ANALYSIS AND DESIGN OF BRIDGE DECKS

UNIT – III

RCC BRIDGE DECKS.

↓ SLAB DECK

↓ TEE BEAM AND SLAB DECKS

↓ PSC DECKS.

IRC CODES FOR ROAD BRIDGES

SECTIONS I II and III.

IRC LOADINGS FOR ROAD BRIDGES.

CLASS 'AA' ↓ Tracked, TOR AND Wheeled.

↓ class 'A'

↓ CLASS B.

DISCUSSION OF VARIOUS PROVISIONS OF IRC CODES

1. Section I — General design requirements
2. Section II — Loadings and effective widths.
3. Section III — Permissible stresses.

DESIGN OF A SLAB BRIDGE (SLAB CULVERT)

BY IRC EFFECTIVE WIDTH METHOD:

EXAMPLE: Design an RCC Slab Culvert for a State highway to suit the following data.

DATA: 2 Lane: 7.5m Wide; Use M25 Concrete and Fe415 Steel.

Kerbs: 600 mm Wide, Clear Span = 6 m; Width of bearing = 400 mm

Loading: IRC class 'AA' and class 'A' whichever gives worst effect.

Use IRC Specifications.

ALLOWABLE STRESSES.

$f_{ck} = 25$, $f_y = 415$, $\sigma_{cb} = 8.3\ N/mm^2$, $\sigma_{st} = 200\ N/mm^2$

Basic shear stress $\tau_{co} = 0.40\ N/mm^2$.

$\tau_{max} = 1.9\ N/mm^2$.

$$m = \frac{280}{3\sigma_{cbc}} = \frac{280}{3 \times 8.3} = \cancel{\text{say}}, 11.$$

But the IRC code adopts $m = 10$ for M20, M25 and M30 mixes

$$n = \frac{m\,\sigma_{cbc}}{m\,\sigma_{cbc} + \sigma_{st}} = \frac{11 \times 8.3}{11 \times 8.3 + 200} = \frac{91.3}{291.30} = 0.32 \quad (K = n)$$

$$j = 1 - \frac{n}{3} = 1 - \frac{0.32}{3} = \text{say } 0.90$$

$$Q = R = \frac{1}{2}\sigma_{cbc}\, j K = \frac{1}{2} \times 8.3 \times 0.9 \times 0.32 = 1.19 \text{ Say } 1.20.$$

EFFECTIVE SPAN: Assuming the thickness of the deck slab = 80 mm/m. of span

Overall thickness = 6 × 80 = 480 mm, Provide 500 mm.

Using 25 ϕ, Eff. Cover = $25 + \frac{25}{2} = 37.5$ mm

Hence, eff. depth = 500 − 37.5 = 462.5 mm.

Eff. span is the least of the following.

a) Clear span + Eff. depth = $6 + 0.4625 = 6.4625\,m$.

b) c/c distance between the bearings = $6 + 0.4 = 6.4\,m$.

Hence, adopt Eff $L = 6.4\,m$.

The cross section of the deck slab is shown in the fig.

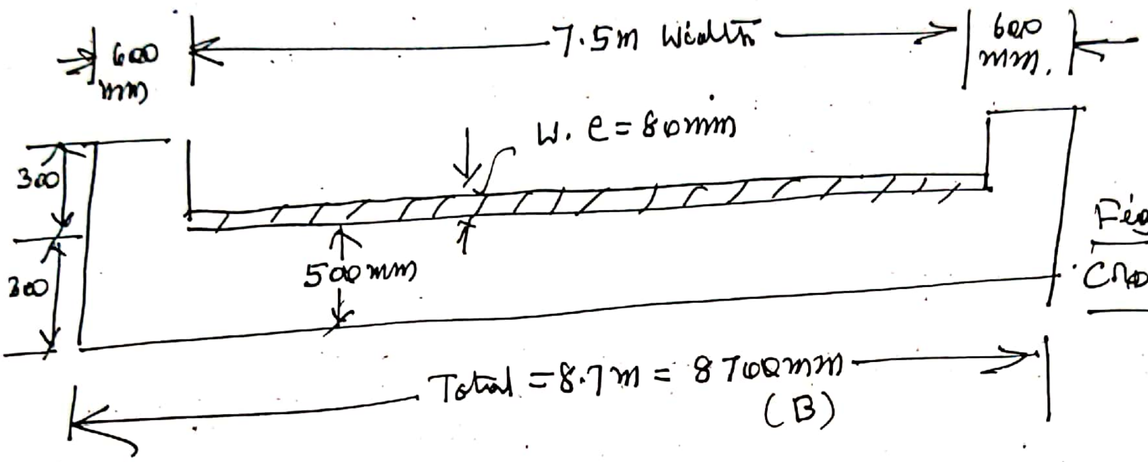


Fig: Cross Section

D.L.B.M

D.L of slab = $0.5 \times 24 = 12\,kN/m^2$.

D.L of W.C = $0.08 \times 22 = 1.76\,kN/m^2$

Total D.L = $13.76\,kN/m^2$.

$$D.L.B.M = \frac{13.76 \times 6.4^2}{8} = 70.4\,kN\,m.$$

EFFECTIVE WIDTH:

The B.M is maximum for IRC class AA tracked Vehicle.

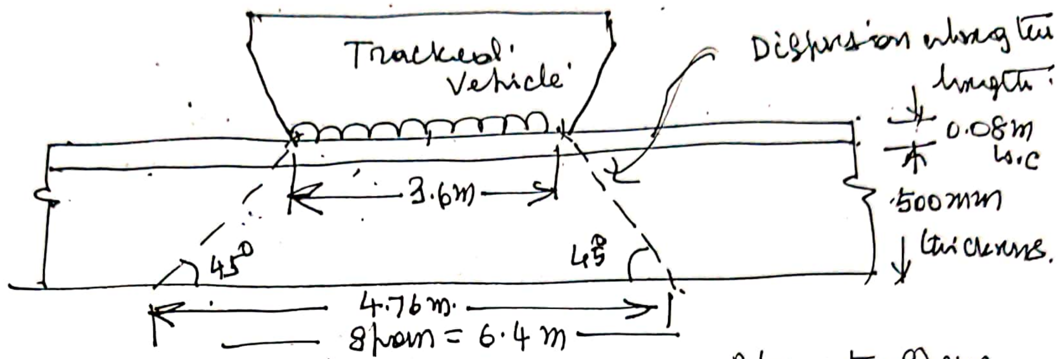
Impact factor for class AA $= 25 - \frac{15}{4}(6.4 - 5) = 19.7\%$.

The tracked Vehicle is placed symmetrically on the span for max. B.M.

[I.F is 25% up to 5m and reducing linearly to 10% up to 9m]

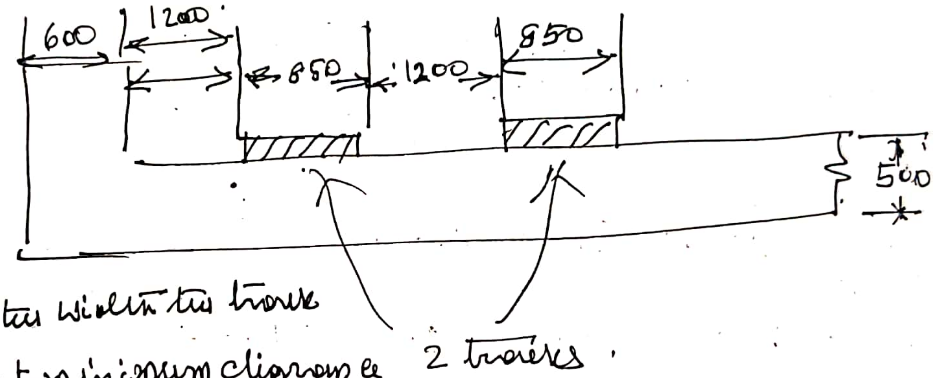
Eff. width perpendicular to span is expressed as

$$b_e = \lambda a \left(1 - \frac{a}{l_o}\right) + b$$



Along the Span

a) Eff. length along the span



(Along the width the track is kept at minimum clearance of 1200 mm from the kerb).

b) Eff. width along the width

By referring to the fig.

$$b_{ef} = \lambda a \left(1 - \frac{a}{l_o}\right) + b_1$$

a: Dist. from the nearest support $= \frac{6.4}{2} = 3.2\,m$

$L = 6.4\,m$, $B = 8.7\,m$

Since $\frac{B}{L} = \frac{8.7}{6.4} = 1.36$, l_o = Eff. span $= 6.4\,m$

Since $k = \lambda = 2.77$ from tables for S.S.

Substituting, eff. width $= b_{ef} = 2.77 \times 3.2 \left(1 - \frac{3.2}{6.4}\right) + 0.85 + 2 \times 0.08$

$$= 2.77 \times 3.2 \left(1 - \frac{3.2}{6.4}\right) + 1.01 = 5.442\,m.$$

Scanned with CamScanner

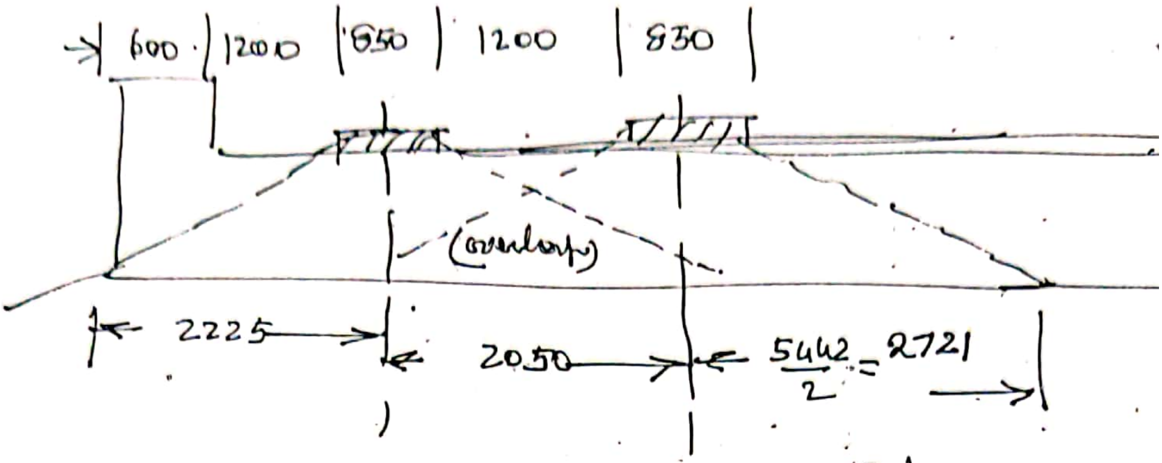


Fig.

From the above fig. it is seen that

the available eff. width for the two tracks

$= 2225 + 2050 + 2721 = 6996 mm = 6.996 m$

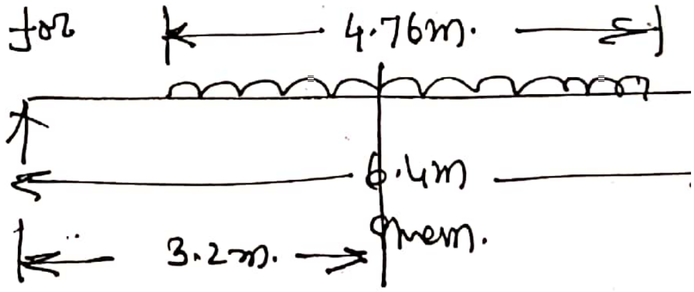
DISPERSION ALONG THE SPAN.

Eff. length of dispersion along the length

$= [3.6 + 2(0.5 + 0.06)] = 4.76 m$

MAX. B.M.

Hence, the area of dispersion for two tracks $= 4.76 \times 6.996 m$

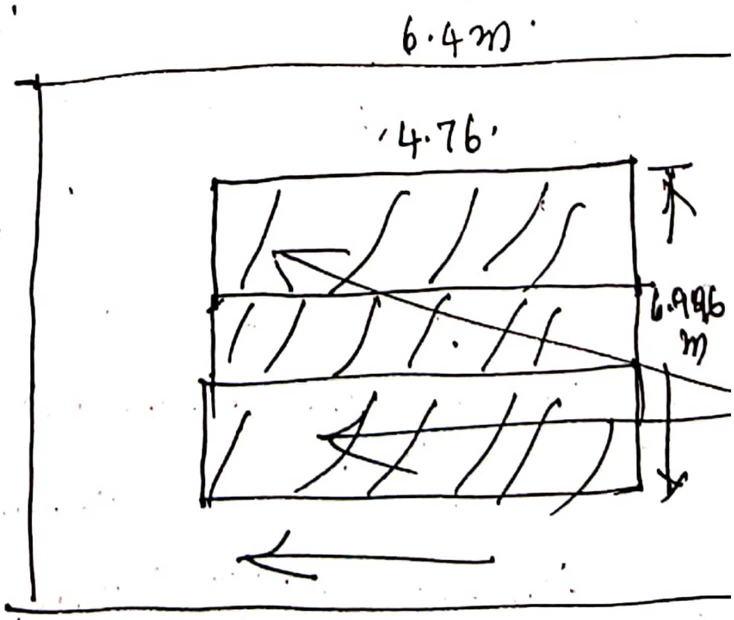


Total load including impact

$= 2 \times 350 \times 1.197 = 838 kN$

Ave. intensity of load

$= \frac{838}{4.76 \times 6.996} = 25.17 kN/m^2$



Hence, Max. B.M at centre (Considering 1m in the other dirc.)

$l_0 = 64$

$$= \frac{\text{Total load}}{2} = \left(\frac{25.17 \times 4.76}{2}\right) \times 3.2 - \frac{(25.17 \times 4.76)}{2} \times \frac{4.76}{4} = 120.36\ \text{kNm}.$$

Total Design B.M = DLBM + LLBM = 70.4 + 120.36 = 191 kNm

LONG. REINFORCEMENT:

$$\text{Eff. depth required} = \sqrt{\frac{M}{Rb}} = \sqrt{\frac{120.36 \times 10^6}{1.2 \times 1000}} = \cancel{2290}\ 415\ \text{mm}$$

Eff. depth provided, $d_{eff} = 462.5$ mm, Okay.

$$A_{st} = \frac{M}{\sigma_{st}\, j\, d} = \frac{120.36 \times 10^6}{200 \times 0.9 \times 462.3} = 2294\ \text{mm}^2$$

Providing 25 ϕ, spacing $= \frac{491}{2294} \times 1000 = 214$ mm

Hence, provide 200 c/c

DIST. STEEL

As per IRC, distribution steel is provided against,

$$(0.3 M_L + 0.2 M_d) = 0.3 \times 120.36 + 0.2 \times 70.4 = 50.2\ \text{kNm}$$

d_{eff} (for dist. steel) = (462.5 − 12.5 − 6) = 444 mm

(12 ϕ is assumed)

$$\text{Hence, } A_{st} = \frac{50.2 \times 10^6}{200 \times 0.90 \times 444} = 628\ \text{mm}^2$$

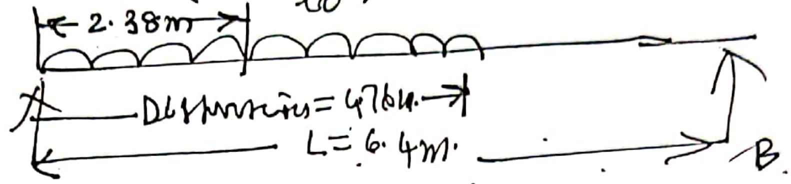
Spacing of 12 ϕ = $\frac{113}{628} \times 1000 = 180$ mm

Hence, provide 12 ϕ distribution steel 180 c/c

SHEAR FORCE

For max. S.F at the support, the class 'AA' loading is arranged as shown in the fig.

Eff. width of dispersion $= \lambda a \left(1 - \frac{a}{l_0}\right) + b_1$.



$a = 2.38m$ to the centre of load.

$(0.85 + 2 \times 0.08) = 1.01m$. (Along the length).

$\lambda = 2.77m$., $l_0 = 6.4m$, $b_1 = 1.01m$.

Hence, eff. width $= 2.77 \times 2.38 \left(1 - \frac{2.38}{6.4}\right) + 1.01 = 5.16m$.

Hence, total width of dispersion $= 2225 + 2050 + \frac{5160}{2} = 6855\ mm$

$= 6.855m$

Total load of two tracks with impact.

$= 700 \times 1.197 = 838\ kN$.

Hence UDL $= \omega = \frac{838}{4.76 \times 6.855} = 25.68\ kN/m^2$

(Average)

Hence, S.F at 'A' $= V_A = 4.76 \times 25.68 \left(6.4 - \frac{4.76}{2}\right) / 6.4$

$= 76.80\ kN$

S.F due to D.L $= \frac{13.76 \times 6.4}{2} = 43.75\ kN$.

Hence, total S.F at 'A' $= 76.80 + 43.75 = 120.55$ say $121\ kN$.

Check for Shear Stress

Design Shear Stress $\tau_v = \frac{V}{bd} = \frac{121 \times 10^3}{1000 \times 462.5} = 0.26\ N/mm^2$.

$< \tau_c(max)$

To calculate the Percentage of tension Steel (Half the bars are bent up and

Hence $A_{st} = 25\phi$ @ 400 c/c is available)

A_{st} (available) $= \frac{491 \times 1000}{400} = 1227.5\ mm^2$

Hence, Percentage Steel $= \frac{1227.5}{1000 \times 462.5} \times 100 = 0.265\%$

Referring to the table of IRC-21, for M25 Concrete

We get $\tau_c = 0.25\ N/mm^2$; From the other table $K = 1$

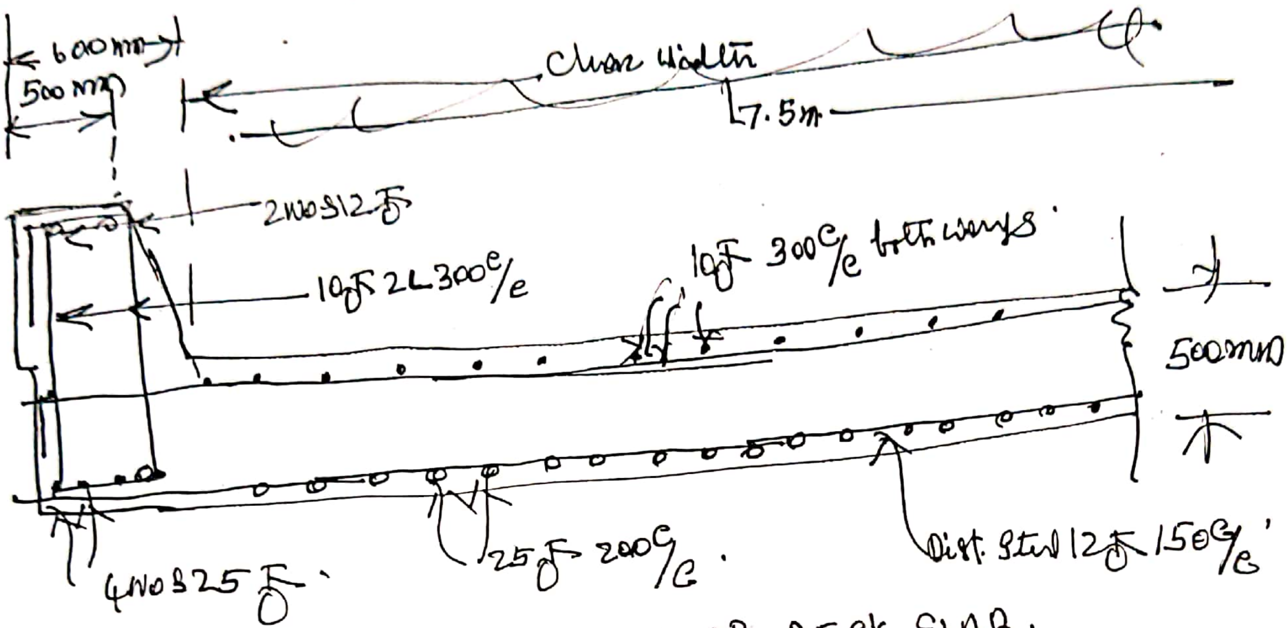
Hence τ_c (Allowable) $(K\tau_c) = 0.25 \times 1 = 0.25\ N/mm^2$

Hence τ_v is almost equal to τ_c

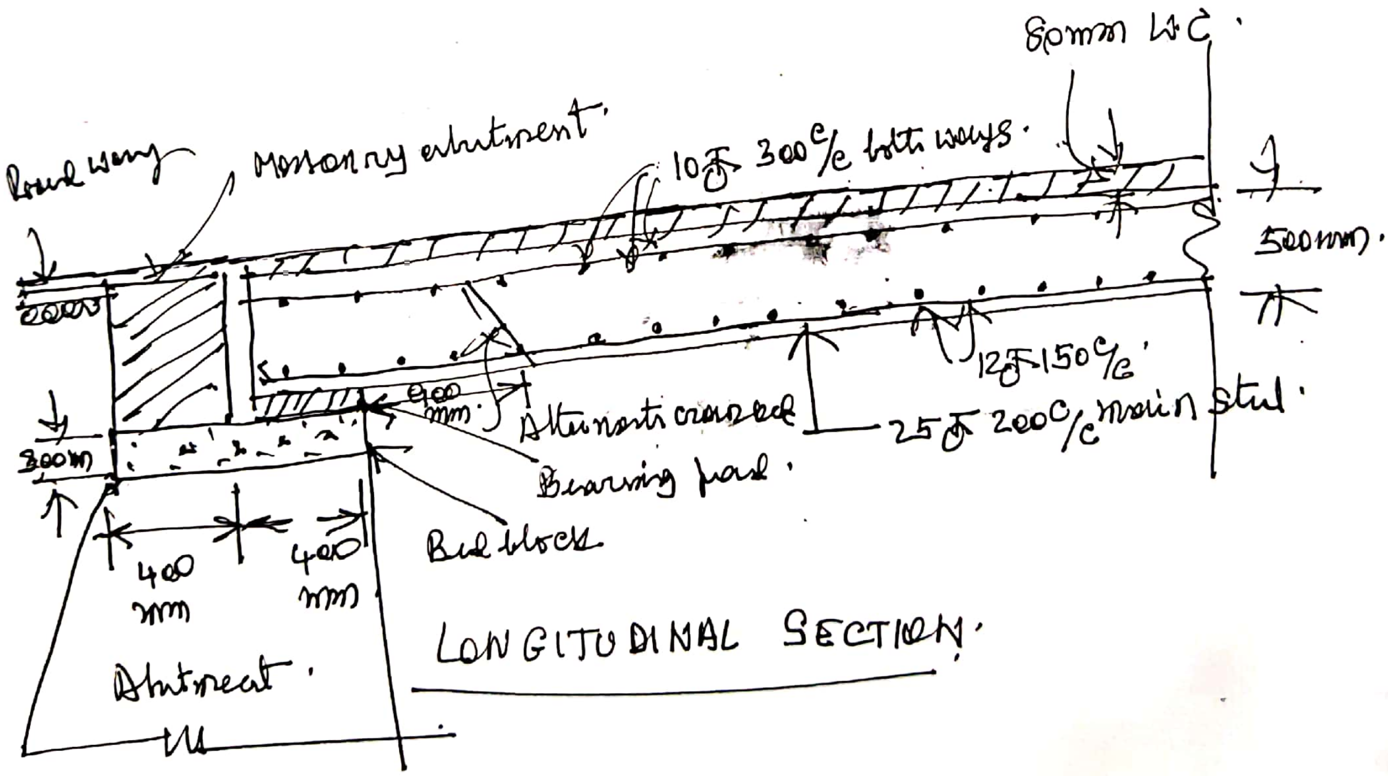
However, alternate bars are also Cranked.

Hence, It is ~~also~~ Safe against Shear.

REINF. DETAILS. OF DECK SLAB



CROSS SECTION OF DECK SLAB



LONGITUDINAL SECTION

DESIGN EXAMPLE.

For a slab bridge of 4.0 m clear span and 2 lanes compute the design BM and design SF. Use M30 concrete with Fe415 steel. Provide footpath of 600 mm width on either side. Consider Class 'A' loading. (Class 'A')

DATA :

Depth of the slab

Assuming 80 mm/m, overall depth = 4 × 80 = 320 mm. ~~Provide 360 mm = D~~

Assuming 20 ϕ with a clear cover of 40 mm, Eff.

$\cancel{d = 360 - \frac{20}{2} - 40} = 310$ mm

Eff. depth = $320 - \frac{20}{2} - 40 = 270$ mm

Hence, eff. span = 4 + 0.27 = 4.27 m.

Design Constants

σ_{cb} (Allowable) = 10.0 N/mm²

$m = 10$, Hence depth of N.A = $n = \frac{10 \times 10}{10 \times 10 + 200} = 0.333$.

$j = 1 - \frac{0.333}{3} = 0.88$; $Q = R = \frac{1}{2} \times 10 \times 0.88 \times 0.333 = 1.465$

Say 1.5.

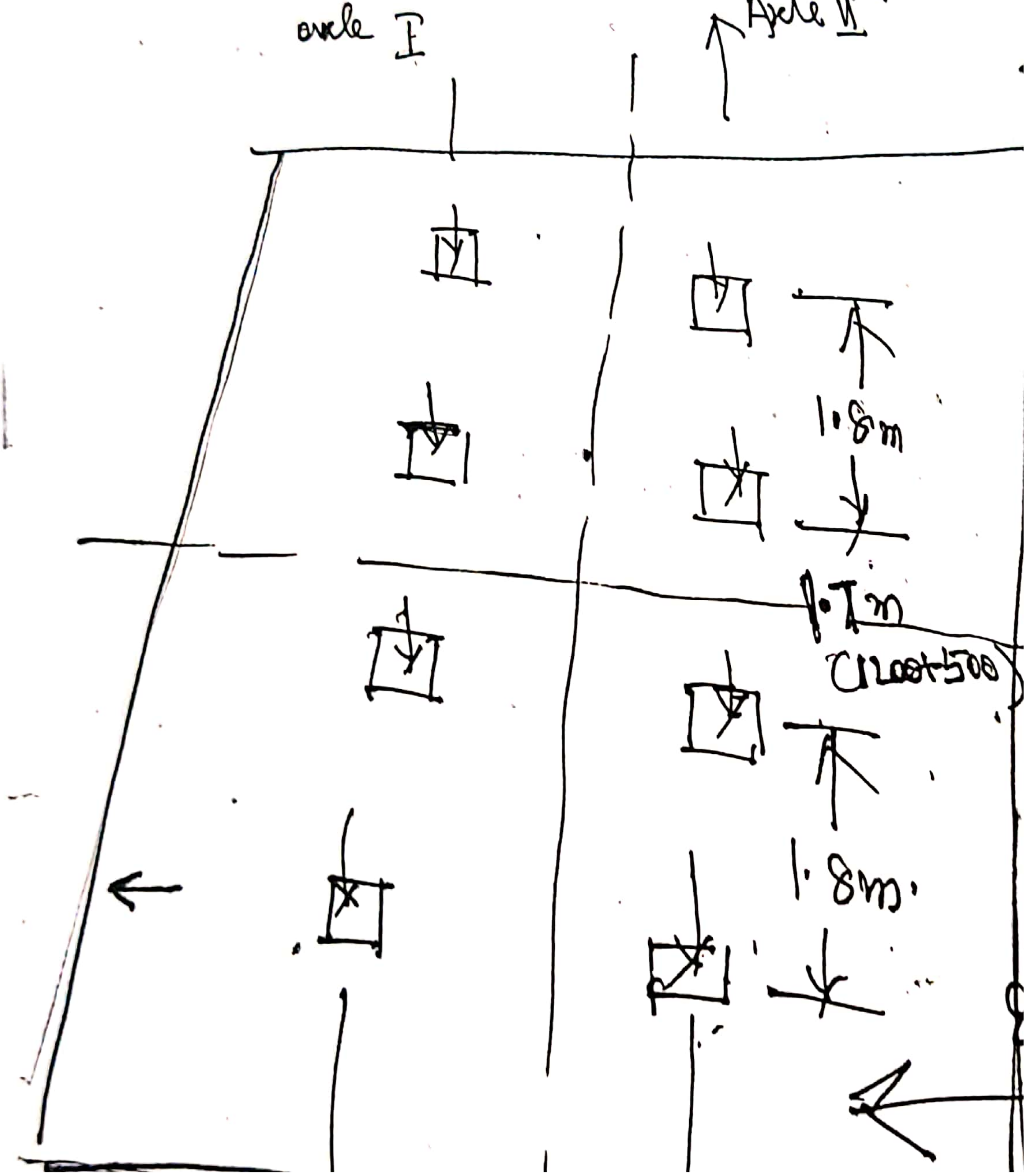
Impact Factor,

$I_f = \frac{4.5}{6 + L}$, 4.5 and 6 are constants.

$L = 4.27$, Hence $\frac{4.5}{6 + 4.27}$ = Say 0.44.

Arrangement of class 'A' Vehicles.

The rear two axles of the leading vehicle carry loads. They are kept symmetrically on the deck. Case of class 'A' two trains can be accommodated 2-lane bridge. Arranging heavy axles symmetrically more effect than considering both loa



Eff. width for a single wheel is given by

$$b_{ef} = \alpha a \cdot \left(1 - \frac{a}{l_0}\right) + b_1$$

For class A
For 2 lanes
$\left[\begin{array}{l} f = 0.15 \\ g = 1200\,mm \end{array}\right]$

$B = 7.5 + 2 \times 0.6 = 8.7\,m, \quad L = 4.3\,m.$

Hence $\frac{B}{L} = \frac{8.7}{4.3} = 2.02$, Hence $\alpha = 3.00$

a : Distance of the centre of the wheel from the nearest support.

$$a = \frac{4.3 - 1.2}{2} = 1.55\,m.$$

BB+

Hence ~~$b_{ef} = 3.00 \times 1.55\left(1 - \frac{1.55}{4.3}\right) + 2 \times (0.27 + 0.08)$~~

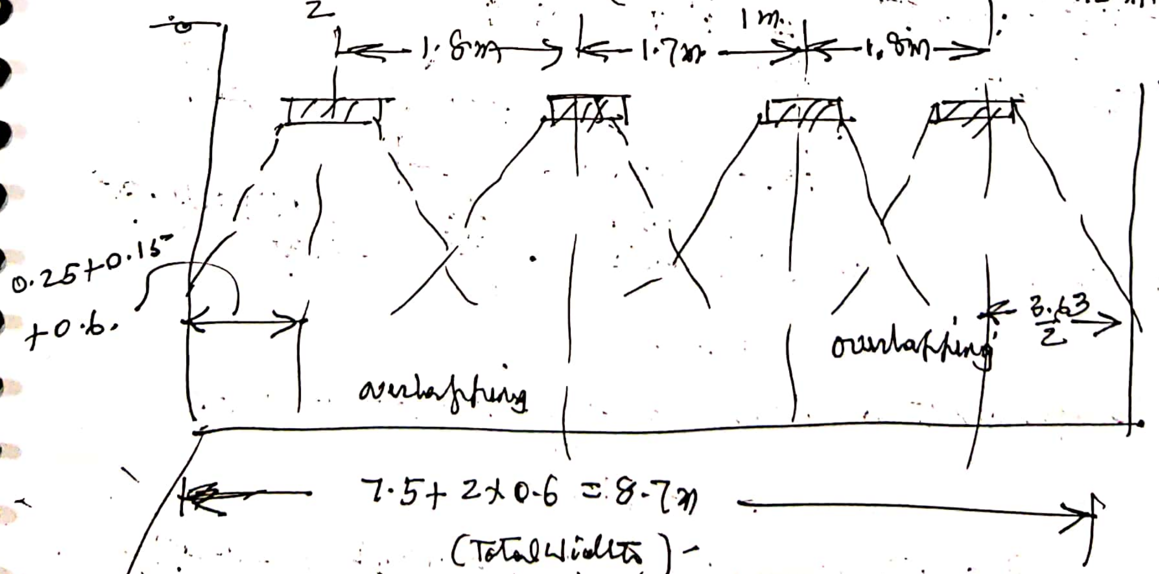
~~$= 3 \times 1.55 \cdot \left(1 - \frac{1.55}{4.3}\right) + \left(\cancel{0.25} + 2 \times 0.35\right)$~~

~~(0.95)~~

$$= 3 \times 1.55\left(1 - \frac{1.55}{4.3}\right) + \left(\overset{0.50}{\cancel{0.25}} + 2 \times 0.08\right) = 3.63\,m.$$

For 4 wheels, the total eff. width $= \frac{3.63}{2} + 1.8 + 1.7 + 1.8 +$ Remaining

$$= \frac{3.63}{2} + 1.8 + 1.7 + 1.8 + (0.25 + 0.15 + 0.6) = 8.115\,m.$$



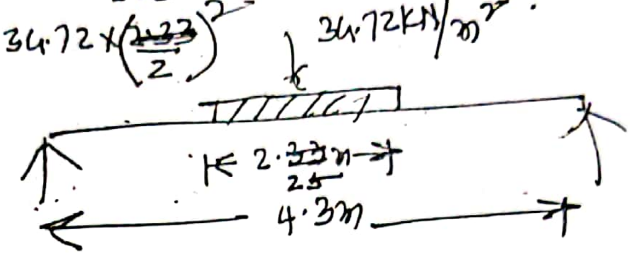
(4)

Hence, distributed load including impact ($I_f = 0.44$)

$$= \frac{1.44 \times 4 \times 114}{8.115 \times 2.\cancel{33}} = 34.72\ kN/m^2$$

I.F = 0.44
Axle ~~total load~~ = 11.4
For 4 wheels = 4 × 11.4

$$\text{Hence LLBM} = \frac{(34.72 \times \overset{2.5}{\cancel{2.33}})}{2} \times \frac{4.3}{2} - 34.72 \times \left(\frac{\cancel{2.33}}{2}\right)^2$$



$= 63.40\ kNm$

D.L on the slab = $(0.3\cancel{4} \times 24 + 0.08 \times 22) = 9.44\ kN/m^2$

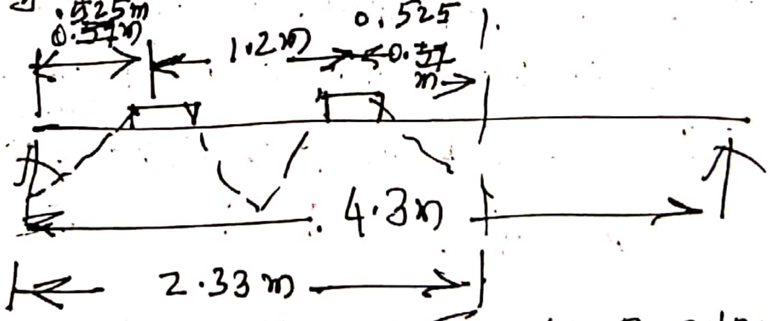
Hence DLBM = $\frac{9.44 \times 4.3^2}{8} = 21.81$ say $22.0\ kNm$

Hence total design moment = $\underline{\underline{63.40}} + 22 = 85.40\ kNm$

<u>SHEAR FORCE</u> The arrangement is shown in the fig.

Dispersion for one wheel along the length = ~~1.13m~~ 1.05m

Hence the wheel is arranged in such a way that its centre is at $\frac{\overset{1.05}{\cancel{1.13}}}{2} = \overset{0.525m}{\cancel{0.57}}$ m from the support.



$$\text{Eff. width for one wheel} = 3 \times \overset{0.525}{\cancel{0.57}}\left(1 - \frac{\overset{0.525}{\cancel{0.57}}}{4.3}\right) + \overset{(0.5+2\times0.08)}{\cancel{0.57}}$$

$= 2.14m$

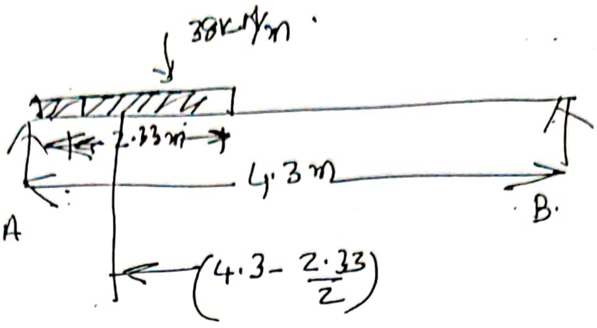
Total eff. width for 4 wheels = $\frac{2.14}{2} + 1.80 + 1.70 + 1.80 + 1.0$

$= 7.37m$

Hence intensity of loading (including impact) = $\frac{1.44 \times 4 \times 114}{7.37 \times 2.33} = 38.207$ say $38.0\ kN/m^2$

(P.5)

Max. S.F = R_A,



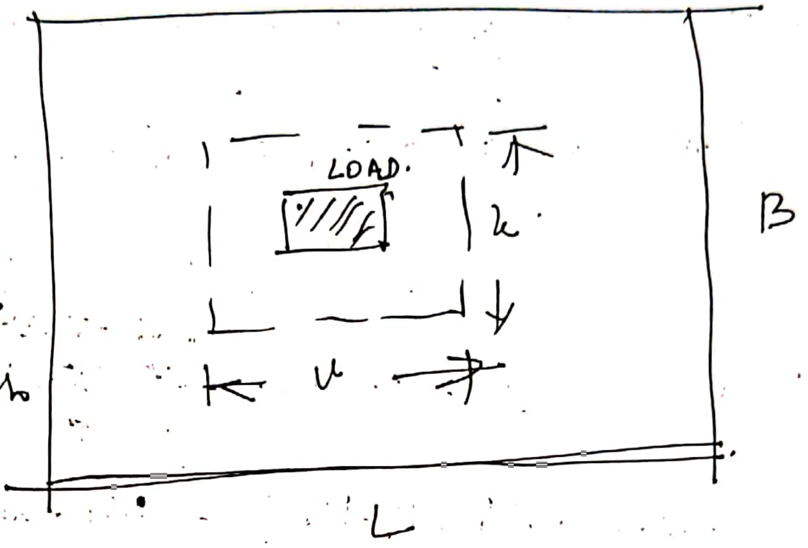
$$R_A = \frac{(2.33 \times 38) \times \left(4.3 - \frac{2.33}{2}\right)}{4.3}$$

$= 65$ kN (Say)

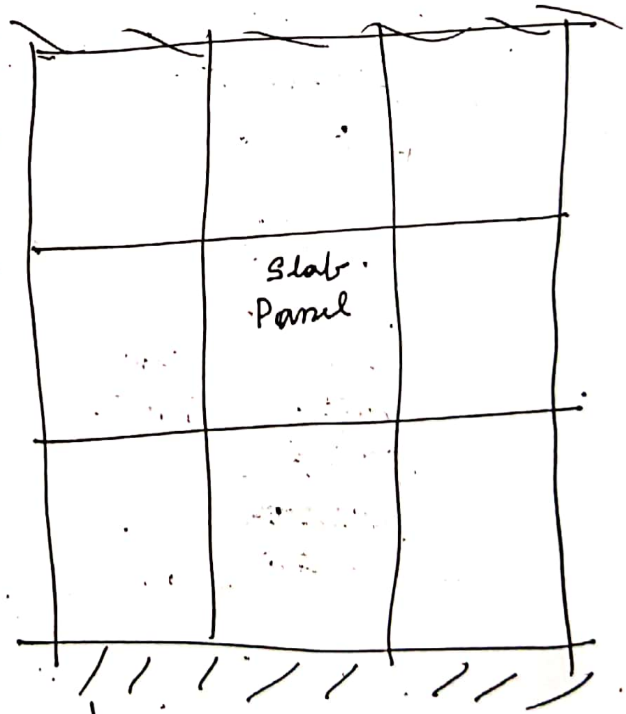
SLABS SPANNING IN TWO DIRECTIONS BY PIGEAUD'S CURVES..

Considering a concentrated wheel load symmetrically placed on the slab, let B and L be the width and length of the panel.

A. u and v are the dispersions in the directions of B and L. u and v are the dispersion lengths calculated at 45° through the thickness of the slab and wearing coat.



m_1 and m_2 are the coefficients for moments for short and long spans.



Hence moments are

M_1 (Short span direction)

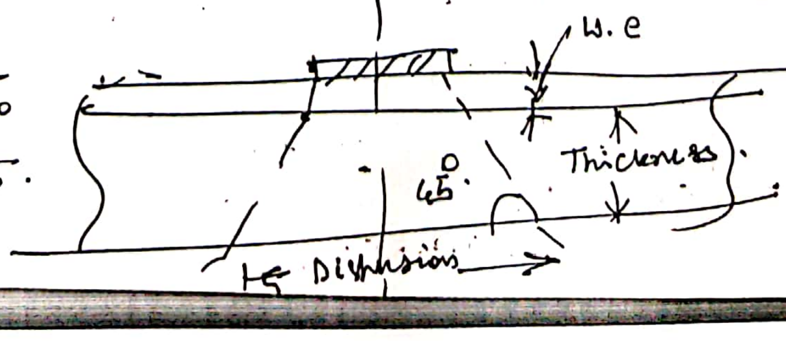
$= (m_1 + \mu m_2) W$.

M_2 (Long span direction)

$= (m_2 + \mu m_1) W$

W : wheel load.

μ : Poisson's ratio for concrete $= 0.15$.



Procedure:

Find out $k = \frac{B}{L}$.

Calculate $\frac{l_e}{B}$ and $\frac{l_e}{L}$, Referring to the chart for the calculated 'k' value, we get from the corresponding chart.

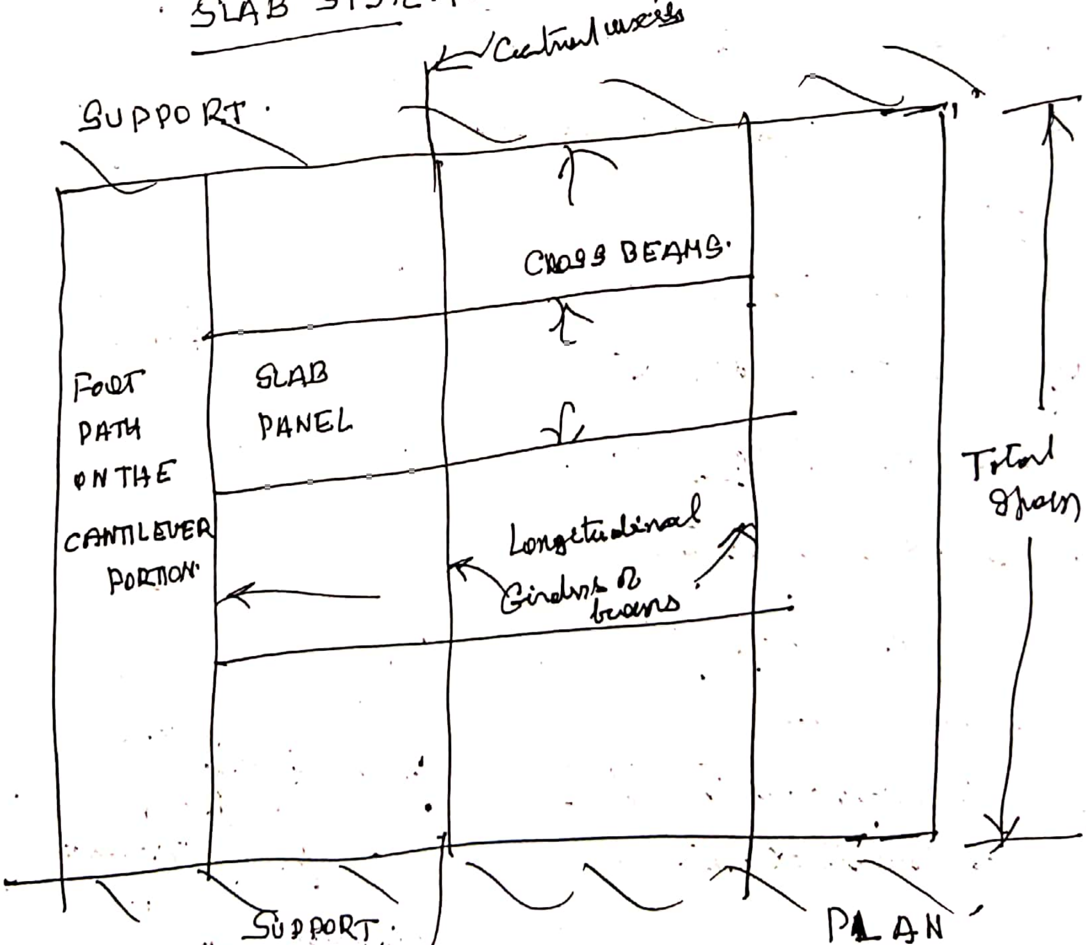
knowing $\frac{l_e}{B}$ and $\frac{l_e}{L}$ values the coefficients m_1 and m_2.

Hence, the B.M's are

$$\left.\begin{aligned} M_1 &= (m_1 + \mu m_2)\, W \\ M_2 &= (m_2 + \mu m_1)\, W \end{aligned}\right] \begin{aligned} &\text{Short span} \\ &\text{Long span} \end{aligned}$$

~~ANALYSIS OF LONG GIRDERS (T-BEAMS) IN GIRDER BRIDGES~~ ~~BRIDGE DECK~~

ANALYSIS OF BRIDGE DECK WITH GIRDER (T BEAMS) AND SLAB SYSTEM.



For the Analysis of Girder Bridges

METHOD OF ANALYSIS

→ Guyon Massonnet → MORRICE AND LITTLE.

→ Hendry - Jaeger Grid Analysis.

→ Courbon's Method. ✓

→ Stiffness method

→ Finite differences.

→ Finite elements.

...t of all the above Courbon's method is the simplest

... somewhat approximate. Certain Conditions are to be satisfied

COURBON'S METHOD

...itions

1. Span / Width of the deck should be greater than 2 but should be less than 2.

The long girders are interconnected by atleast 5 symmetrically placed cross girders.

The cross girders should have a depth equal to atleast 0.75 times the depth of long girders.

ANALYSIS BY COURBON'S METHOD.

Among the long girders, for any long girder,

the reaction factor $R_x = \frac{\Sigma W}{n}\left[1 + \frac{\Sigma I}{\Sigma d_x^2 \cdot I} \cdot d_x \cdot e\right]$

Where, I: M.I of each long girder

d_x: Distance of the girder under consideration from the central axis.
line

W: Total concentrated load

n: number of girders.

e: Eccentricity of the live load w.r.t the axis of the bridge.

Hence, the LL B.M^s are computed for the various long girders.

The B.M^s and shears in cross girders may be computed by approximate method.

DESIGN EXAMPLE.

Design an RCC T-Beam girder bridge to suit the following data.

Clear width of the road way: 7.5m.

Span c/c of bearings: 16m.

Live load: IRC class AA or class 'A' whichever is critical.

Thickness of W.C = 80mm., Use M25 concrete with Fe415 steel.

Design the deck slab, main girder and cross girder.

DATA:

Eff. span of the beams : 16 m.

Road width : 7.5 m.

Thickness of Wearing Coat : 80 mm.

Concrete: Use M25, Steel: Fe 415.

SOLUTION

Permissible Stresses

$\sigma_{cb} = 8.5\ N/mm^2$, $m = 10$, $\sigma_{st} = 200\ N/mm^2$, $j = 0.9$, $Q = R = 1.1$.

Cross Section of deck.

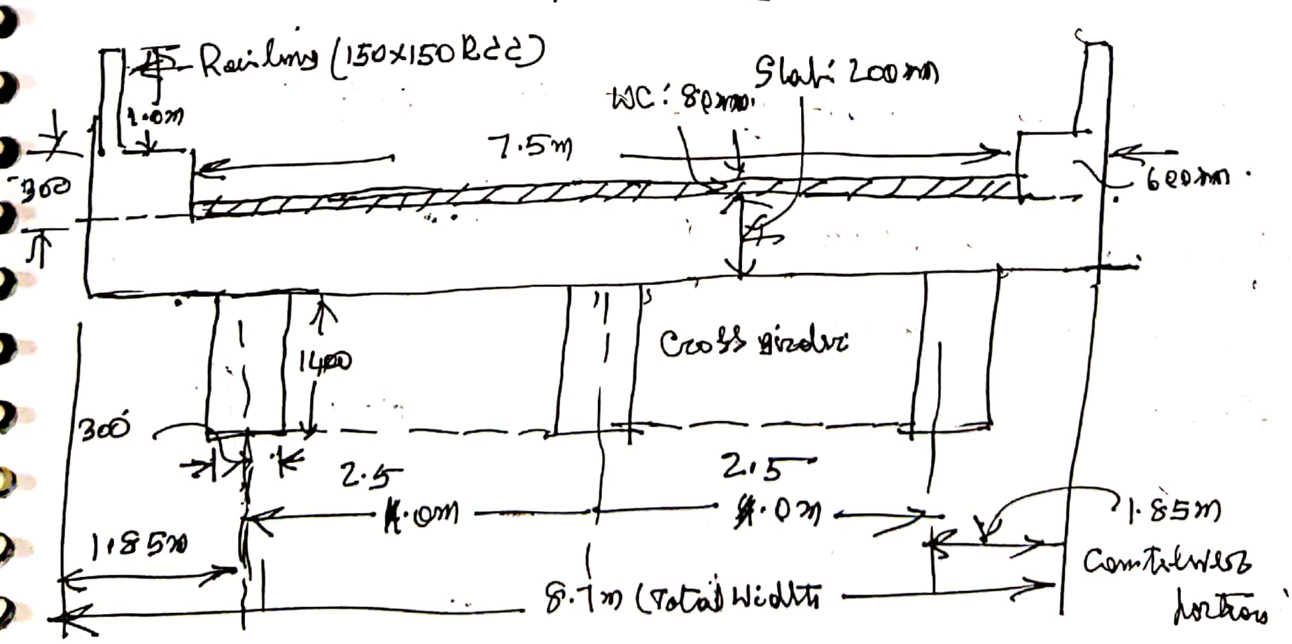
3 nos. of main girders are provided @ 2.5 m c/c.

Assume thickness of the deck slab = 200 mm; W.C = 80 mm.

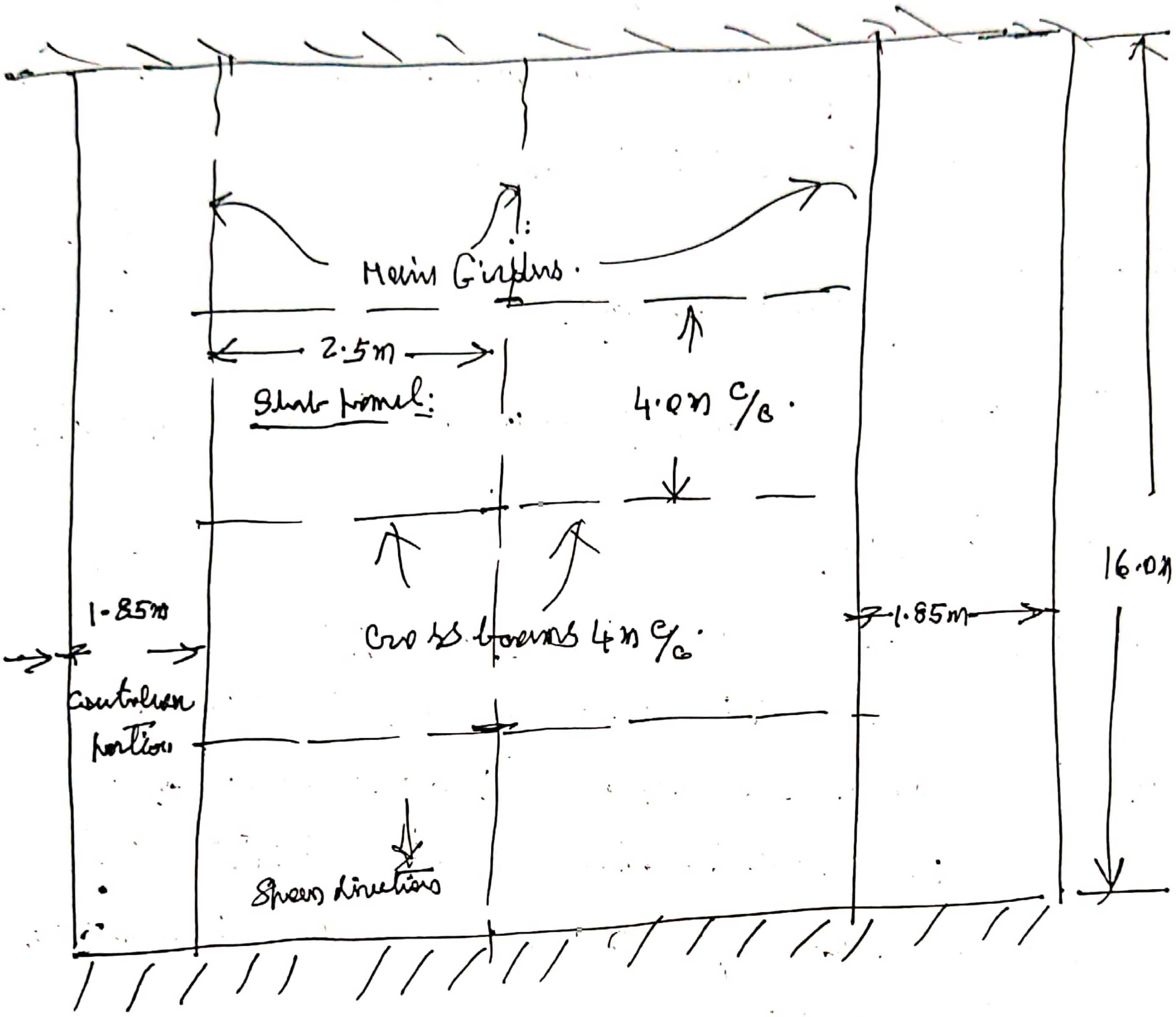
Main girders width = 300 mm, depth = 1600 mm. (Assumed). ($\frac{1}{10}$ to $\frac{1}{12}$ of span).

Kerbs, 300 mm height and 600 mm width.

Cross girders 4 m c/c. Size (same as main girders); 300 x 1600 mm

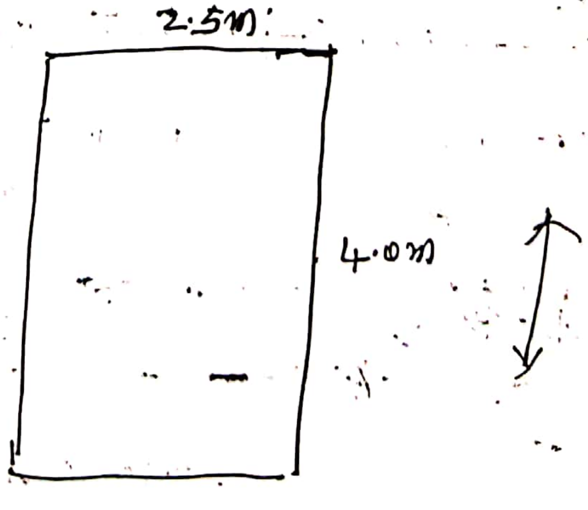


Plan Details of the Deck.



Considering one slab panel (2.5m x 4.0m).

Supported on main and cross beams on all the four sides.



- Dead load of the slab $= 1\times1\times0.2\times24 = 4.8\ kN/m^2$.

D.L of W.C $= 0.08\times22 = \underline{1.76\ kN/m^2}$

Total D.L $= \underline{6.56\ kN/m^2}$

Live load of class-AA (tracked) is placed at centre of the panel.

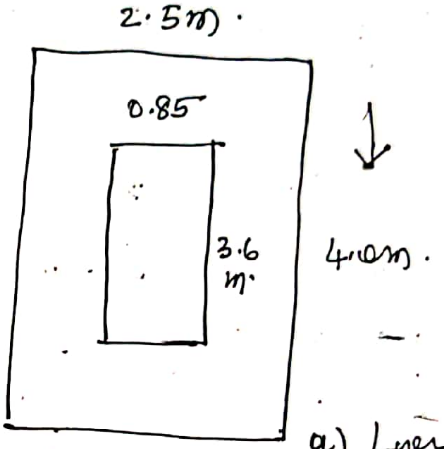
l_e (Along the width of the panel) $= 0.85+2\times0.08 = 1.01\ m$.

l_e: (Along the length of the panel)

$= 3.6+2\times0.08 = 3.76\ m$.

$$\frac{l_e}{B} = \frac{1.01}{2.5} = 0.404, \quad \frac{l_e}{L} = \frac{3.76}{4.0} = 0.94$$

$$K = \frac{B}{L} = \frac{2.5}{4} = 0.625.$$



a) Load.

Referring the curves (for $K = 0.60$)

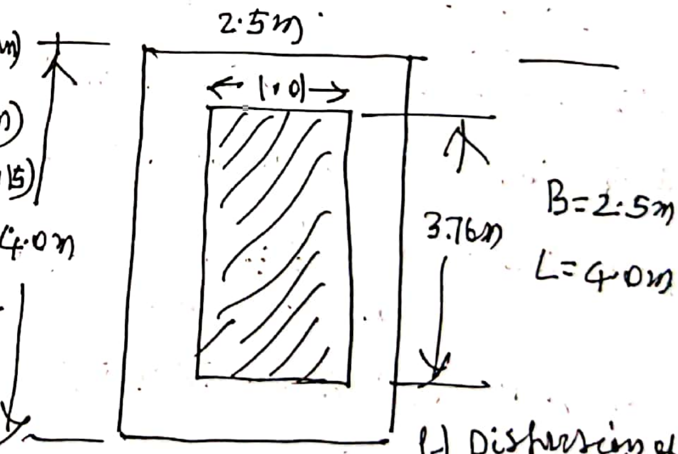
We get $M_1 = 8.5\times10^{-2}$. (Short span)

$M_2 = 2.4\times10^{-2}$. (Long span)

Hence, $M_B = W[M_1 + 0.15 M_2]$ ($\mu = 0.15$)

Hence, $M_B = 350\,[8.5 + 0.15\times2.4]\,10^{-2}$
(one track)

$= 31.01\ kNm$.



b) Dispersion of the load.

$M_L = 350\,[2.4 + 0.15\times8.5]\,10^{-2} = 8.855\ kNm$

M_L (Including impact and Continuity) $= 8.855\times1.25\times0.8$
$= 8.855$

M_B (including impact and Continuity) $= 1.25\times0.8\times31.01 = 31.01\ kNm$.

Scanned with CamScanner

Shear for CC:

For Max. S.F, the load is kept close to the Support in the Short Span.

Dispersion along the length (width of the panel direction)

$= 0.85 + 2(0.08 + 0.2) = 1.41\,m.$ (The whole dispersion in the span direction should be within the span) it is different from BM

Hence, the centre of the load is kept at

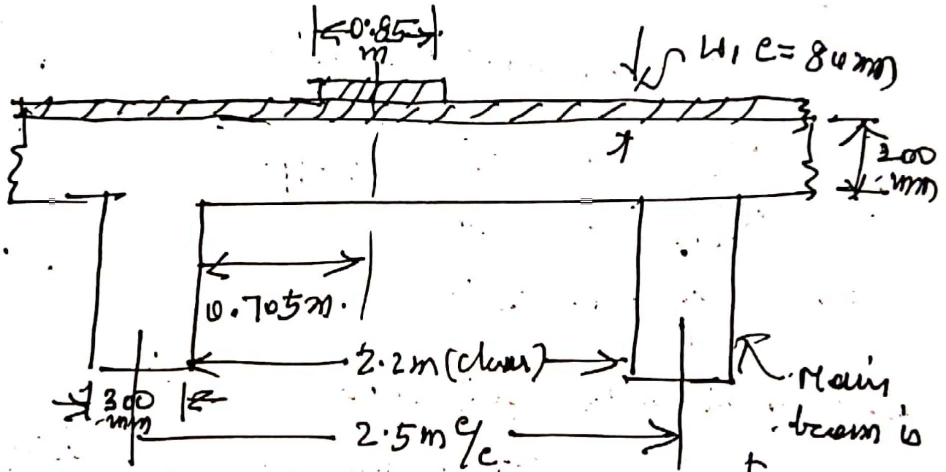
$\frac{1.41}{2} = 0.705\,m$ from the Support

In the other direction,

Eff. Width

$= \alpha a \left[1 - \frac{a}{l_0}\right] + b_w$

Clear $\frac{B}{L} = \frac{2.2}{3.7}$



Main beam is taken as the support for the slab panel

For the slab panel, the length direction is along the width of the bridge and the width direction is along the length of the bridge. Since $\frac{B}{L}_{(clear)} = \frac{3.7}{2.2} = 1.68$, from tables, $\alpha = 2.52$

Hence, eff. width (in the length direction) $= 2.52 \times 0.705 \left[1 - \frac{0.705}{2.2}\right] + (3.6 + 2 \times 0.08)$ (width direction of the panel)

$= 5\,m.$

Hence, load/m $= \frac{350}{5} = 70\,kN/m$

Left Side reaction = S.F $= 70 \left[\frac{2.2 - 0.705}{2.2}\right] = 47.60\,kN$

S.F including impact $= 1.25 \times 47.60 = 59.50\,kN.$

Dead load S.F

Total D.L = 6.56 kN/m²

Total load (occupying the whole panel) $\frac{B}{L} = \frac{4}{2.5} = 1.6 = k$

$\frac{L}{B} = \frac{L}{L} = 1$, ~~$k = \frac{B}{L} = \frac{2.5}{4} = 0.625$~~, $\frac{1}{k} = \cancel{0.6}\ 1.6$

We get from the curves, $M_1 = 4.9 \times 10^{-2}$, $M_2 = 1.5 \times 10^{-2}$

Hence $M_B = 65.6 [4.9 \times 10^{-2} + 0.15 \times 1.5 \times 10^{-2}) = 3.36$ kNm

with continuity $M_B = 0.8 \times 3.36 = 2.688$

$M_L = 65.6 (1.5 \times 10^{-2} + 0.15 \times 4.9 \times 10^{-2}) = 1.468$

With continuity $M_L = 0.8 \times 1.468 = 1.174$ kNm

Dead load SF $= \frac{6.56 \times 2.2}{2} = 7.216$ kN

DESIGN MOMENTS AND SHEARS

Total $M_B = 31.01 + 2.688 = 33.698$ kNm

Total $M_L = 8.855 + 1.174 = 10.029$ kNm

Total S.F $= 59.5 + 7.216 = 66.716$ kN

Design of Section

Eff. depth $= d = \sqrt{\frac{33.698 \times 10^6}{1.1 \times 1000}} = 175$ mm (Provide)

Provide an overall depth of 200 mm with $d_{eff} = 175$ mm

$A_{st} = \frac{33.698 \times 10^6}{200 \times 0.9 \times 175} = 1069$ mm²

For short span 16φ 150 c/c are provided, giving $A_{st\,(pro.)} = 1341$ mm²

For long span, $d_{eff} = 175 - 8 - 5 = 162$ mm. $A_{st} = \frac{10.029 \times 10^6}{200 \times 0.9 \times 162} = 344$ mm²

(10mmφ) Provided 10φ 150 c/c.

Check for Shear Stress

$$\tau_c = \frac{V}{bd} = \frac{66.716\times10^3}{1000\times175} = 0.381\ N/mm^2 < 1.9\ (\tau_{max}).$$

Permissible Shear stress $= K\tau_c$.

From table. 6 of IRC, $K = 1.2$, ~~Hence $K\tau_c = 1.2\times0.38$~~ ~~$= 0.456$ Say $0.46\ N/mm^2$~~

Percentage of Steel $= \frac{1341}{1000\times175}\times100 = 0.77\%$.

from table. 5 (IRC) we get $\tau_c = 0.37\ N/mm^2$.

Permissible $= K\tau_c = 1.2\times0.37 = 0.44\ N/mm^2 > \tau_b\ 0.38\ N/mm^2$

Hence, Safe in Shear. Alternate bars are cranked.

LONGITUDINAL GIRDERS.

IRC class 'AA' tracked Vehicle is arranged with max. eccentricity w.r.t the Centre of the deck. The ~~minim~~ track is kept at minimum clearance from the kerb.

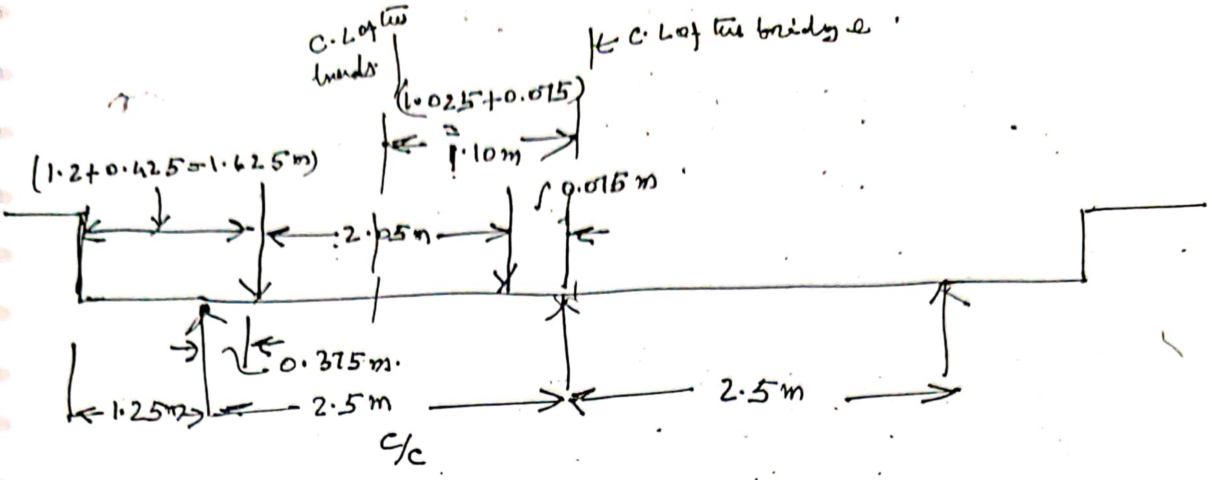
For spans > 5.5m minimum clearance for IRC class 'AA' is 1.2m

Hence, the distance of the Centre of the track from the face of the kerb $= 1.2 + \frac{0.85}{2} = 1.625m$.

Distance of the centre of the end girder from the face of the kerb $= 1.25m$.

Hence, distance of the Centre of track from the Centre of the end girder $= 1.625 - 1.25 = 0.375m$.

Scanned with CamScanner



∴ By Courbon's theory the reaction factor is given by

$$R_x = \frac{\Sigma W}{n}\left[1 + \frac{\Sigma I}{\Sigma d_x^2 \cdot I} \cdot d_x e\right]$$

, e: eccentricity of the loading w.r.t the axis of the bridge.

n: no. of girders

d_x: Dist. of the centre of girder from the long axis of the bridge.

$\Sigma W = 700\,kN$, $W_1 = 350\,kN$, $e = 1.1m$.

$n = 3$, I: Same for all girders, $d_x = 2.5$

R_A (for outer girder) $= \frac{2W_1}{3}$

$$R_A = \frac{2W_1}{3}\left[1 + \frac{3I}{(2 \times 2.5^2)\,I} \times 2.5 \times\right] = 1.107\,W_1$$

For inner girder, $R_B = \frac{2W_1}{3}\left[1 + \frac{3I}{0 \times I} \times 0\right] = \frac{2W_1}{3}$

Hence, $R_A = 1.107 \times 0.5W = 0.5536W$

$RB = 0.667 \times 0.5W = 0.3333W$.

Dead load Effect

Parapet = $0.15 \times 0.15 \times 1.5 \times 24$ = say 0.7 kN/m

Kerb = $0.5 \times 0.6 \times 1 \times 24 = 7.20$ kN/m

W.C = $0.08 \times 1.10 \times 1 \times 24 = 1.936$ kN/m

Slab = $0.2 \times 1.10 \times 24 = 5.280$ kN/m

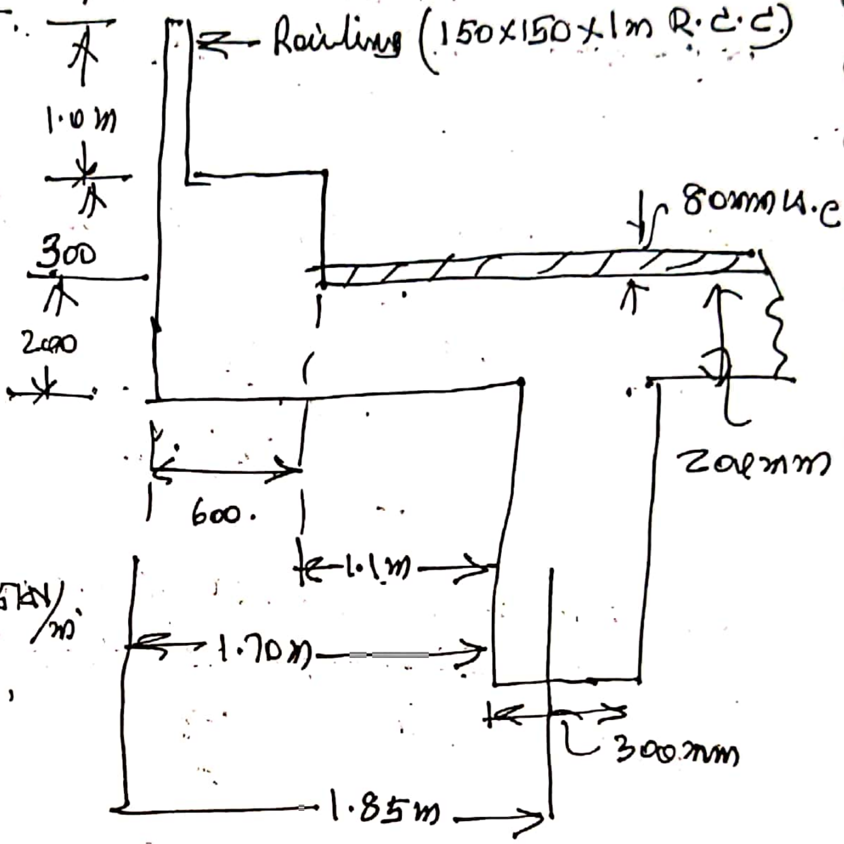
Total = 15.116 kN/m

Width of the deck between the two external girders = 5.3 m

Hence, D.L. of the deck portion = 6.56×5.3

Total D.L on the deck = $(2 \times 15.116 + 6.56 \times 5.3) = 65$ kN/m

DL/girder = $\frac{65}{3} = 21.66$ kN/m



Live load Effect

Area of the diagram below the load = $2 \times \left[\frac{(4+3.1)}{2} \times 1.8\right] 2$

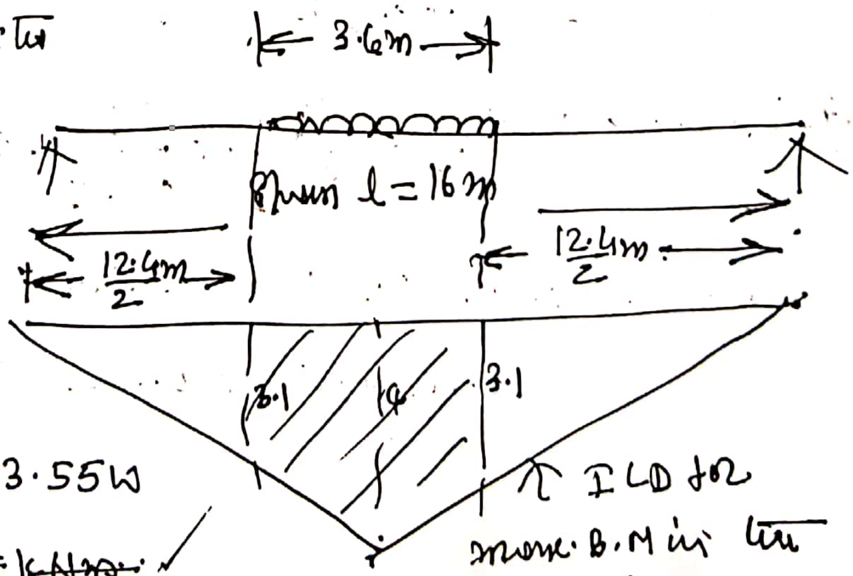
$= (4+3.1) \times 1.8 +$

~~$(4+3.1) \times 1.8$~~

$= \frac{(4+3.1)}{2} \times 3.6 = 3.55W$

$= 3.55 \times 700 =$ ~~2485 kNm~~

$= 2485$ kNm.



B.M including I.F and R.F for, [I.F = 10% for tracked for spans > 9 m]

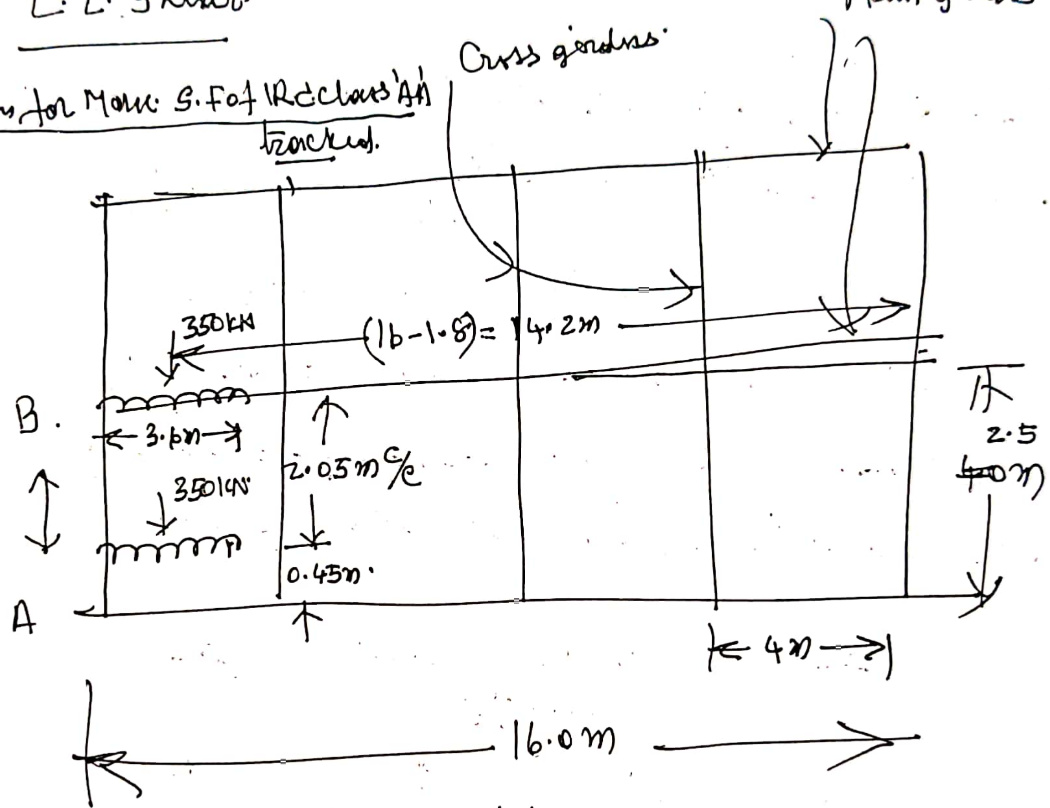
outer girders = 2485 × 1.1 × 0.5536

= 151.3 kNm

Inner girders = 2485 × 1.1 × 0.3333 = 912 kNm

L.L. Shear.

Position for Max. S.F of IRC class 'AA' tracked.



Reaction of one track load on girder 'B' = $\frac{350 \times 0.45}{2.5}$ = 63 kN

" Same track " A = $\frac{350 \times 2.05}{2.5}$ = 287 kN

The second track is acting completely on girder B.

Hence, total on girder 'B' = 63 + 350 = 413 kN

Max. Support reaction on girder 'B' = $\frac{413 \times 14.2}{16}$ = 366 kN

" " girder 'A' = $\frac{287 \times 14.2}{16}$ = 255 kN

Max. L.L Shear including I.F on inner girder (B)

$= 366 \times 1.1 = 402.6$ kN.

on the outer girder (B) $= 255 \times 1.1 = 280.5$ kN.

D.L B.M and S.F on the Inner girder

Dead load of the rib of the main girder $= (1.6 - 0.2) \times 0.3 \times 24 = 10.08$ kN/m.

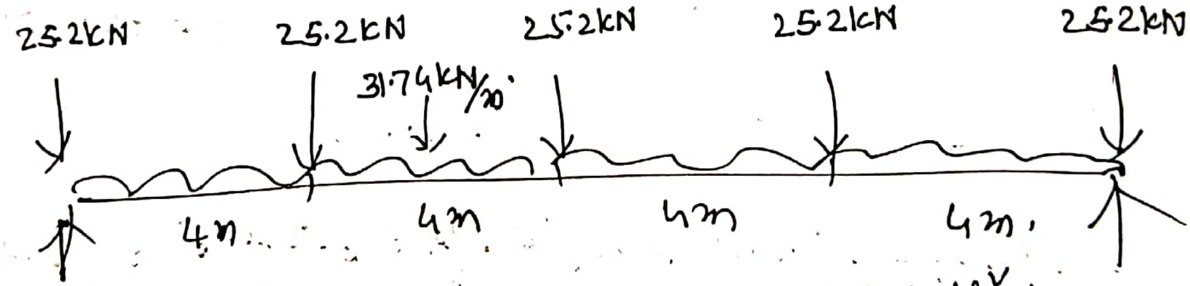
D.L of the cross ~~section~~ girder (same section as main girder) $= 10.08$ kN/m.

Reaction on the main girder $= 10.08 \times 2.5 = 25.2$ kN.

Reaction from deck slab on each girder $= 21.66$ kN/m (calculated)

Hence, total D.L on the girder $= 21.66 + 10.08 = 31.74$ kN/m.

The max. B.M in the girder is calculated as follows



$$M_{max} = \left(\frac{25.2 \times 5}{2}\right) \qquad \left(\frac{wl^2}{8}\right)$$

$$M_{max} = \left(\frac{25.2 \times 5}{2}\right) \times 8 - (25.2) \times 8 - (25.2)\, 4 + \frac{31.74 \times 16^2}{8}$$

$$= 25.2 \times 8 \left[\frac{5}{2} - 1 - \frac{1}{2}\right] + \frac{31.74 \times 16^2}{8} \quad \cancel{25.2 \times 8}$$

$$= 25.2 \times 8 + \frac{31.74 \times 16^2}{8}$$

Hence, $M_{max} = 1218$ kNm.

D.L. Shear (at support) $= \frac{31.74 \times 16}{2} + 25.2 + \frac{25.2}{2} = 292$ kN.

DESIGN OF CROSS GIRDERS.

Arrangement of D.L on the Cross girder

D.L from the slab on the Cross girder $= \left(\frac{1}{2} \times 2.5 \times 1.25 \times 6.36\right)2$

$= 20.5\ kN.$

$UDL = \frac{20.5}{2.5} = 8.2\ kN/m$

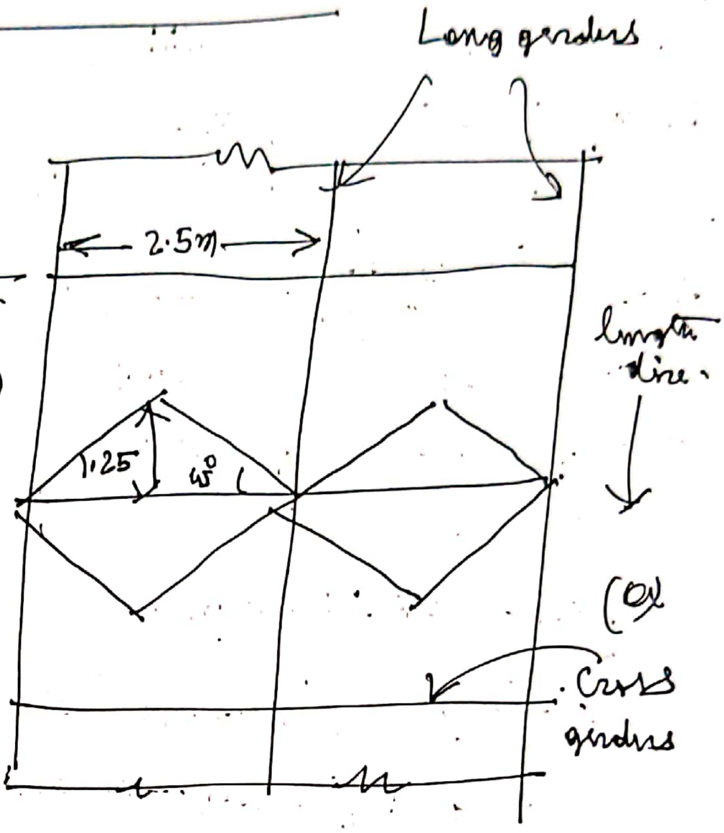
Self wt. $= 10.08\ kN/m$ (Same as main girder)

Total DL $= 8.2 + 10.08 = 18.28\ kN/m$

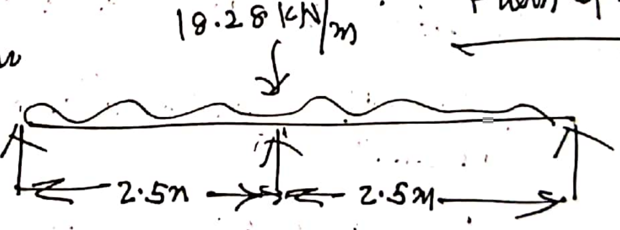
Total load on 5m length of ~~5 no of~~ Cross girders $= 5 \times 18.28$

Hence reaction on each girder taking equally $= \frac{5 \times 18.28}{3}$

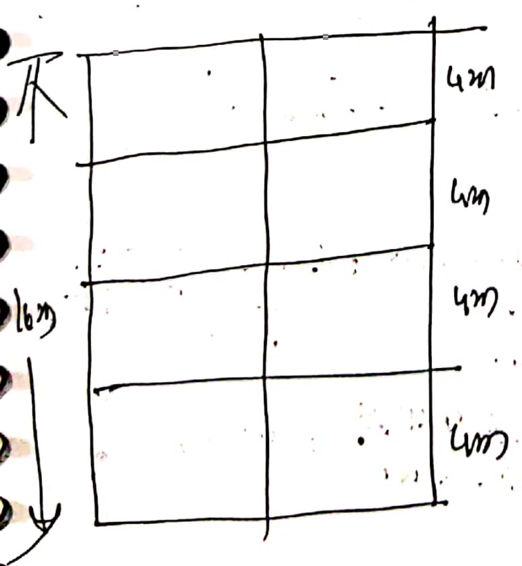
$= 30.47\ kN.$

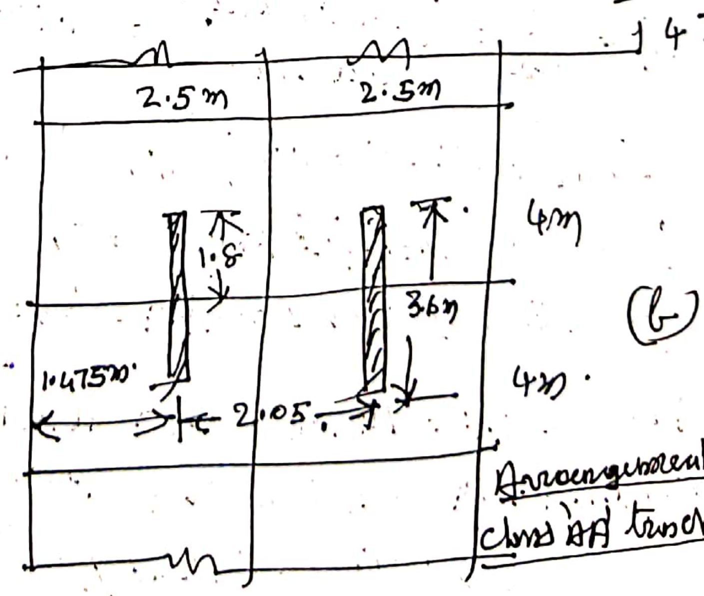


Plan of the deck



$2.50 - 1.025 = 1.475$





Arrangement of class AA tracked

Girder	DL Shear KN	LL Shear KN	Total Shear KN
outer	292	280.1	572.1
Inner	292	402.6	694.6

DESIGN OF SECTIONS.

Outer Girder Max. B.M = 2731 kNm, Max. S.F = 694.6 kN.

Assuming $d_{eff.} = 1600 - 150 = 1450$ mm.

Taking approximate lever arm $= \left(d - \frac{t_s}{2}\right) = 1450 - \frac{200}{2} = 1350$ mm

$$A_{st} = \frac{2731 \times 10^6}{200 \times 1350} = 10,114 \text{ mm}^2$$, Provide 16 Nos 32 ϕ

(A_{st} (act.) = 12864 mm²)

$$\therefore \tau_v = \frac{V}{bd} = \frac{694.6 \times 1000}{300 \times 1450} = 1.596 \text{ N/mm}^2.$$

τ_{max} for M25 = 1.9 N/mm², Hence $\tau_v < \tau_{max}$.

By bending 2 Nos. of ~~25~~ 32 ϕ at support,

Shear taken by the bars = $\sigma_{st} A_{sb} \sin\alpha = \left[200 \times 2 \times 804 \times \frac{1}{\sqrt{2}}\right] \frac{1}{10^3} = 227$ kN.

Balance S.F = 694.6 − 227 = 467.6 kN.

Using 10 ϕ 4L Stirrups, Spacing = $\frac{200 \times 4 \times 79 \times 1450}{467.6 \times 1000} = 195$ mm

Hence provide 10 ϕ 4L 150 c/c.

Arrangement of L.L for max. effect on the cross girders

Due to L.L, reaction on the cross girder (total).

$$= \frac{350\left(4-\frac{1.8}{2}\right)}{4} \times 2 = \frac{350\left(4-\frac{1.8}{2}\right)}{2} = 542.5\ kN.$$

(For two tracks)

$$= (2 \times 271.25)$$

$$\left[\frac{\frac{350}{2}\times\left(4-\frac{1.8}{2}\right)}{4}\right]\times 2$$

Hence the resulting reaction on the long girder

$$= \frac{542.5}{3} = 180.83\ kN.$$ (Distributed among 3 Nos of long girders)

$$= \frac{350\left(4-\frac{1.8}{2}\right)}{4}$$

Hence, Max. B.M on the cross girders due to the LL above $= 180.83 \times 1.475$

$$= 266.67\ kNm.$$

LLBM including impact $= 1.1 \times 266.67 = 293.37\ kNm.$

DLBM at 1.475 m from the support $= 30.47 \times 1.475 - \frac{18.28 \times 1.475^2}{2}$

$$= 25.10\ kNm.$$

Hence, total design B.M

$$= 293.37 + 25.10 = 318.47\ kNm.$$

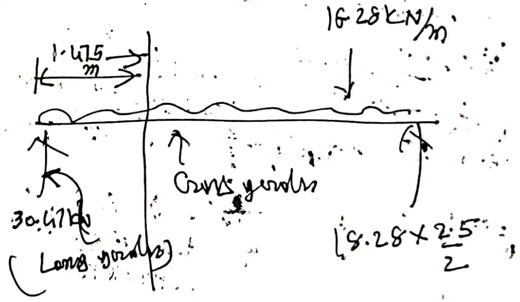
L.L. Shear including impact

$$= \left(\frac{2 \times 271.25}{3}\right) \times 1.1 = 198.917\ kN.$$

(At one long girder)

D.L. Shear $= 30.47\ kN$

Total Shear $= 229.39\ kN$



Assuming an eff. depth of 1450, $d = 1450$ for cross girder;

Main reinf. $= A_{st} = \frac{318.47 \times 10^6}{200 \times 0.9 \times 1450} = 1220\ mm^2$

Provide 4 Nos 20 ϕ (A_{st} (act) $= 1256\ mm^2$)

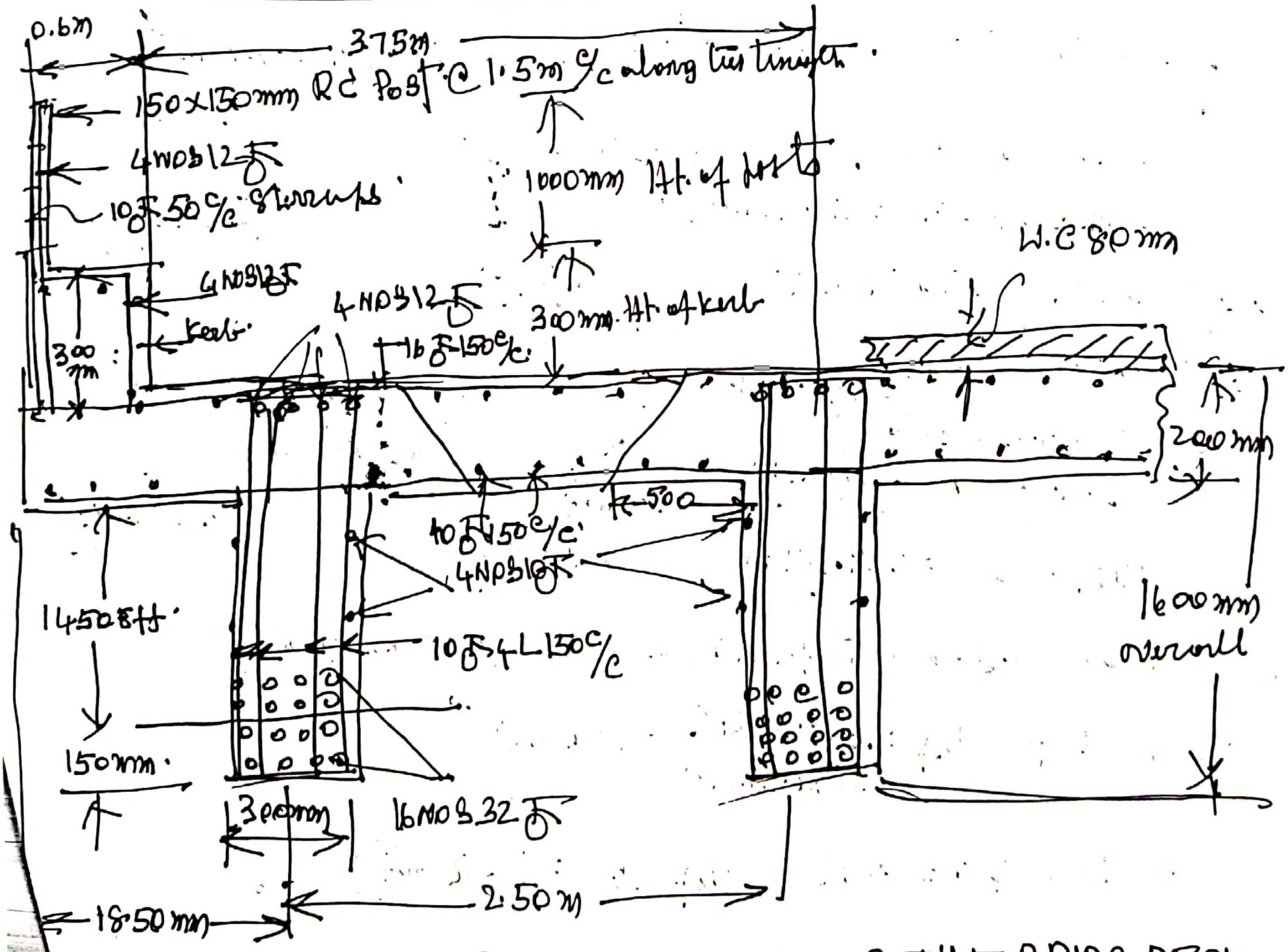
$$\tau_v = \frac{229.39 \times 10^3}{300 \times 1450} = 0.52\ N/mm^2 < \tau_{max}$$

Providing stirrups for the whole shear,

$$\text{Spacing of } 10\phi\ 2L \text{ stirrups} = \frac{200 \times 2 \times 79 \times 1450}{229.39 \times 1000} = 200\ mm \text{ nearly.}$$

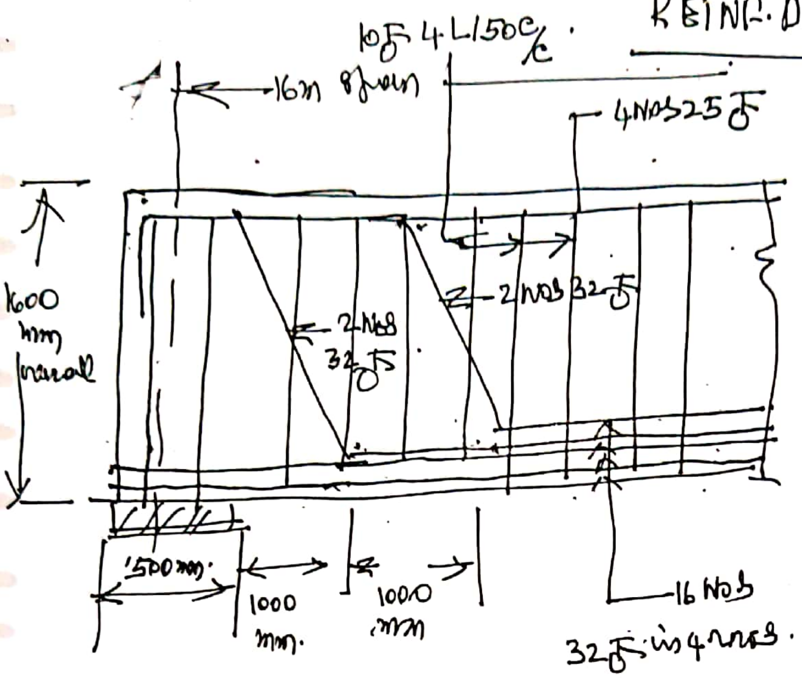
Hence provide $10\phi\ 2L\ 150\ c/c$.

DETAILS OF REINF.

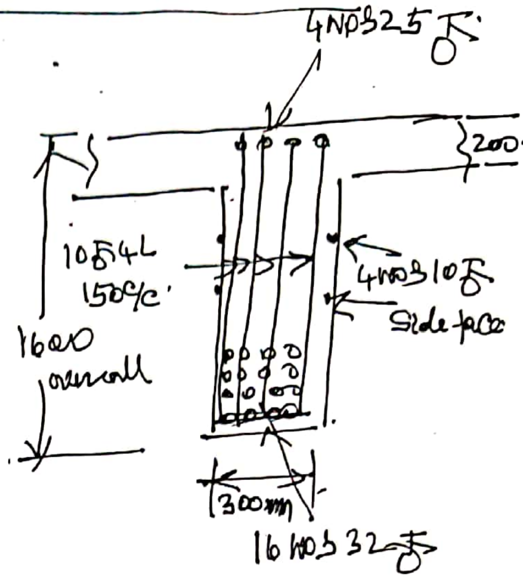


CROSS SECTION OF THE BRIDG DECK.

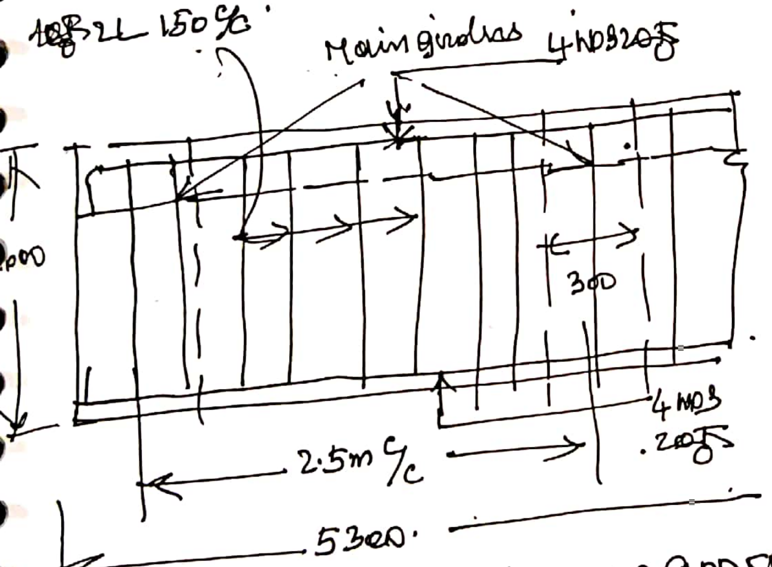
REINF. DETAILS OF GIRDERS.



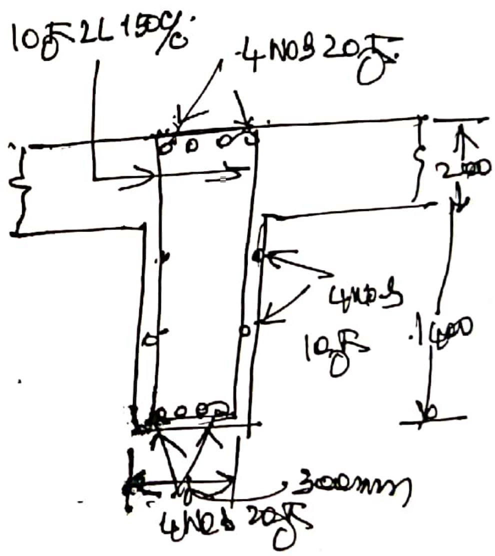
LONG. SECTION OF MAIN GIRDER NEAR THE SUPPORT



CROSS SECTION



LONGITUDINAL SECTION OF CROSS GIRDER



CROSS SECTION