_s^3}\right)^{0.1}$	
	Shear	***Single Lane Loaded*** $DFV_{si} = 0.36 + S/7600$	
		Multiple Lanes Loaded $DFV_{mi} = 0.2 + \frac{S}{3600} - \left(\frac{S}{10700}\right)^2$	
Exterior	Moment	***Single Lane Loaded*** **Use Lever Rule**	$-300 \leq d_e \leq 1700$ mm
		Multiple Lanes Loaded $DFM_{me} = e.DFM_{mi}$ $e = 0.77 + d_e/2800$	
	Shear	***Single Lane Loaded*** **Use Lever Rule**	
		Multiple Lanes Loaded $DFV_{me} = e.DFV_{mi}$ $e = 0.6 + d_e/3000$	



Lever Rule for Exterior Beam

Maximum Live Load Moments Per Unit Width (N.mm/mm)

S mm	Positive Moment	Negative Moment						
		Distance from CL of Girder to Design Section for Negative Moment						
		0.0 mm	75 mm	150 mm	225 mm	300 mm	450 mm	600 mm
1300	21 130	11 720	10 270	8940	7950	7150	6060	5470
1400	21 010	14 140	12 210	10 340	8940	7670	5960	5120
1500	21 050	16 320	14 030	11 720	9980	8240	5820	5250
1600	21 190	18 400	15 780	13 160	11 030	8970	5910	4290
1700	21 440	20 140	17 290	14 450	12 010	9710	6060	4510
1800	21 790	21 690	18 660	15 630	12 930	10 440	6270	4790
1900	22 240	23 050	19 880	16 710	13 780	11 130	6650	5130
2000	22 780	24 260	20 960	17 670	14 550	11 770	7030	5570
2100	23 380	26 780	23 190	19 580	16 060	12 870	7410	6080
2200	24 040	27 670	24 020	20 370	16 740	13 490	7360	6730
2300	24 750	28 450	24 760	21 070	17 380	14 570	9080	8050
2400	25 500	29 140	25 420	21 700	17 980	15 410	10 870	9340
2500	26 310	29 720	25 990	22 250	18 510	16 050	12 400	10 630
2600	27 220	30 220	26 470	22 730	18 980	16 480	13 660	11 880
2700	28 120	30 680	26 920	23 170	19 420	16 760	14 710	13 110
2800	29 020	31 050	27 300	23 550	19 990	17 410	15 540	14 310
2900	29 910	32 490	28 720	24 940	21 260	18 410	16 800	15 480
3000	30 800	34 630	30 790	26 960	23 120	19 460	18 030	16 620
3100	31 660	36 630	32 770	28 890	23 970	21 150	19 230	17 780
3200	32 500	38 570	34 670	30 770	26 880	22 980	20 380	18 910
3300	33 360	40 440	36 520	32 600	28 680	24 770	21 500	20 010
3400	34 210	42 250	38 340	34 430	30 520	26 610	22 600	21 090
3500	35 050	43 970	40 030	36 090	32 150	28 210	23 670	22 130
3600	35 870	45 650	41 700	37 760	33 810	29 870	24 700	23 150
3700	36 670	47 250	43 310	39 370	35 430	31 490	25 790	24 140
3800	37 450	48 820	44 880	40 940	37 010	33 070	27 080	25 100
3900	38 230	50 320	46 390	42 460	38 540	34 600	28 330	25 550
4000	38 970	51 790	47 870	43 950	40 030	36 110	29 570	26 410
4100	39 710	53 190	49 280	45 370	41 470	37 570	30 770	27 850
4200	40 420	54 560	50 670	46 770	42 880	38 990	31 960	28 730
4300	41 120	55 880	52 000	48 130	44 250	40 380	33 130	29 570
4400	41 800	57 150	53 290	49 440	45 580	41 720	34 250	30 400
4500	42 460	58 420	54 580	50 740	46 900	43 060	35 380	31 290
4600	43 110	59 620	55 800	51 980	48 160	44 340	36 700	32 360