Example 3.8

Determine the design bending moment and shear force a two-lane reinforced concrete slab bridge of simple span of 15 m between centers of bearings for which the cross section is shown below. The slab is to be provided with a 50 mm thick nonstructural overlay as well has a provision of 1.2 kN/m² for future wearing surface (FWS). The traffic barriers are 0.5 m wide at the base and weigh 7.5 kN/m each.

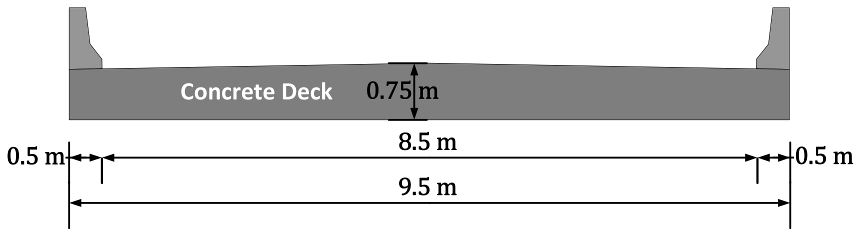


Figure 3-16: Details for Example 3.8

Solution 3.8

From structural perspective, the design of the slab would be based on 1 m wide.

Interior Strip

Unfactored Loads Per Unit Width:

- Dead loads:

$w_d = (h_d + h_{ns})b\Upsilon_c = (0.75 + 0.05)(1)(24) = 19.2 \text{ kN/m}$

$w_{DC} = w_d = 19.2 \text{ kN/m}$

$M_{DC} = w_{DC}L^2/8 = (19.2)(15)^2/8 = 540 \text{ kN.m}$

$V_{DC} = w_{DC}L/2 = (19.2)(15)/2 = 144 \text{ kN}$

$w_{ws} = q_{ws}b = (1.2)(1) = 1.2 \text{ kN/m}$

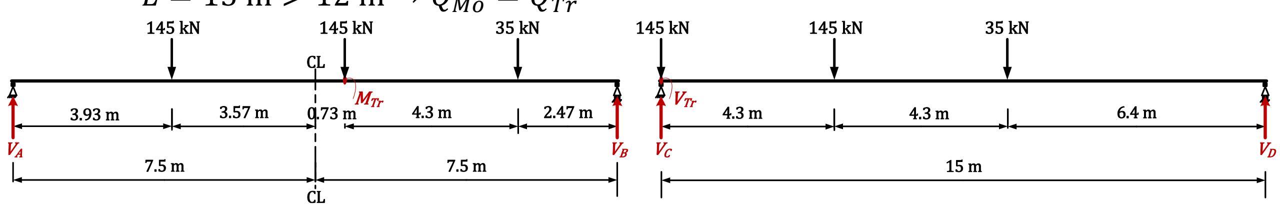
$w_{DW} = w_{ws} = 1.2 \text{ kN/m}$

$M_{DW} = w_{DW}L^2/8 = (1.2)(15)^2/8 = 33.75 \text{ kN.m}$

$V_{DW} = w_{DW}L/2 = (1.2)(15)/2 = 9 \text{ kN}$

- Live loads:

$L = 15 \text{ m} > 12 \text{ m} \rightarrow Q_{Mo} = Q_{Tr}$



$\Sigma M_B = 0 \curvearrowright^{+}$

$V_A\,(15) = (35)(2.47) + (145)(6.77 + 11.07)$

$\therefore V_A = 178.22 \text{ kN}$

$M_{Tr} = (178.22\,)(8.23) - (145)(4.3) = 843.25 \text{ kN.m}$

$\Sigma M_D = 0 \curvearrowright^{+}$

$V_C\,(15) = (35)(6.4) - (145)(10.7 + 15)$

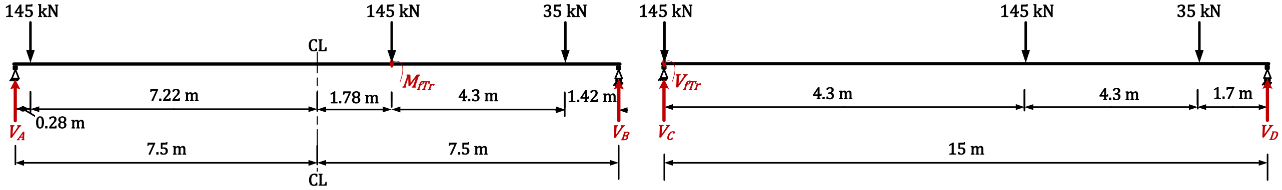
$\therefore V_C = 263.37 \text{ kN}$

$V_{Tr} = V_C = 263.37 \text{ kN}$

$w_{Ln} = 9.3$ kN/m

$M_{Ln} = w_{Ln}L^2/8 = (9.3)(15)^2/8 = 261.56$ kN. m

$V_{Ln} = w_{Ln}\,L/2 = (9.3)(15)/2 = 69.75$ kN



$\Sigma M_B = 0 \curvearrowright^{+}$

$V_A\,(15) = (35)(1.42) + (145)(5.72 + 10.02)$

$\therefore V_A = 155.47$ kN

$M_{fTr} = (155.47\,)(9.25) - (145)(9) = 133.1$ kN.m

Equivalent strip width and distribution factor:

$w = 9$ m

$N_L = \text{INT}(w/3.6) = \text{INT}(8.5/3.6) = 2$

$\because N_L = 2 \rightarrow \therefore$ check both E_{i1} and E_{i2}

$L_1 = L = 15$ m

≤ 18 m governs

$W_1 = W = 9.5$ m governs

≤ 18 m

$E_{i1} = 0.25 + 0.42\sqrt{L_1 W_1}$

$= 0.25 + 0.42\sqrt{(15)(9.5)} = 5.26$ m

$E_{i2} = 2.10 + 0.12\sqrt{L_1 W_1}$

$= 2.10 + 0.12\sqrt{(15)(9.5)} = 3.53$ m governs

$\leq W/N_L = 9.5/2 = 4.75$ m

$\therefore E_i = 3.53$ m

$DF_{im} = DF_{iv} = 1/E_i = 1/3.53 = 0.28$

$DF_{ifm} = DF_{ifv} = m_1/E_{i1} = 1.2/5.26 = 0.23$

$DF_{\Delta} = m_2 = 1.0$

Total live load:

$M_{LL+IM} = [M_{Tr}(1 + IM) + M_{Ln}]DF_{im}$

$= [843.25(1.33) + 261.56](0.28) = 387.26$ kN.m

$V_{LL+IM} = [V_{Tr}(1 + IM) + V_{Ln}]DF_{iv}$

$= [263.37(1.33) + 69.75](0.28) = 117.61$ kN

$M_{f+IM} = \left[M_{fTr}(1 + IM)\right]DF_{ifm}$

$= [133.1(1.15)](0.23) = 35.2$ kN.m

Strength Limit State:

$\eta_i = 1.0$

$M_{u1} = \eta_i[1.25M_{DC} + 1.50M_{DW} + 1.75M_{LL+IM}]$

$$= 1.25(540) + 1.50(33.75) + 1.75(387.26) = 1403.33 \text{ kN.m}$$

$$V_{u1} = \eta_i[1.25M_{DC} + 1.50M_{DW} + 1.75M_{LL+IM}]$$

$$= 1.25(144) + 1.50(9) + 1.75(117.61) = 399.32 \text{ kN}$$

Fatigue Limit State:

$$M_{f1} = 1.0M_{DC} + 1.0M_{DW} + 1.75M_{f+IM}$$

$$= 540 + 33.75 + 1.75(35.2) = 635.35 \text{ kN.m}$$

Service Limit State:

$$M_{s1} = 1.0M_{DC} + 1.0M_{DW} + 1.0M_{LL+IM}$$

$$= 540 + 33.75 + 387.26 = 961.01 \text{ kN.m}$$

Exterior Strip

Equivalent Strip Width:

$$W_e = 0.5 \text{ m}$$

$$E_e = W_e + 0.3 + E_i/4 = 0.5 + 0.3 + 3.53/4 = 1.68 \text{ m}$$

$$\leq E_i/2 = 3.53/2 = 1.77 \text{ m}$$

$$\leq 1.8 \text{ m}$$

$$\therefore E_e = 1.68 \text{ m}$$

Unfactored Loads Per Unit Width:

- Dead loads:

$$w_d = 19.2 \text{ kN/m}$$

$$w_{ba} = 7.5 \text{ kN/m}$$

$$w_{DC} = w_d + w_{ba} = 19.2 + 7.5 = 26.7 \text{ kN/m}$$

$$M_{DC} = w_{DC}L^2/8 = (26.7)(15)^2/8 = 750.94 \text{ kN.m}$$

$$V_{DC} = w_{DC}L/2 = (26.7)(15)/2 = 200.25 \text{ kN}$$

$$w_{ws} = 1.2 \text{ kN/m}$$

$$w_{DW} = w_{ws}(E_e - W_e)/E_e = 1.2(1.68 - 0.5)/1.68 = 0.84 \text{ kN/m}$$

$$M_{DW} = w_{DW}L^2/8 = (0.84)(15)^2/8 = 23.63 \text{ kN.m}$$

$$V_{DW} = w_{DW}L/2 = (0.84)(15)/2 = 6.3 \text{ kN}$$

- Live loads:

$$M_{eTr} = M_{Tr}/2 = 843.25/2 = 421.63 \text{ kN.m}$$

$$V_{eTr} = V_{Tr}/2 = 263.37/2 = 131.69 \text{ kN}$$

$$w_{Ln} = (9.3/3)(E_e - W_e) = (3.1)(1.68 - 0.5) = 3.66 \text{ kN/m}$$

$$M_{Ln} = w_{Ln}L^2/8 = (3.66)(15)^2/8 = 102.94 \text{ kN. m}$$

$$V_{Ln} = w_{Ln}\,L/2 = (3.66)(15)/2 = 27.45 \text{ kN}$$

Equivalent strip width and distribution factor:

$$DF_{em} = DF_{ev} = 1/E_e = 1/1.68 = 0.6$$

$$DF_\Delta = 1.0$$

Total live load:

$$M_{LL+IM} = [M_{Tr}(1 + IM) + M_{Ln}]DF_{em}$$

$$= [421.63(1.33) + 102.94](0.6) = 398.22 \text{ kN.m}$$

$$V_{LL+IM} = [V_{Tr}(1 + IM) + V_{Ln}]DF_{ev}$$
$$= [131.69(1.33) + 27.45](0.6) = 121.56 \text{ kN}$$

Strength Limit State:

$$\eta_i = 1.0$$
$$M_{u1} = \eta_i[1.25M_{DC} + 1.50M_{DW} + 1.75M_{LL+IM}]$$
$$= 1.25(750.94) + 1.50(23.63) + 1.75(398.22) = 1671 \text{ kN.m}$$
$$V_{u1} = \eta_i[1.25M_{DC} + 1.50M_{DW} + 1.75M_{LL+IM}]$$
$$= 1.25(200.25) + 1.50(6.3) + 1.75(121.56) = 472.49 \text{ kN}$$

Service Limit State:

$$M_{s1} = M_{DC} + M_{DW} + M_{LL+IM}$$
$$= 750.94 + 23.63 + 398.22 = 1172.79 \text{ kN.m}$$