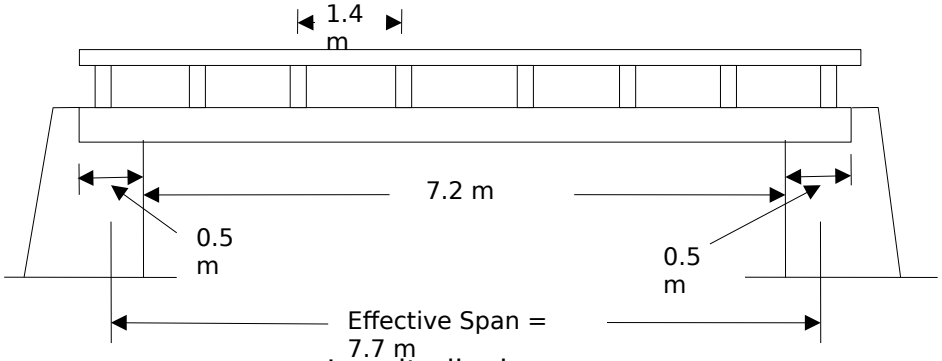
Slab Bridge - Design Example

Assumptions

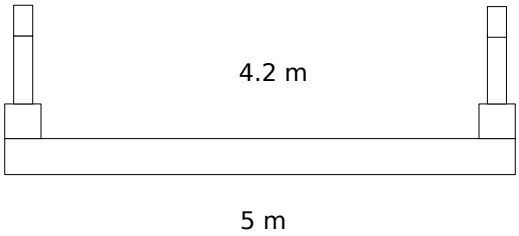
- Main reinforcements are placed parallel to the center line of road way
- The bottom of the slab is assumed level
- Center to center support is assumed perpendicular to the supports
- Additional amount of concrete thickness for cross fall is not considered for flexural design

Preliminary dimensions:

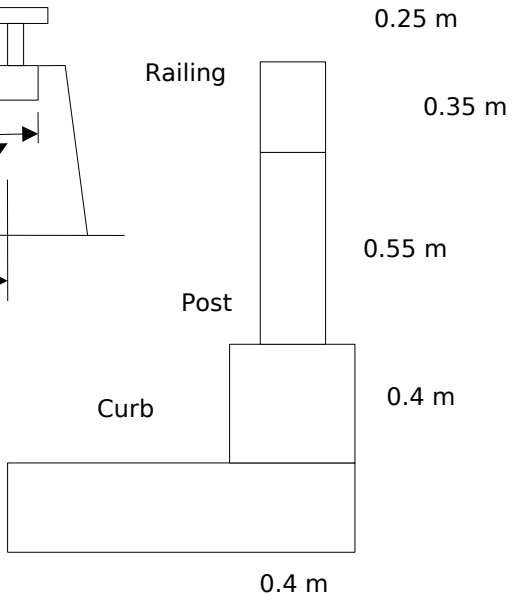
- Clear span = 7.2 m
- Width of abutment shelf = 0.5 m
- Clear width of super structure = 4.2 m
- Total width of super structure = 5 m
- No. of lane = 1
- Total length of super structure = 7.2 + 0.5 + 0.5 = 8.2 m
- Skewness angle = 0˚ 00' 00"
- Railing depth = 0.35 m
- Railing width = 0.25 m
- Post cross section = 0.25 m * 0.25 m
- Post height = 0.55 m
- Average post spacing = 1.4 m



Longitudinal



Cross sectional



Details of Curb, Post and

Materials:

- Concrete: f'_c = 30MPa
- Unit weight of concrete = 24 kN/m^3
- Steel: For bar size > 20 mm diameter,Grade:60: f_{yk} = 420 MPa
- For bar size <= 20 mm diameter, Grade:40: f_{yk} = 300 MPa

- $E_s = 2 * 10^5$MPa; E_c = 24000 MPa; .....spec pg3
- Modulus of rupture = $f_r = 0.63\sqrt{f'_c}$ = 3.45 MPa

Preliminary thickness of slab:

Depth of slab = 6% of the span length = (6/100)* 7700 = 462 mm (Normally the slab is made with a uniform depth over the whole bridge. **The required design depth is usually 5.5 - 6 % of the span length,** due to the width of the cracks. If **stressed reinforced** concrete is used, the design depth shall be reduced to **4.5 %of the span length.) …….spec pg 1**

- Consider overall depth of slab = 470 mm

Live loads:

Equivalent width of longitudinal strips per lane for both shear and moment with one lane =

- E_1 = 250 + 0.42 $\sqrt{L_1 W_1}$ mm L_1 = 7700 mm W_1 = 5000

E_1 = 250 + 0.42 $\sqrt{7700 * 5000}$ = 2856 mm = 2.86 m (***Equivalent strip widths for slab bridge*:** The equivalent width of longitudinal strips per lane for both shear and moment with one lane, i.e., two lines of wheels, loaded shall be determined as: $E = 250 + 0.42\sqrt{L_1 W_1}$ spec pg7

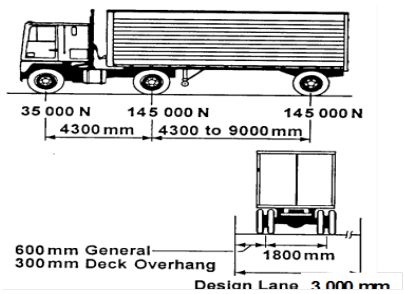
Impact factor (Dynamic load allowance): (1 + IM/100) = (1 + 33/100) = 1.33

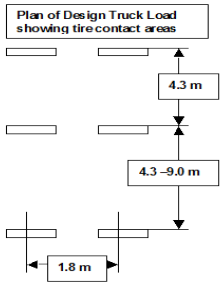
(The factor to be applied to the static load shall be taken as: **(1 + IM/100)**. The dynamic load allowance shall not be applied to pedestrian loads or to the design lane load.)

Component	IM
Deck Joints – All Limit States	75%
All Other Components • Fatigue and Fracture Limit State • All Other Limit States	 15% 33%

....(.loads)pg4

Design truck load:





Design Tandem The design tandem used for Strategic Bridges (see *Chapter 2: General Requirements*) shall consist of a pair of **110 kN** axles spaced **1.2 m apart**. The transverse spacing of wheels shall be taken as **1.8 m**. A dynamic load allowance shall be considered as specified in a following subchapter

Front axle load = 35 kN; Load dispersed per m in transverse direction = $\frac{35}{2.86}$ = 12.24kN/m

Other axle loads = 145 kN Load dispersed per m in transverse direction = $\frac{145}{2.86}$ = 50.7 kN/m

Design tandem load: Axle load = 110 kN; Load dispersed per m in transverse direction = 38.46kN/m.....(loads) pg 3

Lane load:

Load = 9.3 kN/m; (from ERA bridge design manual 2002, chapter 3)

Load dispersed per m in transverse direction = $\frac{9.3}{3}$ = 3.1kN/m²

Shear force calculation:

Loads on span:

50.7 kN 50.7 kN

4.3 m

38.46 kN 38.46 kN Tandem load Truck load

1.2 m Lane load = 3.1 kN/m2

A B

7.7 m

0.8442

1 0.4416

IL for maximum reaction at A

Maximum shear at A due to truck loads = 50.7 * 1 + 50.7 * 0.4416 = 73.09 kN

Maximum shear at A due to tandem loads = 38.46 * 1 + 38.46 * 0.8442 = 70.93 kN

Maximum shear at A due to lane load = 3.1 [½ * 7.7 * 1] = 11.94 kN

Design truck load governs.

with dynamic load allowance = (73.09 * 1.33) + 11.94 = 109.15 kN

3.6 Application of Design Vehicular Live Loads

The effects of **an axle sequence and the lane load are superimposed** in order to obtain extreme values. Unless otherwise specified, the extreme force effect shall be taken as the larger of the following:

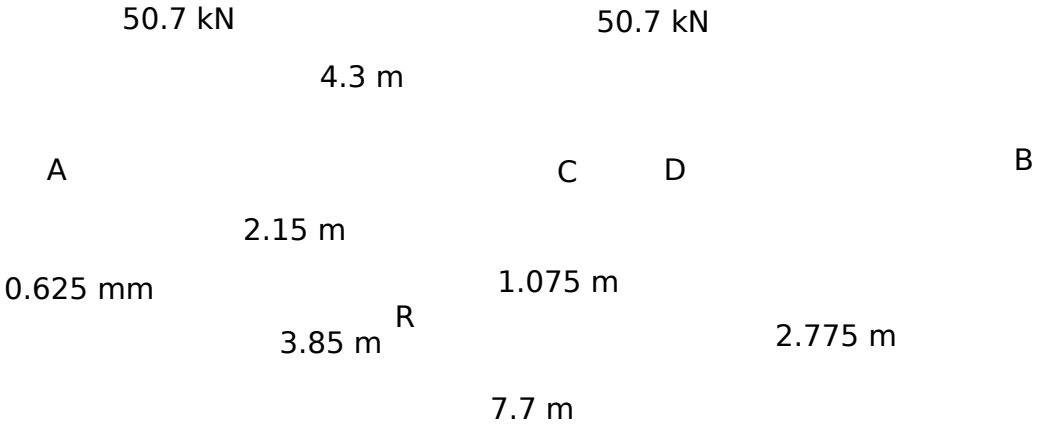
- The effect of the design tandem combined with the effect of the design lane load, or The effect of one design truck with the variable axle spacing specified in the subchapter *Multiple Presence of Live Load* above, combined with the effect of the design lane load, and
- For both negative and positive moment between points of contraflexure under a uniform load on all spans, and reaction at interior piers only, 90% of the effect of two design trucks spaced a minimum of 15.0 m between the lead axle of one truck and the rear axle of the other truck, combined with 90% of the effect of the design lane load. The distance between the 145 kN axles of each truck shall be taken as 4.3 m.

The design truck or tandem shall be positioned transversely such that the center of any wheel load is not closer than:.....(loads) pg 6

Bending moment calculation:

Absolute maximum bending moment due to moving loads is found by placing one of the axle loads and the resultant of the system at equidistant from the center.

For design truck load:



3.5 Tire Contact Area

The tire contact area of a wheel consisting of one or two tires shall be assumed to be a single rectangle, whose **width is 50 mm**.....ch3p5

The design truck or tandem shall be positioned transversely such that the center of any wheel load is not closer than:

- For the design of the deck **overhang - 300 mm** from the face of the curb or railing, and
- For the design of all **other components - 600 mm** from the edge of the design lane.....ch3p6

For this moving load of design truck, absolute maximum bending moment occurs at section D, for the load position shown .

(4.925 * 2.775)/7.7 = 1.775

0.225

ILD for bending moment at D

BM at D = 50.7 (1.775 + 0.225) = 101.4 kN m

For Design Tandem Load:

Load position for absolute maximum BM to occur at D, a section 0.3 m from mid span section is shown below.

Maximum BM at D = 38.46 * (1.9133 + 1.36) = 125.89 kN m

Hence the BM is governed by design tandem load

38.46 kN 38.46 kN

1.2 m

A B

C D

2.95 m

R 0.3 m

3.85 m 3.55 m 5

4.15 m

7.7 m

(4.15 * 3.55)/7.7 = 1.9133

ILD for BM at D

For Design Lane Load:

Lane load BM is determined at the section of maximum BM, section D, of design tandem loading

Lane load BM at D = 3.1*(7.7 * 1.9133)/2 = 22.84 kN m

Total maximum BM

Total maximum BM with IM = (125.89*1.33) + 22.84 = 190.27 kN m

Dead Loads

Assume depth of wearing surface = 0.075 m

Weight of wearing surface = 0.075 * 22.5 = 1.6875 kN/m^2

Weight of deck slab = 0.47 * 24 = 11.28 kN/m^2

Weight of railing, post and curb

=[{(0.35 * 0.25 * 24) + 0.7143 * (0.25 * 0.25 * 0.55 * 24) + (0.4 * 0.4 * 24)} * 2] ÷ 5

= 2.6 kN/m^2

Total weight of components DC = 11.28 + 2.6 = 13.88 kN/m^2

Maximum shear due to DC = V_{DC} = 13.88 [½ * 7.7 * 1] = 53.44 kN/m width

Maximum Shear due to DW = V_{DW} = 1.6875 [½ * 7.7 * 1] = 6.5 kN/m width

Maximum bending moment due to DC at the section of maximum LL BM

13.88 kN/m

4.15 m 3.55 m

4.15 * 3.55 / 7.7 =

BM at the section D due to the load DC = = 13.88 [½ * 7.7 * 1.9133] = 102.24 kNm

Maximum BM due to DW at the section of maximum LL BM = = 1.6875 [½ * 7.7 * 1.9133] = 12.43 kNm

Design load combination for strength I limit state

$$Q = \eta_i \gamma_i Q_i$$

Consider the design to be of conventional one, non-redundant and typical bridge, for these assumptions,

$\eta_D = 1.00$ $\eta_R = 1.05$ $\eta_I = 1.00$

Factored resistant moment $Mu = 1.05[1.25\ M_{DC} + 1.5M_{DW} + 1.75M_{LL+IM}]$ ch3pg22-23

$= 1.05[1.25\ (102.24\ ) + 1.5(12.43\ ) + 1.75(190.27)] =$ 479.4 kNm

3.12 Load Factors and Combinations

General

The total factored force effect: $Q = \Sigma\eta_i\gamma_i\ Q_i$ ---------- Equation 3.4 where:

η_i= load modifier (a factor relating to ductility, redundancy and operational importance)

Q_i = force effects from loads specified herein

γ_i = load factors ch3 p18

As per ERA bridge design manual LRF design procedure, factored resistant moment $M_u = \phi M_n$

Where, M_n = Nominal resistant moment,

Φ = Resistance factor

$M_n = M_u/\phi$, has to be used in the equation for steel ratio ρ

Steel ratio ρ can be written as,

$$\rho = \left[1 - \sqrt{1 - \frac{2M_u}{\varnothing b d^2 f_c^{'}}}\right]\frac{f_c^{'}}{f_y} = \left[1 - \sqrt{1 - \frac{2*479.4*10^6}{0.9*1000*433^2*30}}\right]\frac{30}{420} =$$

0.00712

ρ_{min} = 0.03 * (30/420) = 0.00241 <0.00712.....=0.03 fcd/fyd..... spec pg5

A_s = 0.00712 * 1000 * 433 = 3082.96 mm^2

Spacing of 24 mm diameter rods = $\frac{\pi * 12^2 * 1000}{3082.96}$ = 146.74 mm.....as1000/A_s

Provide 24 mm diameter rods at 140 mm c/c as main flexural reinforcement along the span.

As provided = $\frac{\pi * (12)^2 * 1000}{140} = 3231\, mm^2$

Distribution of main reinforcement to resist against cracking:

Concrete is considered cracked if tensile stress in concrete >= 80% of the modulus of rupture

f_r = Modulus of rupture = 3.45 MPa (as determined in the earlier steps)

Service load moment M_u = 1.05[1.00(102.24) + 1.00(12.43) + 1.00(190.27)] = 320.187 kNm

f_{ct} = tensile stress in concrete = M/Z = $\frac{320.187 * 10^6}{1000 * 470^2/6}$ = 8.69 MPa

$0.8f_r$ = 0.8 * 3.45 = 2.76; f_{ct}> $0.8f_r$ Therefore the section has to be taken as a cracked section

Steel stress: To find the steel stress, for cracked section, consider the equivalent transformed section of concrete.

Modular ratio = m = E_s/E_c = 2 * 10^5/24000 = 8.33; mA_s = 8.33 * 3231 = 26914.23 mm^2

x can be determined by taking moments of areas above and below NA

1000 * x * x/2 = 26914.23 (433 – x)

It can be reduced to a quadratic equation,

x^2 + 53.8x – 23307.7 = 0 X = 128.12 mm

Moment of inertia I = 1/3(1000 * 128.12^3) + 26914.23 $(433 – 128.12)^2$ = 3.2 * 10^9 mm^4

f_s/m = My/I = $\frac{320.187 * 10^6 * (433 - 128.12)}{3.2 * 10^9}$ = 30.5; f_s = 8.33 * 30.5 = 254.11 MPa

$f_{sa} = \frac{Z}{(d_c A)^{1/3}}$ Where Z = 30,000 for moderate exposure; d_c = 25 + 24/2 = 37 mm

$A = 2d_cS/1 = 2 * 37 * 140/1 = 10360\ mm^2$

$f_{sa} = \frac{30000}{[37(10360)]^{1/3}} = 412.98$ MPa But $f_{sa} = \frac{Z}{(d_c A)^{1/3}} \leq 0.6\ f_y$; 0.6(420) = 252 MPa

$f_s > f_{sa}$ Hence the provision of spacing of main reinforcement is **not safe** against cracking.

The spacing of reinforcement shall be adjusted to satisfy the above criterion

Distributor reinforcement

For primary reinforcement parallel to traffic, % of main reinforcement as distributor reinforcement =

$$1750/\sqrt{s} \leq 50\%$$

Where S = Span length = 7.7m = 7700 mm

$$1750/\sqrt{7700} = 20\%$$

20% of main reinforcement = (20/100)*3231 = 646.2 mm^2

Spacing of 16 mm dia rods = $\frac{\pi(8^2)1000}{646.2}$ = 311.15 mm

Provide 16 mm diameter rods at 300 mm c/c as distribution reinforcement

Temperature and shrinkage reinforcement

Temperature and shrinkage reinforcement $A_s \geq 0.75\ A_g/f_y$

$A_s = 0.75 * 1000*470/420 = 839.3\ mm^2$ for both direction

For top layer alone: A_s = 839.3/2 = 419.6 mm2

Spacing of 12 mm dia rods = $\frac{\pi(6^2)1000}{419.6}$ = 269.5 mm

Provide 12 mm dia rods at 260 mm C/C in both directions at the top as temperature and shrinkage reinforcements.