DECK SLAB BRIDGE

Reinforced concrete slab type decks are referred to as culverts and are commonly used for small spans. This type of super structure is economical for span up to 8 m. Slab decks are simpler for construction due to easier fabrication of form work, reinforcement detailing and placement of concrete. In case of culverts, the slab is supported on two opposite sides on piers or abutments. The deck slab is designed as a one way slab to support the dead and live loads with impact. NH bridge deck slabs are designed to support IRC Class AA or A type vehicle loads whichever gives the worst ~~cond~~ effect.

IRC : 21-2000 code prescribes the following guide lines for control of cracking in concrete to satisfy the serviceability requirements under the limit state of local damage

a) For slabs, the diameter and spacing of reinforcing bars shall not exceed 25 mm and 150 mm respectively.

b) For beams, including top and bottom flanges in rectangular voided slab and box beams and for solid slabs; the diameter and spacing of reinforcing bar shall not exceed 32 mm and 150 mm respectively.

c) For columns; the diameter and spacing of reinforcing bar shall not exceed 32 mm and 300 mm.

The detailing of reinforcements in all the structural components of bridge deck should conform to the following cover requirements to ensure durability and serviceability.

i) Minimum clear cover to any reinforcement bar closest to the concrete surface shall be 40 mm.

ii) Under severe exposure conditions, the min^m cover shall be ~~iner~~ 50 mm

iii) In case of foundations, the min^m clear cover = 75 mm.

iv) For factory made, precast concrete elements, the minimum cover mentioned above can be reduced by 5 mm.

The diameter and spacing of bars should conform to the following specifications:

i) Max^m dia of reinforcing bar is limited to 40 mm.

ii) Dia of transverse ties, helicals, stirrups and all secondary reinforcement should not be less than 8 mm.

iii) Dia of longitudinal reinforcements in a column should not be less than 12 mm

iv) Dia of reinforcements in slabs is restricted to 1/10^th the depth of slab.

v) Dia of shear reinfor. ~~in webs of beams~~ in webs of beams, including cranked bars should be limited to 1/8^th the thickness of the web.

vi) The hori spacing bet^n two parallel reinforcing bars should satisfy following requirements:—

a) Dia of bar, if diameters are equal.

b) Dia of largest bar if diameters are unequal.

c) 10 mm more than nominal size of coarse aggregate used in concrete.

vii) Min^m vertical distance between two horizontal main reinforcing bars shall be 12 mm or max^m diameter of the coarse aggregate or the max^m size of bar, whichever is greater.

viii) Modular ratio 'm' = 10 as per specifications of IRC:21-2000.

Analysis of Deck slabs

RC slab decks used for small span culverts are generally spanning in one direction and hence the moments due to DL & LL's are critical in longitudinal dir^n i.e. the dir^n of moving loads.

a) Solid slabs spanning in one direction

The DL moments are directly computed assuming the slab to be simply supported bet^n the bearings. Live loads of vehicles transmitted through wheels are considered as concentrated loads spread over the contact area of the tyres with the deck slab. BM per unit width of slab developed by conc. loads on solid slabs may be calculated by assuming the width of slab considered as effective in resisting the BM due to concentrated loads.

IRC:21-2000 code specifies the method of computing effective width of slab, by considering various parameters like the span length, dimensions of slab and concentration area of the wheel load.

i) For single concentrated load;

Effective width $\boxed{b_e = Kx\left[1 - \frac{x}{L}\right] + b_w}$

b_e = eff. width of slab on which the load acts

L = eff. span

x = distance of c.g of load from nearer support

b_w = breadth of concentration area of load i.e. dimensions of tyre or track contact area over the road surface of slab in a direction at right angles to the span plus twice the thickness of wearing coat or surface finish above the structural slab.

K = constant depending on B/L ratio

The eff. width shall not exceed the actual width of the slab.

2) b) Two or More concentrated loads in line in the dir^n of span:

When two or more concentrated loads are positioned in a line in the direction of span, the BM per unit width of slab shall be calculated seperately for each load according to its appropriate effective width of slab as specified under single conc load.

3) a) Two or more concentrated loads not in line in the dir^n of span

In case, where effective width of slab for one load overlaps the other effective width of slab for an adjacent load; the resultant effective width for the two loads equals the sum of the effective widths for each load minus the width of overlap, b shall be considered.

b) Solid Cantilever Slab

The effective width of dispersion in the dir^n parallel to the supported edge for single concentrated load: is;

$$b_e = 1.2x + b_w$$

b_e = effective width

x = distance of cg of concentrated load from face of cantilever support.

b_w = breadth of concentration area of the load i.e. the dimension of tyre contact area over the road surface of slab in a direction parallel to supporting edge of cantilever plus twice the thickness of wearing coat or surface finish above the structural slab.

c) Dispersion of Loads along the span.

The effective length of dispersion along the span;

$$V = x + 2(D + H)$$

D = depth of the wearing coat

H = depth of slab

x = wheel load contact area along the span.

V = eff length of dispersion along the span.

d) Dispersion of Loads in slabs spanning in two directions

In bridge decks comprising slab integrally cast with longitudinal and cross girders as in case of T-beams and slab decks; the moments developed due to wheel loads on the slab both in longitudinal and transverse directions.

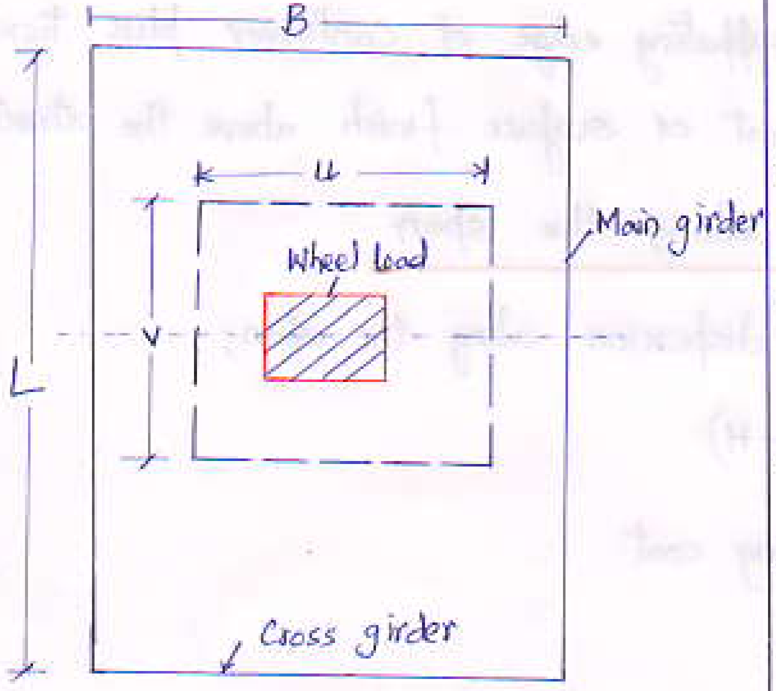
These moments are computed by using design curves developed by M. Pigeaud or Westergaard's method. Pigeaud's method is applicable to rectangular slabs supported freely on all the four sides and the slab should be symmetrically loaded as shown in figure.

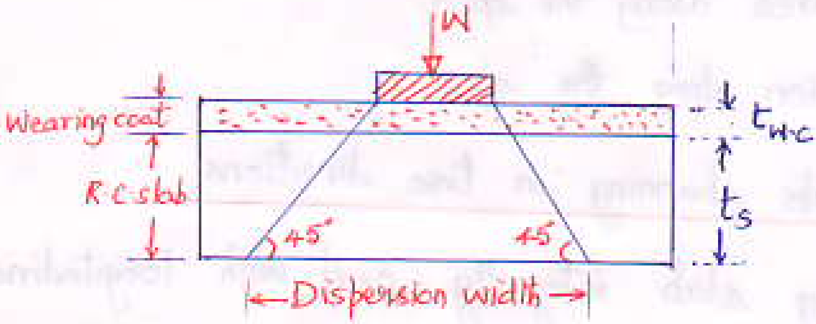
The following notations are used;

L = long span length

B = short span length

u & v = Dimensions of load spread after allowing for dispersion through the wearing coat and structural slab.





Dispersion of wheel load thr wearing coat and deck slab @ 45°

K = Ratio of short to long span $= B/L$

M_1 = Moment in short span dir^n

M_2 = Moment in the long span dir^n

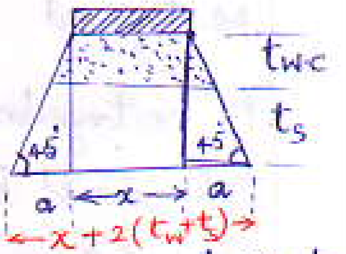
m_1 & m_2 = Co-efficients for moments along short and long spans

μ = Poisson's ratio for concrete, assumed as 0.15 as per IRC: 21-2000

W = wheel load under consideration

According to IRC: 21-2000 specifications, the dispersion of wheel or track load may be assumed at 45° through the wearing coat and structural slab.

$\therefore$ Dispersion width = Tyre contact + $2(t_w + t_s)$



$\tan 45° = \dfrac{t_w + t_s}{a}$

$\therefore a = t_w + t_s$

BM in short span dir^n $M_1 = (m_1 + \mu m_2) W$

BM " long " " $M_2 = (m_2 + \mu m_1) W$

The values of moment co-efficients m_1 and m_2 depend upon the parameters u/B and v/L and value of $K = B/L$

According to Victor; the dispersion is assumed to be at 45° through the wearing coat which is flexible, and at a steeper angle through the deck slab which is rigid.

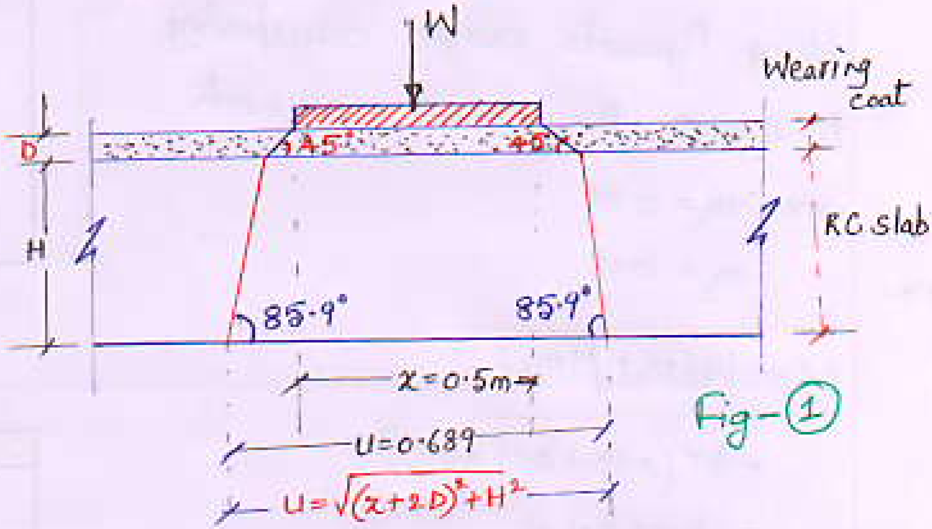


Fig-(1)

The BM's developed in short and long span directions of a deck slab is presented for three different types of cases for a wheel load, using following data:

Data: IRC class 'A' Wheel load W = 57 KN.

Wheel contact dimensions = 500 mm by 250 mm

Thickness of wearing coat D = 80 mm.

Thickness of structural slab H = 200 mm

Dimensions of slab L = 4m and B = 2m

Ratio $K = B/L = 2/4 = 0.5$

Poissons ratio $\mu = 0.15$

Case 1: Dispersion of wheel load through wearing coat only.

From fig-(2) + (3);

$u = 0.5 + 2(0.08) = 0.66$ m

$V = 0.25 + 2(0.08) = 0.41\ m$

$\frac{u}{B} = \frac{0.66}{2.0} = 0.33$

$\frac{v}{L} = \frac{0.41}{4.0} = 0.102$

$K = B/L = 2/4 = 0.5$

Using Pigeaud's curves corresponding to $K=0.5$; the moment co-efficients are $m_1 = 0.18$

$m_2 = 0.13$

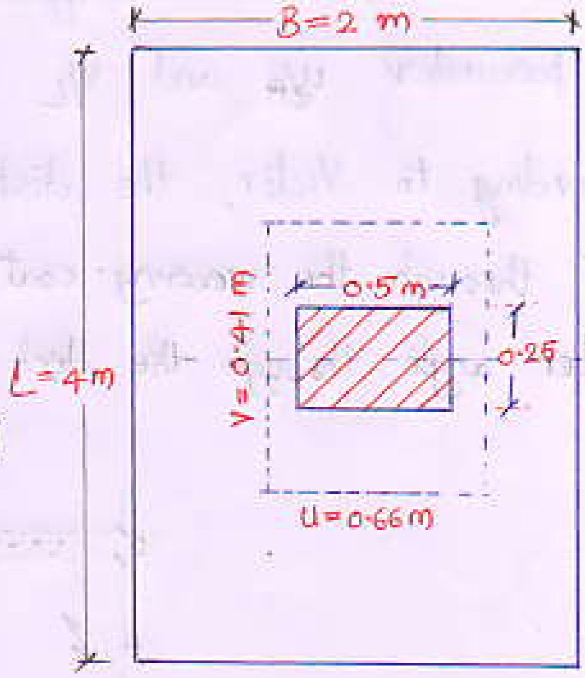


Fig-②

$\boxed{M_B = W(m_1 + \mu m_2)}$

$= 57(0.18 + 0.15 \times 0.13)$

$= 11.37\ kN \cdot m$

$\boxed{M_L = W(m_2 + \mu m_1)}$

$= 57(0.13 + 0.15 \times 0.18)$

$= 8.94\ kN\ m$

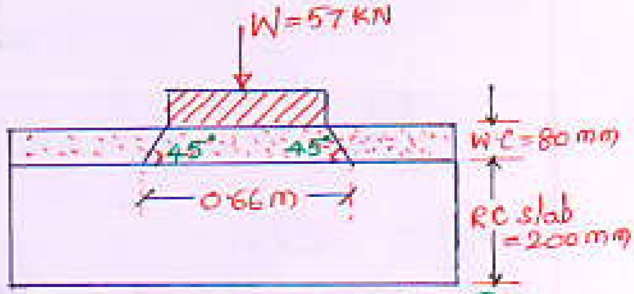


Fig-③

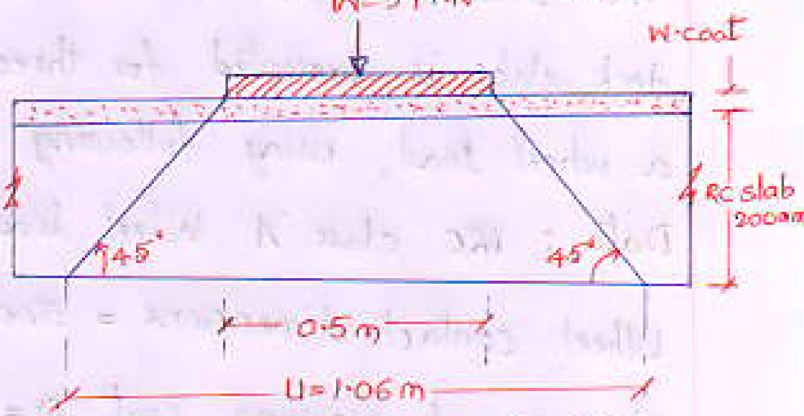


Fig-④

Case-2 : Dispersion of wheel load through wearing coat and structural slab @ 45°

From fig-④;

$U = 0.5 + 2(0.08 + 0.2) = 1.06\ m$

$V = 0.25 + 2(0.08 + 0.2) = 0.81\ m$

$\frac{u}{B} = \frac{1.06}{2} = 0.53$

$\frac{v}{L} = \frac{0.81}{4} = 0.202$

$K = B/L = 2/4 = 0.5$

Using Pigeaud's curves corresponding to $K=0.5$, the moment co-efficients are $m_1 = 0.138$ & $m_2 = 0.080$

$\boxed{M_B = W(m_1 + \mu m_2)} = 57(0.138 + 0.15 \times 0.08) = 8.55\ kNm$

$\boxed{M_L = W(m_2 + \mu m_1)} = 57(0.08 + 0.15 \times 0.138) = 5.74\ kNm$

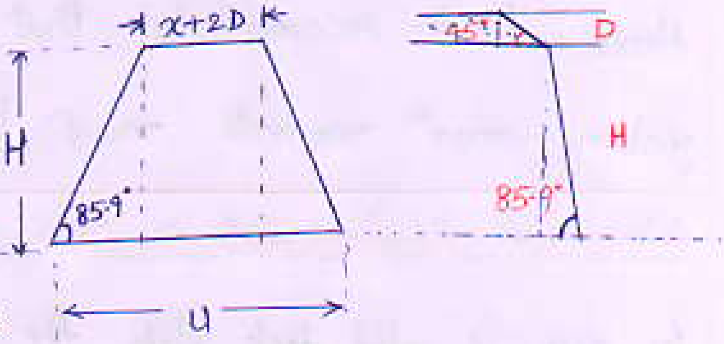
Case-3: Dispersion of wheel load th' wearing coat and 85.9° th' structural slab.

Referring to fig-① in page-4;

$u = (x + 2D) + 2\left(\frac{H}{\tan 85.9^\circ}\right)$

$x = 0.5;\ D = 0.08\,m;\ H = 0.2\,m$

$\tan 85.9 = \frac{H}{a}$



$a = \frac{H}{\tan 85.9^\circ} = \frac{0.2}{13.95} = \cancel{0.1433}\ 0.0143$

$u = \left[0.5 + 2(0.08) + 2(\cancel{0.1433}\ 0.01433)\right] = 0.689\ m$

lly $v = \left[0.25 + 2(0.08) + 2(0.1433)\right] = 0.438\ m.$

$\frac{u}{B} = \frac{0.689}{2.0} = 0.3445;\qquad \frac{v}{L} = \frac{0.438}{4.0} = 0.1095$

$K = B/L = 2/4 = 0.5$

Using Pigeaud's curves corresponding to $K = 0.5$, the moment co-efficients,

$m_1 = 0.18;\quad m_2 = 0.125$

$\therefore M_B = W(m_1 + \mu m_2) = 57(0.18 + 0.15 \times 0.125) = 11.04\ kNm$

$M_L = W(m_2 + \mu m_1) = 57(0.125 + 0.15 \times 0.18) = 8.62\ kNm$

The comparative study of moments resulting from different types of ~~coord~~ dispersion of wheel load indicates that the value of moments are maximum for case-I in which the dispersion is assumed at 45° through wearing coat only. If dispersion is assumed at 85.9° thr the stiffer structural slab, the moments are 3% less than Case I.

If dispersion is assumed at an uniform angle of 45° thr both wearing coat and slab; the moments are at least with a difference of 24 per cent in comparison with results of Case I.

Hence it is recommended that case I type of load dispersion yielding max^m moments may be used for two-way slabs.

Minimum Reinforcements in Slabs (governed by IRC: 21-2000 code)

In case of solid deck slabs, the tension reinforcement shall be not less than 0.12 per cent of the total c/s area when using Fe415/500 grade bars; and not less than 0.15 per cent of total c/s area when using Fe250 grade bars.

UNIT – III 3 [redacted]

Culvert is C.D-work whose length betn inner faces of dirtwalls is less than 6m

Reinforced concrete slab culvert

The RC slab-type deck is used for spans upto 8m. The slab decks are supported at the ends on piers or abutments. The deck slab is designed as a one-way slab to support the DL + LL with impact.

Slabs spanning in one direction: The DL moments can be computed directly, assuming the slab to be simply supported between the supports. For a single concentrated load the effective width of dispersion ~~may be~~ is given by;

$\frac{\text{longer span}}{\text{smaller span}} > 2$ [one-w

$$b_e = k \cdot x \left(1 - \frac{x}{L}\right) + b_w$$

b_e = effective width of slab

k = a constant depending on ratio B/L;

B = width of slab

x = distance of c.g of load from nearer support

L = Effective ~~length~~ span.

b_w = breadth of concentration area of load.

Slabs spanning in two directions: In case of bridge decks with T-beams & cross-girders, the deck slab is supported on all the four sides and is spanning in two dirns.

Let L = long span length

B = short " "

u v = dimensions of load spread after allowing for k = ratio of short to long span (B/L)

M_1 = moment in short span dirn.

M_2 = " " long " "

m_1 and m_2 = coefficients for moments along short & long spans.

μ = Poisson's ratio for concrete $(= 0.15)$.

W = Load from wheel under consideration.

The bending moments are computed as;

$$M_1 = (m_1 + \mu m_2) W$$

$$M_2 = (m_2 + \mu m_1) W$$

Prob Design an R.C slab culvert for a NH to suit following data:

A two-lane carriage way (7.5 m wide)

Foot paths on either side (1 m wide)

Clear span = 6 m; Wearing coat = 80 mm

Width of bearing = 0.4 m Materials : M25 & Fe4[illegible]

Loading: IRC class AA tracked vehicle.

Design the R.C deck slab and sketch the details of reinforcements in the longitudinal & cross sections of the slab.

Soln. step 1. Given data:

Clear span = 6 m

Type of loading : class AA

Materials : M25 & Fe415

Step 2 : Permissible stresses

$\sigma_{cb} = 8.3\ N/mm^2$ $\sigma_{st} = 200\ N/mm^2$ $m = \frac{280}{3\sigma_{cb}} = 10$

$k = \frac{m\sigma_{cb}}{m\sigma_{cb} + \sigma_{st}} =$; $j = 1 - \frac{k}{3} = 0.9$ $R = \frac{1}{2}cjk$ or $Q = 1.1$

Step 3 : Depth of slab & effective span.

Assume thickness of slab at 80 mm per metre of span for highway bridge decks.

Overall slab thickness = $80 \times 60 = 480$ mm say 500 mm

Using 25 mm diameter bars with clear cover of 25 mm

Eff. depth $= 500 - (25 + 12.5) = 462.5$ mm.

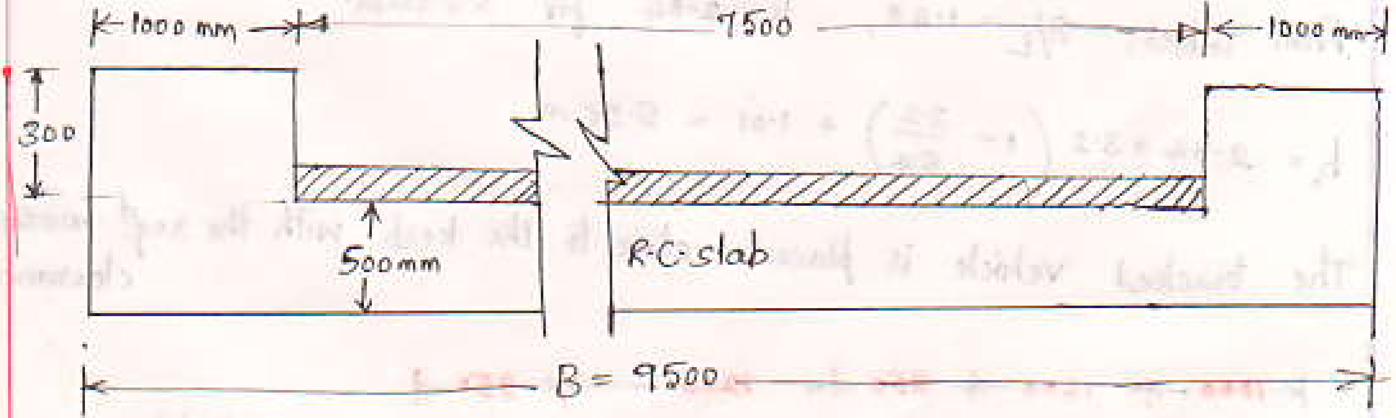
Width of bearing = 400 mm

Eff. span is the least of

i) Clear span + effective depth $= (6\,m + 0.4625) = 6.4625$ m

ii) c/c of bearings $= (6 + 0.4) = 6.4$ m

Eff. span $L = 6.4$ m.



Step 4: DL BM

Dead weight of slab $= (0.5 \times 24) = 12\ kN/m^2$

$$DL\ BM = \frac{14 \times 6.4^2}{8} = 72\ \text{kN/m}\cdot\text{kN-m}$$

Step ⑤ : LL BM:

BM due to LL will be max^m for IRC class AA tracked vehicles.

Impact factor for class AA tracked vehicle : 25% for 5 m span decreasingly linearly to 10% for 9 m span

$$\frac{15}{4} = \frac{y}{2.6}$$

$$\text{Impact factor} = 25 - \frac{15}{4}(6.4 - 5)$$

$$= 19.7\%$$

The tracked vehicle is placed symmetrically on the span.

$$\text{Eff. length of load} = 3.6 + 2(0.5 + 0.08) = 4.76\ m$$

3.6 = wheel Base; 0.5 : t_s; 0.08 : $t_{w.coat}$

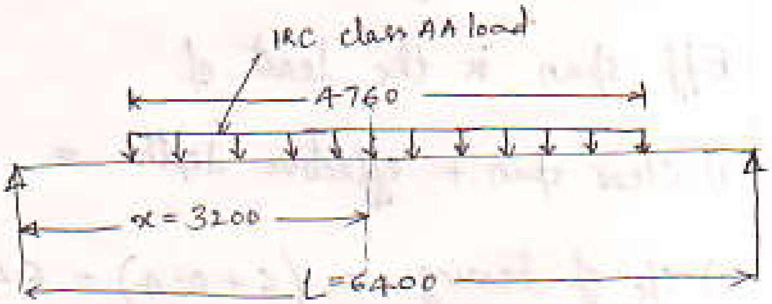
Eff. width of slab $\perp^r$ to span is; $b_e = kx\left(1 - \frac{x}{L}\right) + b_w$

$x = 3.2\ m$;

$L = 6.4\ m$;

$B = 9.5\ m$

$B/L = 1.48$



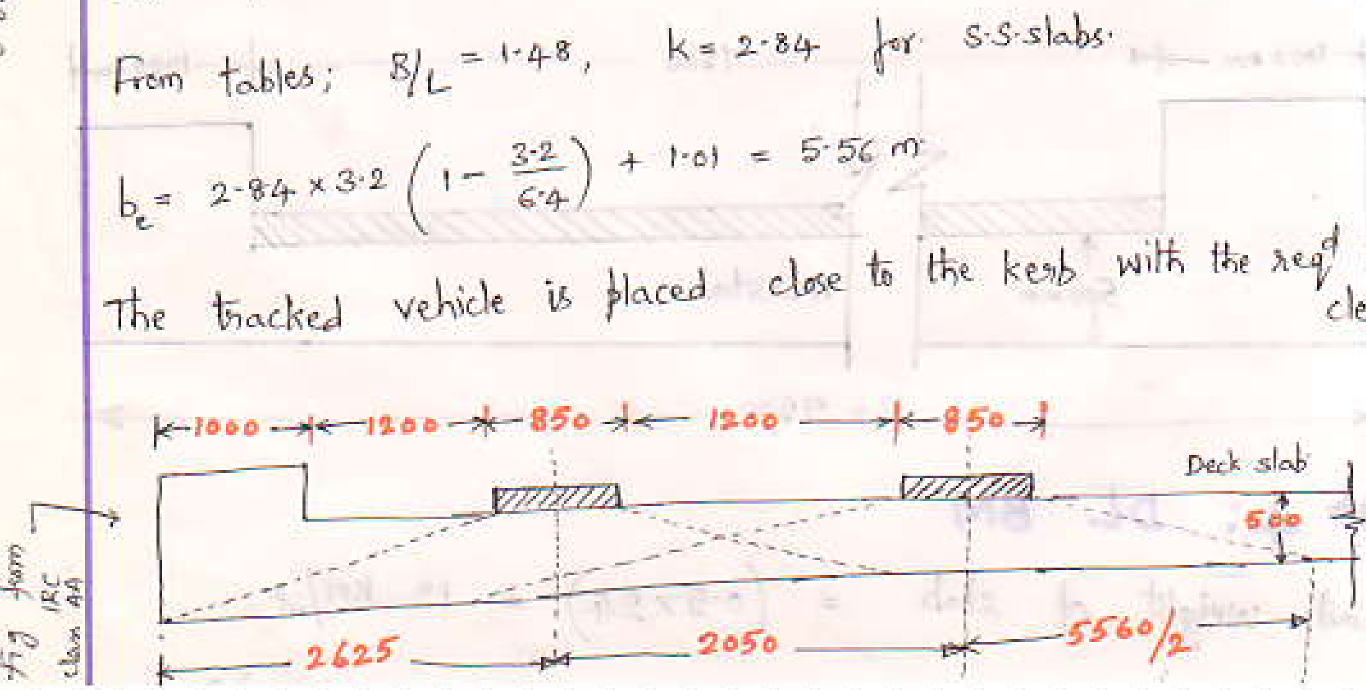
0.85 : ~~width~~ base width

$$b_w = (0.85 + 2 \times 0.08) = 1.01\ m$$

From tables; $B/L = 1.48$, $k = 2.84$ for S.S. slabs.

$$b_e = 2.84 \times 3.2\left(1 - \frac{3.2}{6.4}\right) + 1.01 = 5.56\ m$$

The tracked vehicle is placed close to the kerb with the req^d minimum clearance.



Net effective width of dispersion = 7.455 m

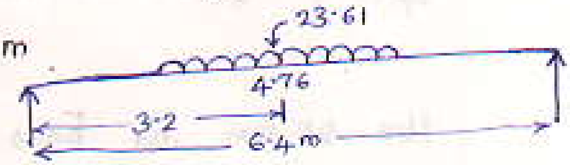
Total load of two tracks with impact = $700 \times 1.197 = 838$ KN

Average intensity of loaded load per m^2 = $\left[\dfrac{838}{4.76 \times 7.455}\right] = 23.61\ KN/m^2$

4.76 m is eff. length of load.

Max^m BM due to live load $M_{max} = \left[\dfrac{23.61 \times 4.76}{2} \times 3.2\right] - \left[\dfrac{23.61 \times 4.76}{2} \times \dfrac{4.76}{4}\right]$

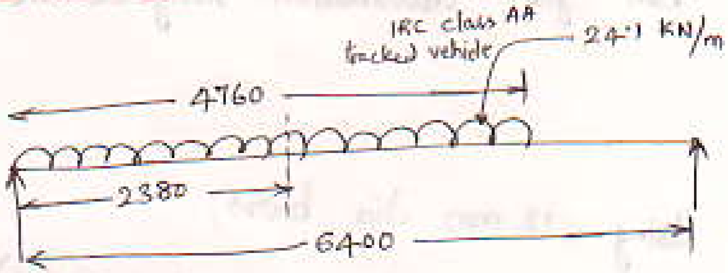
$= 113$ KN·m



Total design BM = $(113 + 72) = 185$ KN·m

Step 6 : Shear due to class AA tracked vehicle.

For max^m shear at support, the IRC class AA tracked vehicle is arranged as shown



Eff. width of dispersion

$$b_e = kx\left(1 - \frac{x}{L}\right) + b_w$$

0.85 : base width

$b_w = (0.85 + 2 \times 0.08) = 1.01$ m

$x = 2.38$ m; $B = 9.5$ m; $L = 6.4$ m $B/L = 1.48$; $k = 2.84$; $b_w = 1.01$ m

$$b_e = 2.84 \times 2.38\left(1 - \frac{2.38}{6.40}\right) + 1.10 = 5.256 \text{ m}$$

Width of dispersion = $\left[2625 + 2050 + \dfrac{5256}{2}\right] = 7303$ mm

$$W = \frac{838}{4.76 \times 7.303} = 24.1\ KN/m^2$$

$6.4 - 2.38 = 4.02$

Shear force $V_A = \dfrac{24.1 \times 4.76 \times 4.02}{6.4} = 72$ KN

$V_a \times 6.4 = 24.1 \times 4.76$

Dead load shear = $\dfrac{14 \times 6.4}{2} = 45$ KN.

$14\ \dfrac{KN}{m^2}$ = total DL from step 4

Total design shear = $72 + 45 = 117$ KN.

Step 7 : Design of deck slab.

Eff. depth req^d $d = \sqrt{\dfrac{M}{Q \cdot b}} = \left(\dfrac{185 \times 10^6}{1.1 \times 1000}\right)^{1/2} = 410$ mm.

Eff. depth provided = 462.5 mm

$M = Q b d^2$

Q : MR factor

j : lever arm factor

K : N.A. factor

$A_{st} = \dfrac{M}{\sigma_{st} \cdot j \cdot d} = \dfrac{185 \times 10^6}{200 \times 0.9 \times 462.5} = 2222$ mm^2

Spacing of 25 mm dia bars $= \dfrac{\frac{\pi}{4}(25)^2}{2222} \times 1000 = 220$ mm

Use 25 mm dia bars @ 200 mm c/c as main reinforcement

BM for distribution reinforcement $= 0.3M_L + 0.2M_d$

$= (0.3 \times 113) + (0.2 \times 72)$

$= 49$ KN.m

Using 12 mm dia bars;

Eff. depth $= [462.5 - (12.5 + 6)] = 444$ mm

$A_{st} = \dfrac{M}{\sigma_{st} \cdot j \cdot d} = \dfrac{49 \times 10^6}{200 \times 0.9 \times 444} = 613$ mm^2

Spacing of 12 mm dia bars $= \dfrac{113}{613} \times 1000 = 184$ mm

Provide 12 mm dia bars @ 170 mm c/c as distribution steel.

Step 8 : Check for shear stress.

As per IRC : 21- 1987, shear stresses in the slab are checked as follows :

Design shear stress $\tau_v = \dfrac{V}{bd}$

V = design SF

b = width of section

d = eff. depth

Permissible sh. stress in slabs, $\tau_c = k_1 k_2 \cdot \tau_{co}$

... expressed in metres.

 [redacted]

τ_{co} = basic values of permissible shear stress.

Grade of concrete →	M15	M20	M25	M30	M35	M40
τ_{co} →	0·28	0·34	0·4	0·45	0·50	0·50

$p = \dfrac{100 A_s}{bd}$; b = width of section.

$\tau_v = \dfrac{V}{bd} = \dfrac{117 \times 10^3}{1000 \times 462.5} = 0.254\ N/mm^2$

$\dfrac{\text{area of each bar}}{\text{spacing}} \times 1000$

$k_1 = (1.14 - 0.7 \times 0.4625) = 0.82 \geq 0.5$

$k_2 = (0.5 + 0.25p)$; $p = \dfrac{100 A_s}{bd} = \dfrac{100 \times \left(\frac{491}{200} \times 1000\right)}{1000 \times 462.5} = 0.53$

$= (0.5 + 0.25 \times 0.53) = 0.63 \geq 1 \quad \therefore k_2 = 1.$

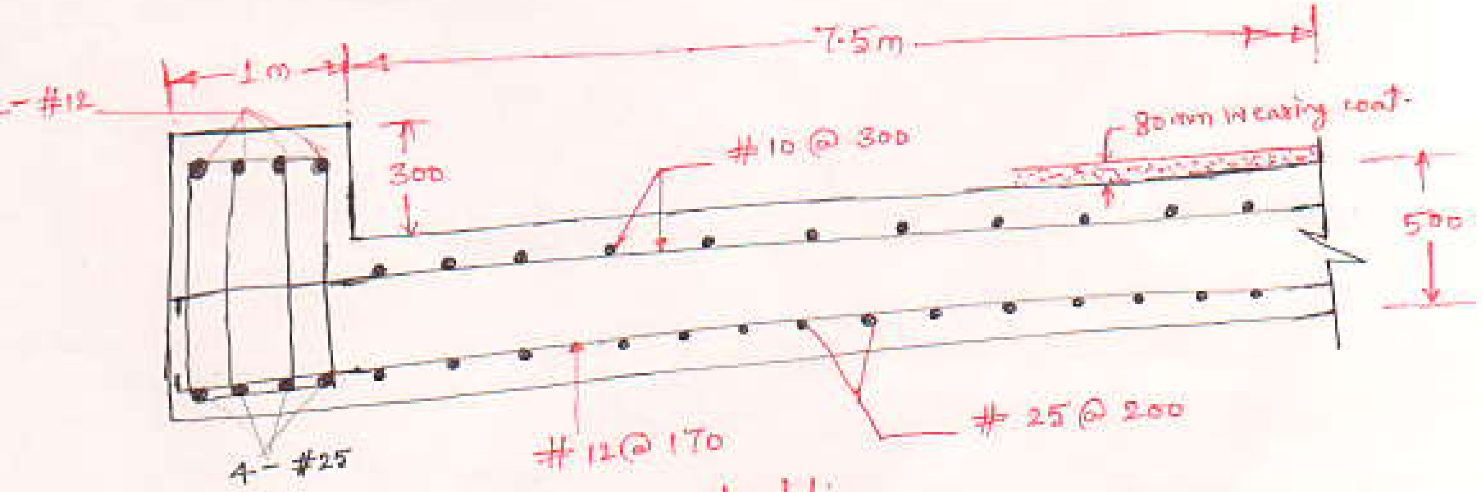
$A_{st} =$

spacing $= \dfrac{A_\phi \times 1000}{A_{st}}$

For M25 concrete, $\tau_{co} = 0.40\ N/mm^2$

$\tau_c = k_1 k_2 \tau_{co} = 0.82 \times 1 \times 0.40 = 0.328\ N/mm^2$

$\because \tau_v < \tau_c$ shear stresses are within permissible limits.



c/s of Deck slab