Reinforced Concrete Road Bridges

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Lectures - 09, 10 and 11

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Overview

Design of slab bridges

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Design of slab bridges

- A slab bridge is the simplest type of construction, adopted for small spans
- Slab bridges of span 10m, are mostly observed and the range of span, 8-12m is generally used
- The thickness of the slab will be considerably high, but its construction is simpler and the cost of the formwork is also less

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Design of slab bridges

- For design of bridges, two aspects are looked into:

  Hydralic design: when the bridge crosses the water body, such as, canals, rivers etc.

  Structural design: This is applicable for all bridges, fly overs etc. to provide suitable depth, reinforcement, plate thickness etc.

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Design of slab bridges

- We shall take the structural design of slab deck bridge

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Wheel load on slabs

- Generally during structural analysis, wheel loads are considered as concentrated load on the slab
- But the wheel is having certain impression, i.e. the load gets dispersed along spanwise and widthwise direction.

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Wheel load on slabs

- There are methods available for analysis of slabs subjected to concentrated load

  (1) Effective width method: Applicable where one way action prevails, in the present case, in slab bridges

  (2) Piegeaud's coefficient method: The slab is supported on all four sides. The short span and long span bending moment coefficients are read from Pigeaud's chart. This will be used during design of RCC T beam bridges

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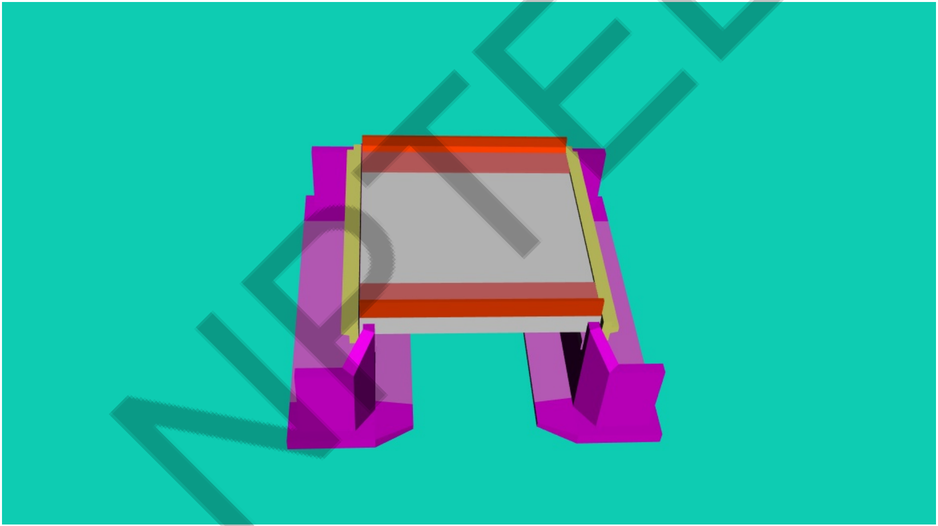
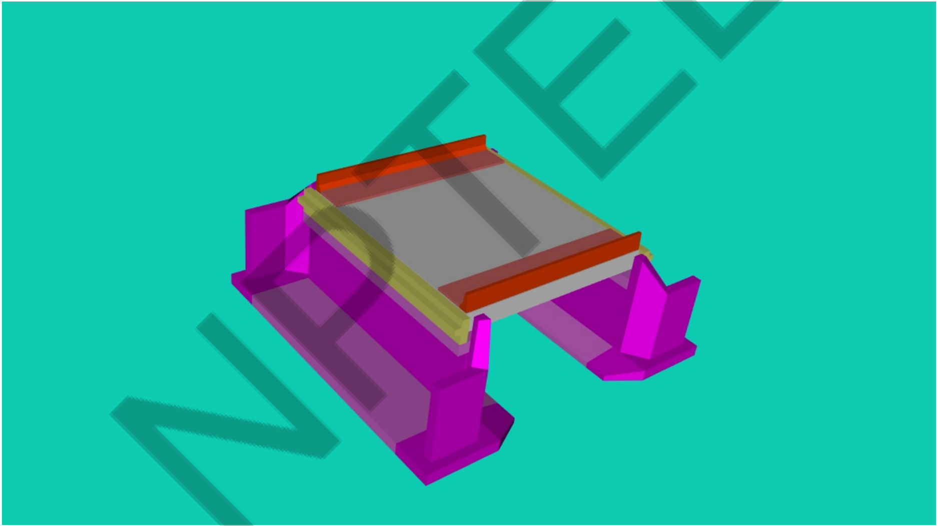
Different components of slab bridges

Different components of slab bridges



Different components of slab bridges



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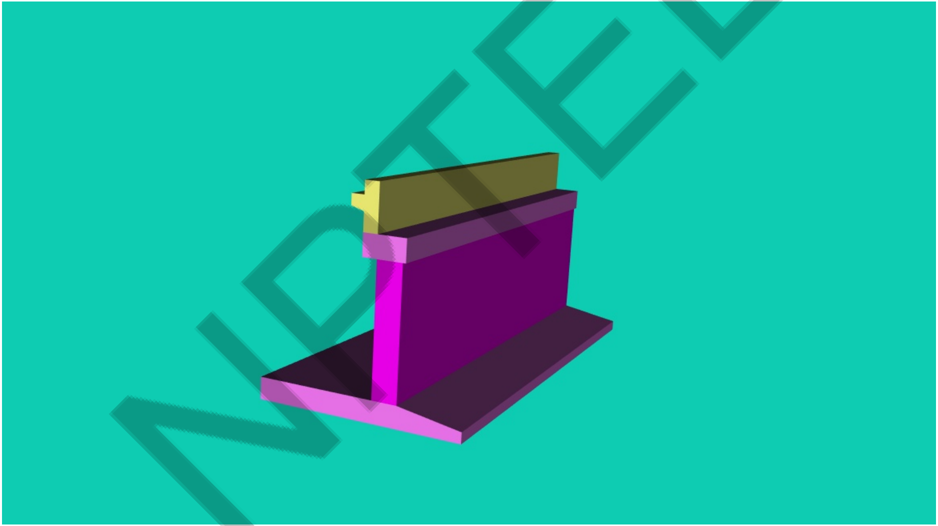
Different components of slab bridges



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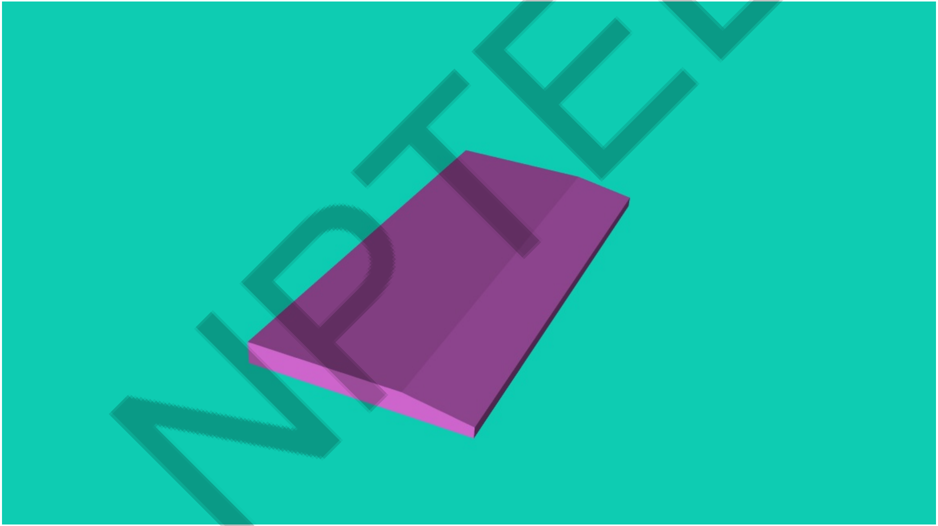

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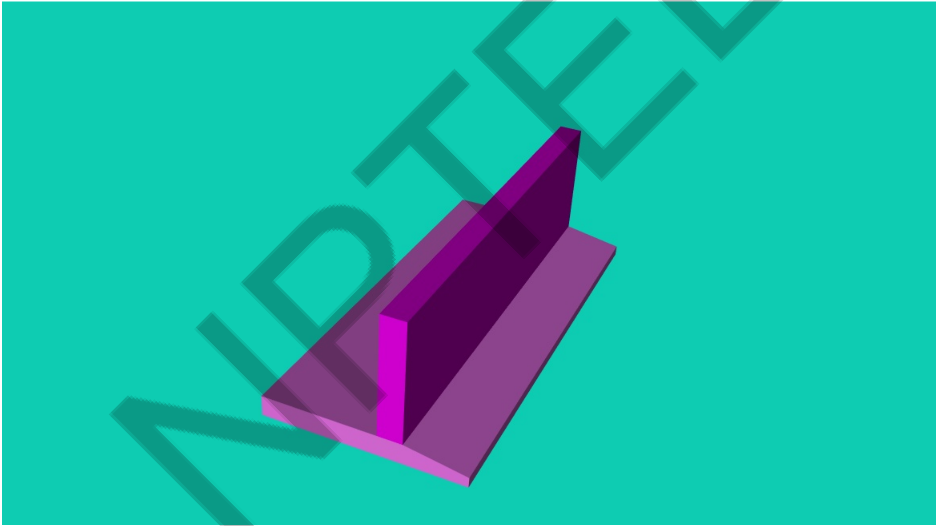

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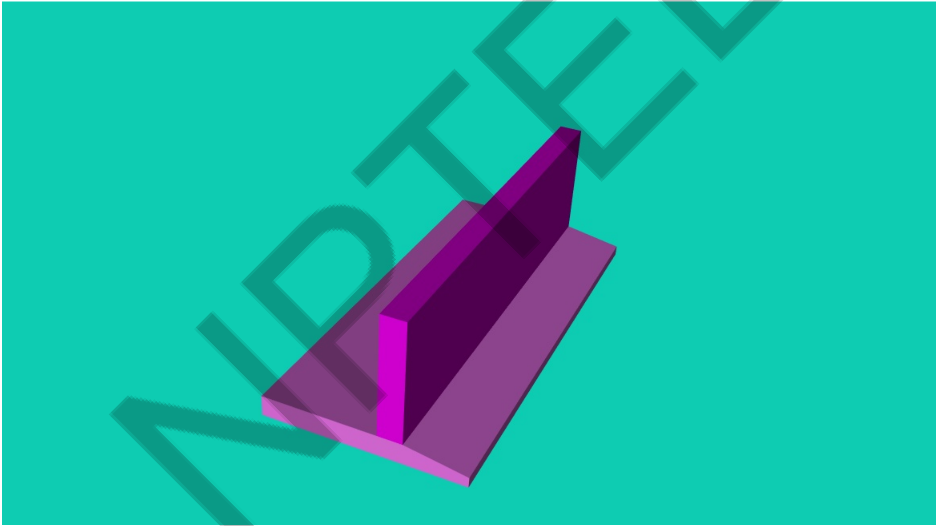
Different components of slab bridges



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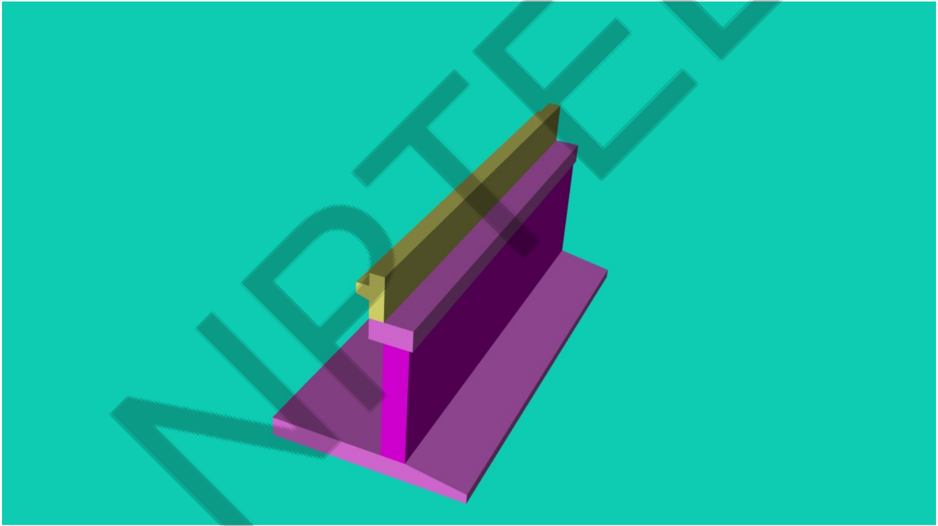

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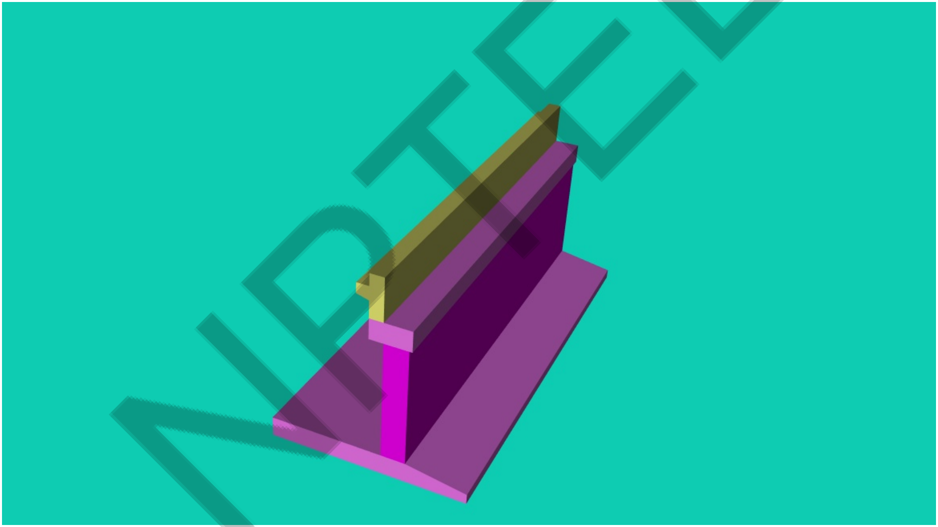

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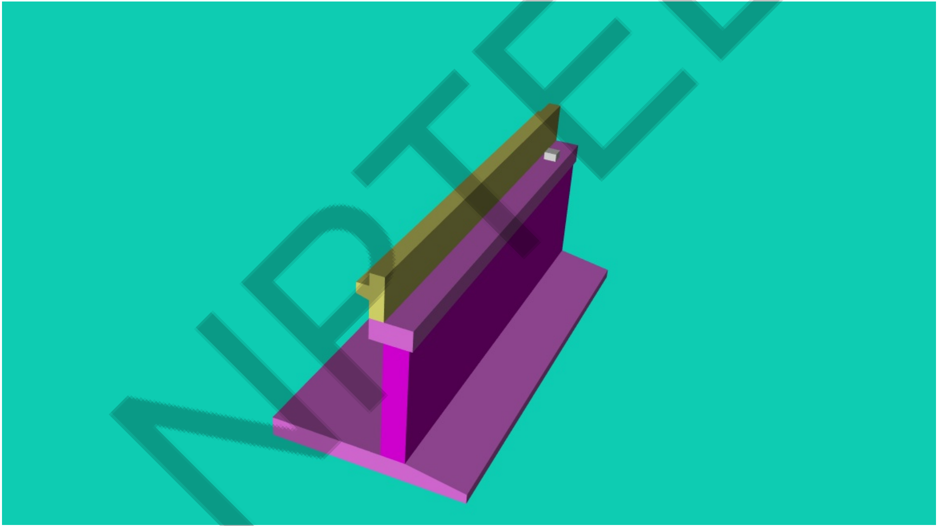

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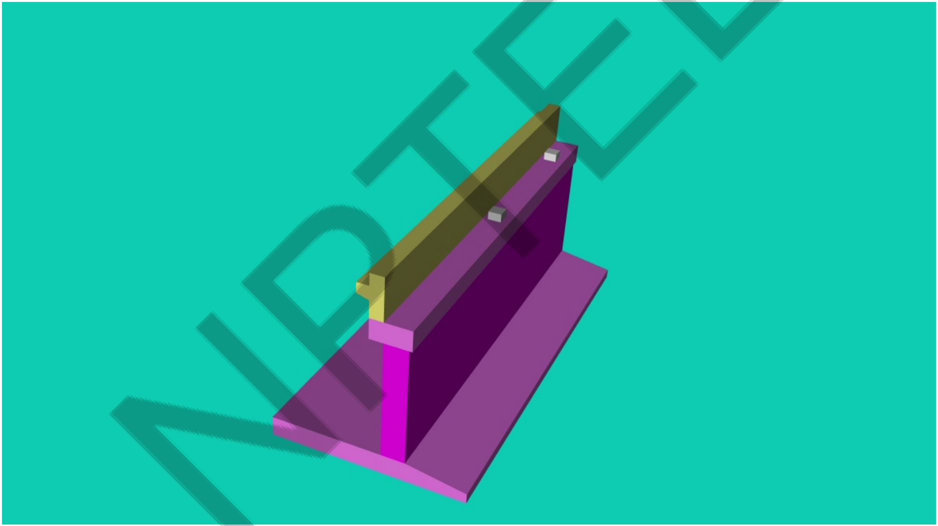

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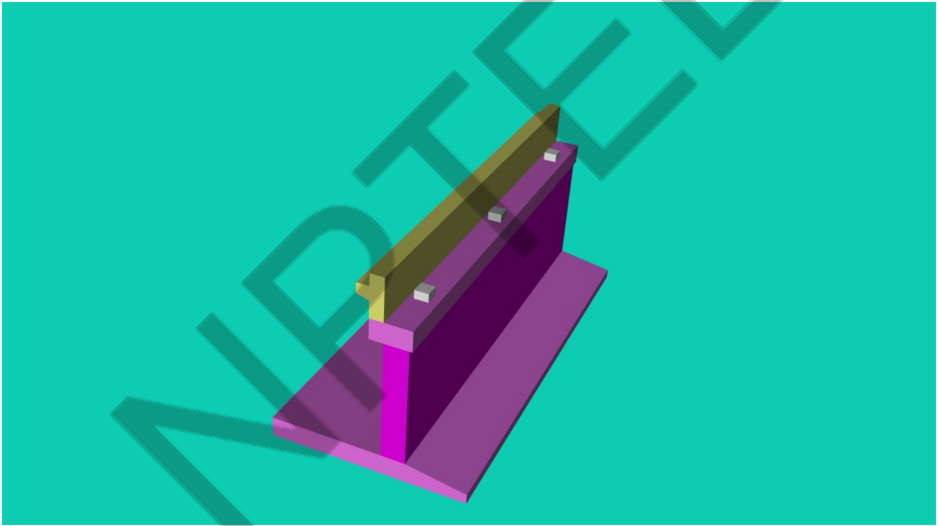

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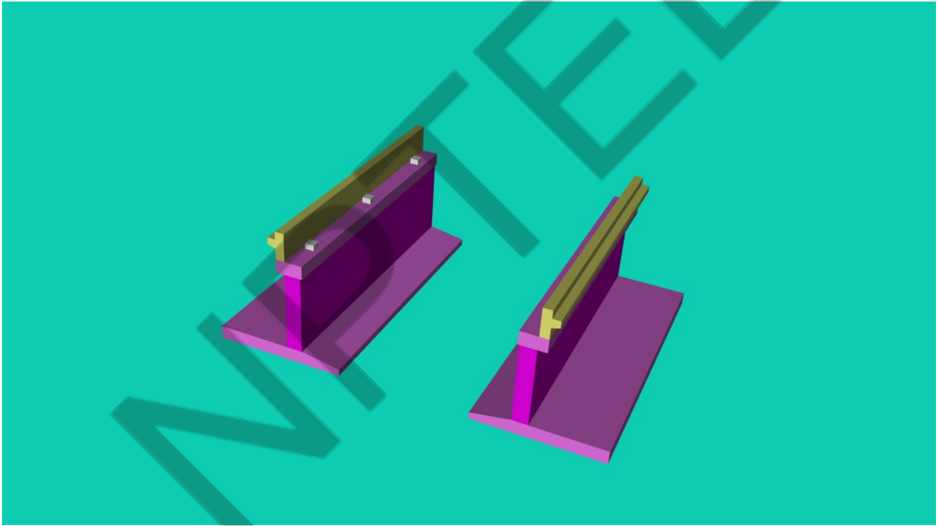

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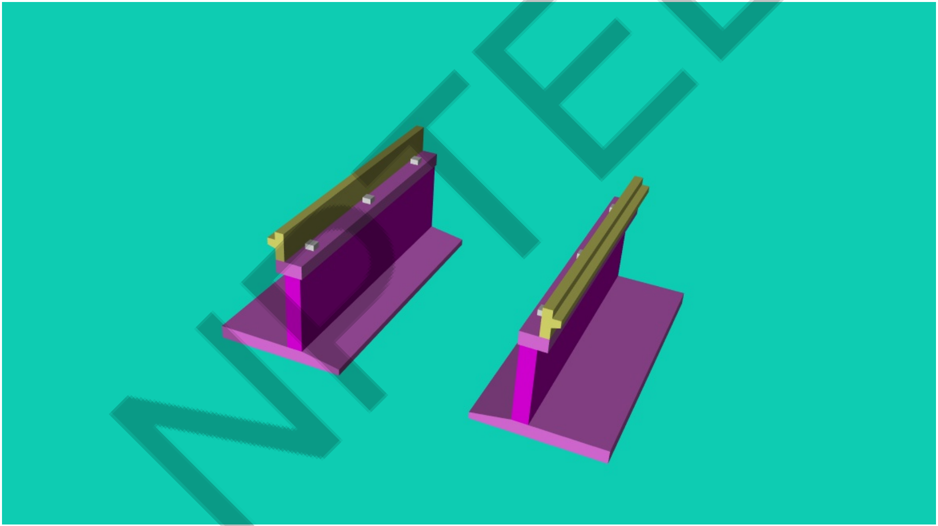

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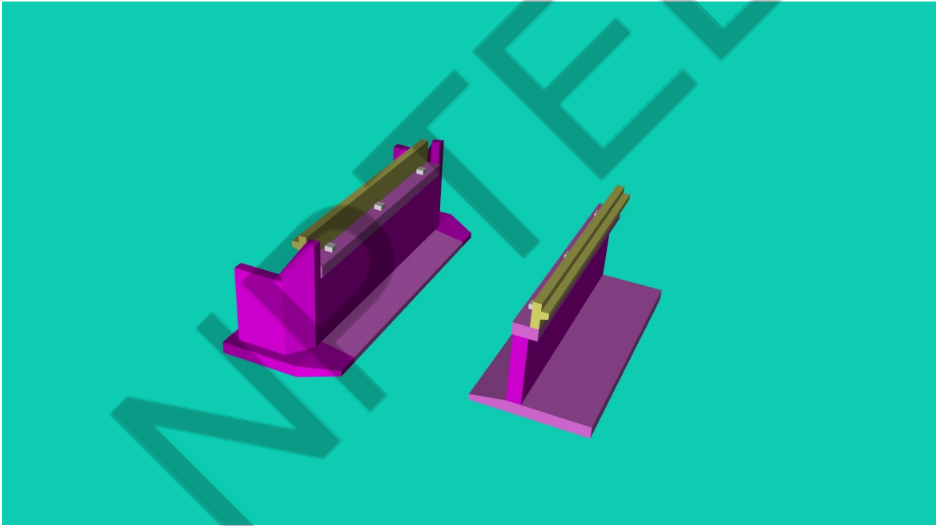

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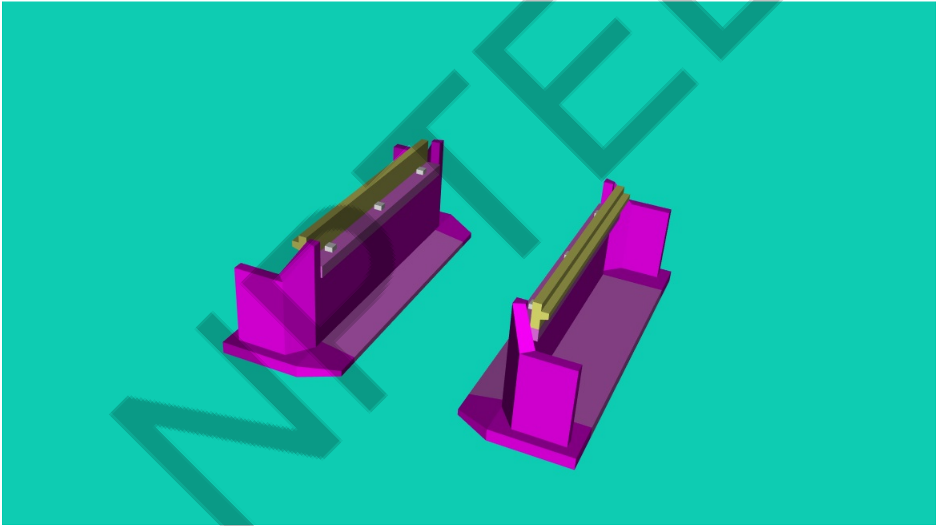

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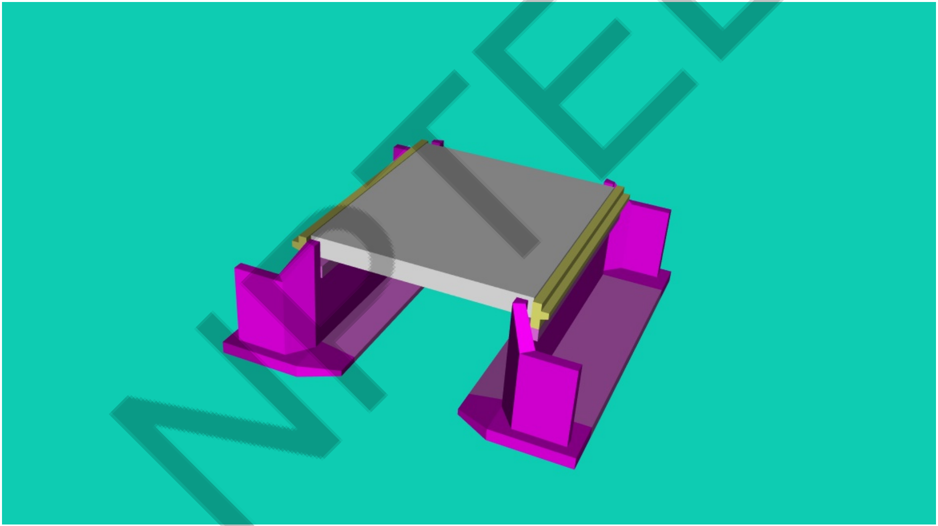

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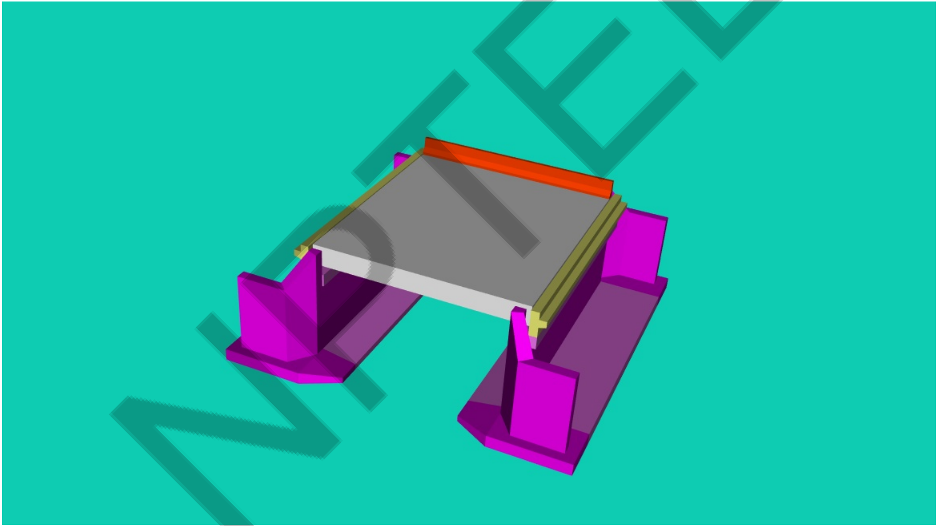

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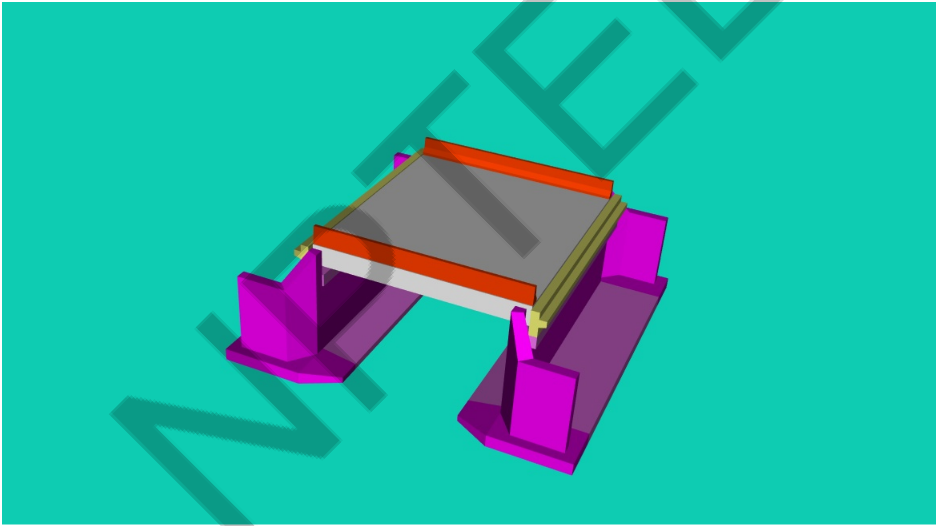

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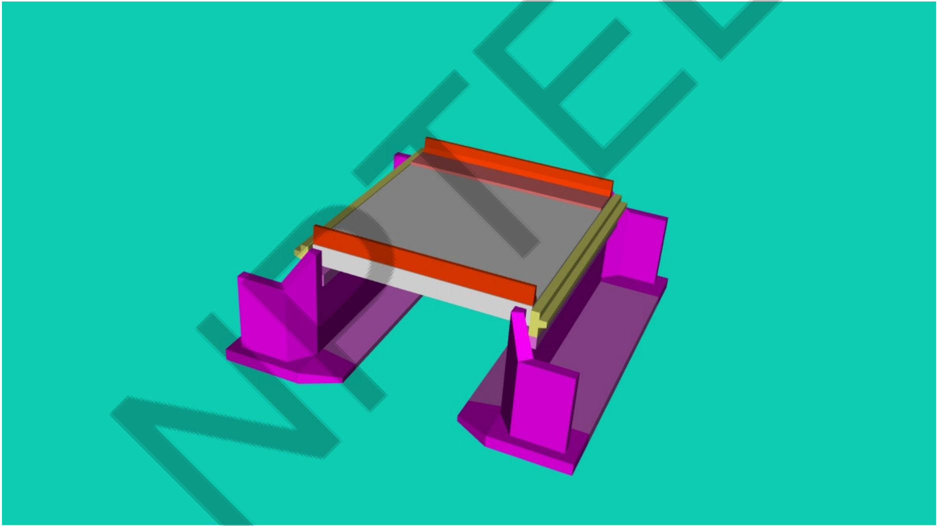

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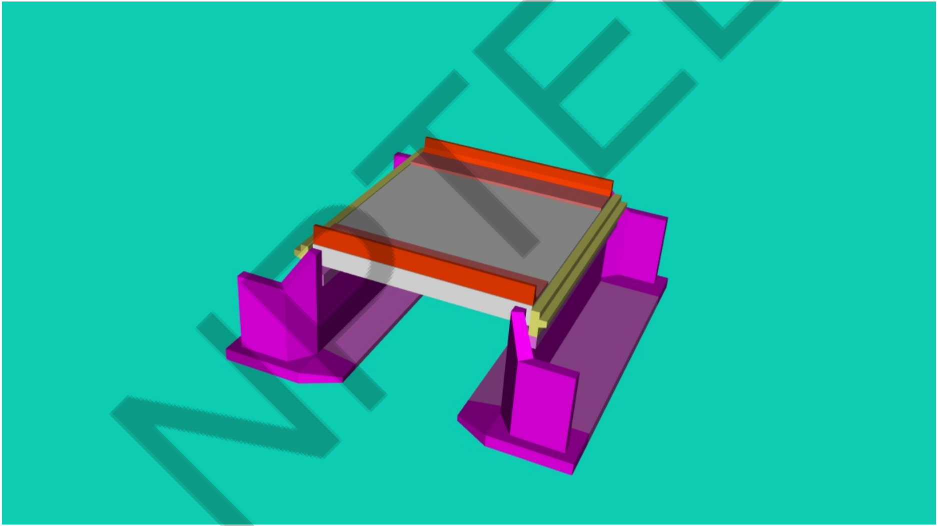
Different components of slab bridges



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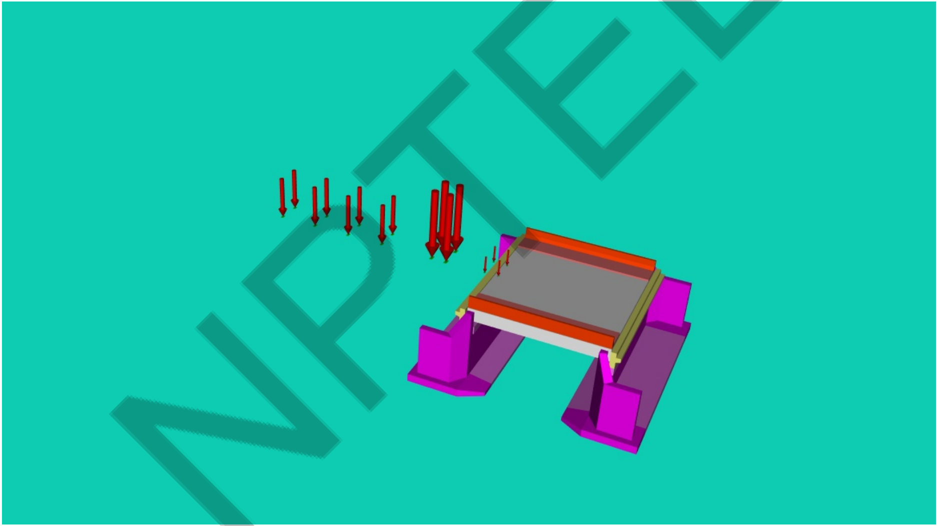

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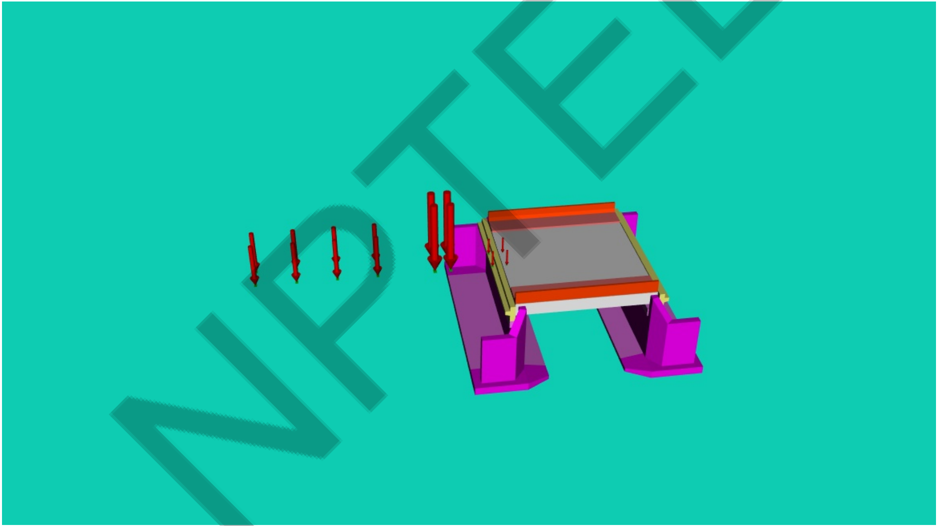

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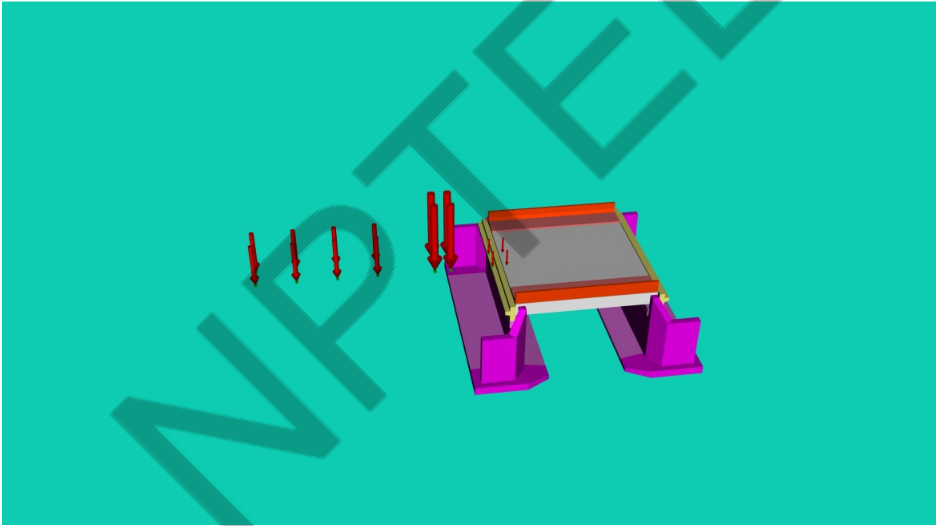
Different components of slab bridges



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Problem Statement : Design of slab bridges

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Problem Statement : Design of slab bridges

Problem : 1 Design a deck slab bridge for the following parameters :

- Clear span: 5.500 m
- Width of carriage way : 7500.0 mm
- Width of the foot path : 1000.0 mm on either side
- Wearing coat: 100 mm
- Loading : IRC 70R (tracked)
- Materials : Concrete : M25, Steel : Fe415

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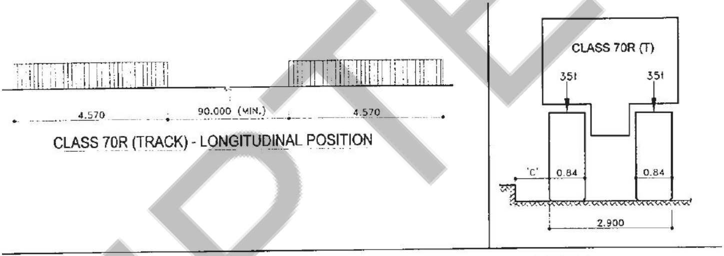
IRC 70R Tracked Vehicle



WHEEL ARRANGEMENT FOR 70R (TRACKED) VEHICLE

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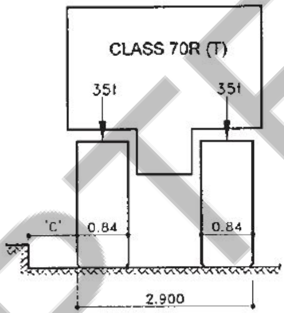
IRC 70R Tracked Vehicle



- The minimum clearance between the road face of the kerb and the outer edge of the wheel or track,'c', shall be 1.2 m.
- Therefore,Class 7OR loading is applicable only for bridges having carriageway width of 5.3 m and above(i.e. 1.2 x 2 + 2.9 = 5.3).

IRC 70R Tracked Vehicle - longitudinal position

- The nose to tailspacing between two successive vehicles shall not be less than 90 m for tracked vehicle and 30 m for wheeled vehicle.

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Design parameters

(A) Effective span of the bridge

- Assume clear span by overall depth as 12
- Estimated overall depth of the slab :

$$L_{estim} = \frac{5.500}{12.0} = 0.458m \tag{1}$$

- Overall depth of the slab (assumed) = 460.0 mm
- Assume width of the bearing = 400.0 mm
- Effective span, L = 5.500 + 0.400 = 5.900 m

Dead load

(B.1) Dead Load :

- Dead load of the slab:

$$q_{slab} = 0.460 \times 24.0 = 11.040 \; kN/m^2 \tag{2}$$

- Dead load of the wearing coat:

$$q_{wc} = 0.100 \times 22.0 = 2.200 \; kN/m^2 \tag{3}$$

- Dead load:

$$q_{dl} = 11.040 + 2.2 = 13.240 \; kN/m^2 \tag{4}$$

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Dead load : Bending Moment and Shear Force

(B.2) Dead Load : Bending Moment

- Dead load bending moment :

$$\begin{aligned} M_{dl} &= \frac{q_{dl} \times L^2}{8} \\ &= \frac{13.240 \times 5.900^2}{8} \\ &= 57.611 \ kNm/m \ width \ of \ slab \end{aligned} \tag{5}$$

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Dead load : Bending Moment and Shear Force

(B.3) Dead Load : Shear Force

- Dead load shear force :

$$
\begin{aligned}
V_{dl} &= \frac{q_{dl} \times L}{2} \\
&= \frac{13.240 \times 5.900}{2} \qquad (6) \\
&= 39.058\ kN/m\ width\ of\ slab
\end{aligned}
$$

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Slab carrying concentrated load

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Slab carrying concentrated load

If a solid slab

- supported on two opposite edges,
- carries concentrated loads

the maximum bending moment caused by the concentrated loads shall be assumed to be resisted by an effective width of slab (measured parallel to the supporting edges)

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Slab carrying concentrated load

- For a single concentrated load, the effective width shall be calculated in accordance with the following equation provided that it shall not exceed the actual width of the slab:

$$b_{ef} = \alpha \ x \ (1 - \frac{x}{L}) \ + \ b \tag{7}$$

Slab carrying concentrated load

- For a single concentrated load, the effective width shall be calculated in accordance with the following equation provided that it shall not exceed the actual width of the slab:

$$b_{ef} = \alpha\ x\ (1 - \frac{x}{L})\ +\ b \tag{8}$$

  - b_{ef} = effective width of slab,
  - α = constant having the values given in the following table dependig upon the ratio of the width of the slab (B) to the effective span (L)
  - x = distance of the centroid of the concentrated load from nearer support,
  - L = effective span, and
  - b = width of the contact area of the concentrated load from nearer support measured parallel to the supported edge

Slab carrying concentrated load(IRC 21)

$\frac{B}{L}$	α for simply supported slab	α for continuous slab	$\frac{B}{L}$	α for simply supported slab	α for continuous slab
0.1	0.40	0.40	1.1	2.60	2.28
0.2	0.80	0.80	1.2	2.64	2.36
0.3	1.16	1.16	1.3	2.72	2.40
0.4	1.48	1.44	1.4	2.80	2.48
0.5	1.72	1.68	1.5	2.84	2.48
0.6	1.96	1.84	1.6	2.88	2.52
0.7	2.12	1.96	1.7	2.92	2.56
0.8	2.24	2.08	1.8	2.96	2.60
0.9	2.36	2.16	1.9	3.00	2.60
1.0	2.48	2.24	2.0 & above	3.00	2.60

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Slab carrying concentrated load

(C.1) Live Load :

- Width of the deck slab :

$$B = 7.500 + 2 \times 1.000 = 9.500\ m \tag{9}$$

- Therefore,

$$\frac{B}{L} = \frac{9.500}{5.900} = 1.610 \tag{10}$$

- From the table for simply supported slab, α=2.880
- The effective width of load parallel to support :

$$b_{ef} = \alpha\ x\ (1 - \frac{x}{L}) + b \tag{11}$$

- where

$$\begin{aligned} x &= \frac{5.900}{2} = 2.950\ m \\ b &= 0.840 + 2 \times 0.100 = 1.040\ m \end{aligned} \tag{12}$$

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Slab carrying concentrated load

(C.2) Live Load for Bending Moment:

- Effective width of dispersion for single load:

$$\begin{aligned} b_{ef} &= \alpha \; x \; \left(1 - \frac{x}{L}\right) \; + \; b \\ &= 2.880 \; \times \; 2.950 \; \times \; \left(1 - \frac{2.950}{5.900}\right) \; + \; 1.040 \\ &= 5.288 \; m \end{aligned} \tag{13}$$

- Effective length of dispersion :

$$l_{ef} \; = \; 4.570 + 2 \times 0.460 + 2 \times 0.100 \; = \; 5.690 \; m \tag{14}$$

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Impact Factors

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Impact factors for Live Load

(D.1) Impact Factors for class A or class B loading

- The impact factor fraction shall be determined for reinforced concrete bridges for spans between 3 m and 45 m:

$$= \frac{4.5}{6 + L} \tag{15}$$

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Impact factors for Live Load

(D.2) Impact Factors for Class AA Loading and Class 70R Loading

- (1) For spans less than 9 m, the value of the impact percentage shall be taken as follows:
  - (a) For tracked vehicles : 25 percent for spans upto 5 m linearly reducing to 10 percent for spans upto 9 m
  - (b) For wheeled vehicles : 25 percent

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Impact factors for Live Load

(D.3) Impact Factors for Class AA Loading and Class 70R Loading

- (2) For spans of 9m or more, the value of the impact percentage shall be taken as follows:
  - (a) For tracked vehicles : 10 percent upto a span of 40 m and in accordance with the curve in Fig. 5 of IRC 6:2014 for spans in excess of 40 m
  - (b) For wheeled vehicles :25 percent for spans upto 12 m and in accordance with the curve in Fig. 5 of IRC 6:2014 for spans in excess of 12 m.

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Summary

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Summary

- Design of slab bridges is shown in step by step.

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References

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References

IRC 21 : 2000 Standard specifications and code of practice for road bridges, Section III : Cement concrete (plain and reinforced) (Indian Roads Congress, New Delhi)

IRC 112 : 2011 Code of practice for concrete road bridges (Indian Roads Congress, New Delhi)

IS 456 : 2000 Indian Standard Plain and Reinforced Concrete (Bureau of Indian Standards, New Delhi)

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Thank you

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Reinforced Concrete Road Bridges

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Lecture-12

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Overview

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Design of Slab Bridge

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Problem statement

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- Width of carriage way : 7500.0 mm
- Width of the foot path : 1000.0 mm on either side
- Wearing coat: 100 mm
- Loading : IRC 70R (tracked)
- Materials : Concrete : M25, Steel : Fe415

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(A) Design parameters

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- Assume clear span by overall depth as 12
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$$D_{estim} = \frac{5.500}{12.0} = 0.458m \tag{1}$$

- Overall depth of the slab (assumed) = 460.0 mm
- Assume width of the bearing = 400.0 mm
- Effective span, L = 5.500 + 0.400 = 5.900 m

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(B) Dead Load

(i) Dead Load :

- Dead load of the slab:

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- Dead load:

$$q_{dl} = 11.040 + 2.2 = 13.240 \ kN/m^2 \tag{4}$$

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(B) Dead Load

(ii) Dead Load : Bending Moment

- Dead load bending moment :

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\begin{aligned}
M_{dl} &= \frac{q_{dl} \times L^2}{8} \\
&= \frac{13.240 \times 5.900^2}{8} \\
&= 57.611 \; kNm/m \; width \; of \; slab
\end{aligned} \tag{5}
$$

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(B) Dead Load

(iii) Dead Load : Shear Force

- Dead load shear force :

$$\begin{aligned} V_{dl} &= \frac{q_{dl} \times L}{2} \\ &= \frac{13.240 \times 5.900}{2} \\ &= 39.058 \ kN/m \ width \ of \ slab \end{aligned} \quad (6)$$

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(C) Effective width for Live Load Bending Moment

(i) Effective width for single track for Live Load BM :

- As per IRC 6: 2014, the size of each track of IRC 70R (tracked) vehicle : 4570.0 $mm \times$ 840.0 mm
- Thickness of wearing coat : 100.0 mm
- Therefore, at top of concrete deck, the effective size of each track

$$\begin{aligned} b &= 0.840 + 2 \times 0.100 = 1.040\ m \\ l &= 4.570 + 2 \times 0.100 = 4.770\ m \end{aligned} \tag{7}$$

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(C) Effective width for Live Load Bending Moment

(ii) Width of deck slab :

$$B = 7.500 + 2 \times 1.000 = 9.500\ m \tag{8}$$

Therefore,

$$\frac{B}{L} = \frac{9.500}{5.900} = 1.610 \tag{9}$$

Therefore,

$$\alpha = 2.880 + \frac{2.920 - 2.880}{0.1}(1.610 - 1.600) = 2.884 \tag{10}$$

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(C) Effective width for Live Load Bending Moment

(iii) The effective width of load parallel to support :

$$b_{ef} = \alpha \ x \ (1 - \frac{x}{L}) \ + \ b \tag{11}$$

where

$$\begin{aligned} L &= 5.900 \\ x &= \frac{5.900}{2} = 2.950 \ m \\ b &= 0.840 + 2 \times 0.100 = 1.040 \ m \end{aligned} \tag{12}$$

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(C) Effective width for Live Load Bending Moment

- Effective width of dispersion for single load:

$$\begin{aligned} b_{ef} &= \alpha\ x\ \left(1 - \frac{x}{L}\right)\ +\ b \\ &= 2.884\ \times\ 2.950\ \times\ \left(1 - \frac{2.950}{5.900}\right)\ +\ 1.040 \\ &= 5.294\ m \end{aligned} \tag{13}$$

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(C) Effective width for Live Load Bending Moment

(iv) Effective width for IRC 70R (tracked) vehicle for Live Load BM :

(iv-a) Left part of dispersion

- The center of left track from the left end of bridge :

$$1.000 \; + \; 1.200 \; + \; \frac{0.840}{2} \; = \; 2.620 \; m \tag{14}$$

- The half of the effective width of dispersion :

$$\frac{5.294}{2} = 2.647 \; m \tag{15}$$

- Therefore, the left part of dispersion will be extended upto : 2.620 m from the center of left wheel

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(C) Effective width for Live Load Bending Moment

(iv-b) Right part of dispersion :

- The center of right wheel from the left end of bridge :

$$1.000 \ + \ 1.200 \ + \ 2.900 \ - \ \frac{0.840}{2} \ = \ 4.680 \ m \tag{16}$$

- The center of right track from the right end of bridge :

$$9.500 \ - \ 4.680 \ = \ 4.820 \ m \tag{17}$$

- The half of the effective width of dispersion :

$$\frac{5.294}{2} = 2.647 \ m \tag{18}$$

- Therefore, the right part of dispersion will be extended upto : 2.647 m from the center of right wheel

(C) Effective width for Live Load Bending Moment

(iv-c) Effective width for IRC 70R (tracked) vehicle for Live Load BM :

- The total width of dispersion has three parts :
  - (a) The left part of dispersion is extended upto : 2.620 m from the center of left wheel
  - (b) The center to center distance of wheels :

$$2.900 - 2 \times \frac{0.840}{2} = 2.060m \tag{19}$$

  - (c) The right part of dispersion is extended upto : 2.647 m from the center of right wheel
- Therefore, the effective width of dispersion for shear force :

$$b_{ef} = 2.620 + 2.060 + 2.647 = 7.327\ m \tag{20}$$

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(C) Effective width for Live Load Bending Moment

(v) Effective length of dispersion for Live Load BM :

- Effective length of dispersion :

$$l_{ef} = 4.570 + 2 \times 0.460 + 2 \times 0.100 = 5.690\ m \quad (21)$$

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(D) Effective width for Live Load Shear Force

(i) Effective length of dispersion for Live Load SF :

- Effective length of dispersion for SF will be same as effective length for BM :

$$l_{ef} = 4.570 + 2 \times 0.460 + 2 \times 0.100 = 5.690\ m \quad (22)$$

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(D) Effective width for Live Load Shear Force

(ii) Width of the deck slab :

$$B = 7.500 + 2 \times 1.000 = 9.500\ m \tag{23}$$

Therefore,

$$\frac{B}{L} = \frac{9.500}{5.900} = 1.610 \tag{24}$$

Therefore,

$$\alpha = 2.880 + \frac{2.920 - 2.880}{0.1}(1.610 - 1.600) = 2.884 \tag{25}$$

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(D) Effective width for Live Load Shear Force

(iii) The effective length of dispersion : 5.690 m

Therefore, the load will be placed from the left support itself for getting maximum shear force in left support

The effective width of load parallel to support :

$$b_{ef} = \alpha\ x\ (1 - \frac{x}{L})\ +\ b \tag{26}$$

where

$$\begin{aligned} L &= 5.900 \\ x &= \frac{5.690}{2} = 2.385\ m \\ b &= 0.840 + 2 \times 0.100 = 1.040\ m \end{aligned} \tag{27}$$

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(D) Effective width for Live Load Shear Force

- Effective width of dispersion for single load:

$$
\begin{aligned}
b_{ef} &= \alpha\ x\ \left(1 - \frac{x}{L}\right)\ +\ b \\
&= 2.884\ \times\ 2.385\ \times\ \left(1 - \frac{2.385}{5.900}\right)\ +\ 1.040 \qquad (28) \\
&= 5.138\ m
\end{aligned}
$$

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(D) Effective width for Live Load Shear Force

(iv) Effective width for IRC 70R (tracked) vehicle for Live Load SF:

(iv-a) Left part of dispersion

- The center of left track from the left end of bridge :

$$1.000 + 1.200 + \frac{0.840}{2} = 2.620\ m \tag{29}$$

- The half of the effective width of dispersion :

$$\frac{5.138}{2} = 2.569\ m \tag{30}$$

- Therefore, the left part of dispersion will be extended upto : 2.569 m from the center of left wheel

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(D) Effective width for Live Load Shear Force

(iv-b) Right part of dispersion :

- The center of right wheel from the left end of bridge :

$$1.000 + 1.200 + 2.900 - \frac{0.840}{2} = 4.680\ m \qquad (31)$$

- The center of right track from the right end of bridge :

$$9.500 - 4.680 = 4.820\ m \qquad (32)$$

- The half of the effective width of dispersion :

$$\frac{5.138}{2} = 2.569\ m \qquad (33)$$

- Therefore, the right part of dispersion will be extended upto : 2.569 m from the center of right wheel

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(D) Effective width for Live Load Shear Force

(iv-c) Effective width for IRC 70R (tracked) vehicle for Live Load SF :

- The total width of dispersion has three parts :
  - (a) The left part of dispersion is extended upto : 2.569 m from the center of left wheel
  - (b) The center to center distance of wheels :

$$2.900 - 2 \times \frac{0.840}{2} = 2.060m \tag{34}$$

  - (c) The right part of dispersion is extended upto : 2.569 m from the center of right wheel
- Therefore, the effective width of dispersion for shear force :

$$b_{ef} = 2.569 + 2.060 + 2.569 = 7.198\ m \tag{35}$$

NPTEL

(E) Impact Factor for Vehicle Load

(i) Impact percentage for Class AA Loading and Class 70R Loading for RCC bridges

- (1) For spans less than 9 m, the value of the impact percentage shall be taken as follows:
  - (a) For tracked vehicles : 25 percent for spans upto 5 m linearly reducing to 10 percent for spans upto 9 m
  - (b) For wheeled vehicles : 25 percent
- (2) For spans of 9m or more, the value of the impact percentage shall be taken as follows:
  - (a) For tracked vehicles : 10 percent upto a span of 40 m and in accordance with the curve in Fig. 5 of IRC 6 : 2014 for spans in excess of 40 m
  - (b) For wheeled vehicles :25 percent for spans upto 12 m and in accordance with the curve in Fig. 5 of IRC 6 : 2014 for spans in excess of 12 m.

NPTEL

(E) Impact factor for Vehicle Load

(ii) Impact factors for Class AA Loading and Class 70R Loading

- For RCC bridges of span, 5.900 m and class IRC 70R (Tracked) loading
  - Impact percentage (for span greater than 5m but less than 9m) $= 25 - \frac{5.900 - 5}{9-5} \times (25 - 10) = 21.625$
  - Impact factor : 1.216

NPTEL

(F) Bending moment due to Live Load

(i) Intensity of loading due to vehicle load :

$$\frac{1.216 \times 700.000}{7.327 \times 5.690} = 20.421 \; kN/m^2 \tag{36}$$

(ii) Maximum live load bending moment :

$$\frac{20.421 \times 5.690}{2} \times \frac{5.900}{2} - 20.421 \times \frac{5.900}{2} \times \frac{5.900}{2} = 82.533 \; kNm \tag{37}$$

(iii) Design bending moment = Dead load BM + Live load BM

$$57.611 + 82.533 = 140.143 \; kNm \tag{38}$$

NPTEL

(G) Shear force due to Live Load

(i) Intensity of loading due to vehicle load :

$$\frac{1.216 \times 700.000}{7.198 \times 5.690} = 20.787 \; kN/m^2 \tag{39}$$

(ii) Maximum live load shear force :

$$20.787 \times 5.690 \times \frac{(5.900 - 5.690/2)}{5.900} = 61.245 \; kN \tag{40}$$

(iii) Design shear force = Dead load SF + Live load SF

$$39.058 + 61.245 = 100.303 \; kN \tag{41}$$

NPTEL

(H) Analysis of reinforced concrete section - WSM

(i) Applied bending moment : 140.143 kNm

- **(a)** Concrete grade : M25
- **(b)** Steel grade : Fe415
- **(c)** Overall depth provided : 460.0 mm
- **(d)** Clear cover : 30.0 mm
- **(e)** Dia. of longitudinal bars : 25 mm
- **(f)** σ_{cbc} : 8.5 N/mm^2
- **(g)** σ_{st} : 190.0 N/mm^2
- **(h)** Modular ration, m :

$$\frac{280}{3\sigma_{cbc}} = \frac{280}{3 \times 8.5} = 11.0 \tag{42}$$

NPTEL

(H) Analysis of reinforced concrete section - WSM

(i) Effective depth (d) provided :

$$D - cc - \frac{\phi_t}{2} = 460.0 - 30.0 - \frac{25.0}{2} = 417.5\ mm \quad (43)$$

For balanced section, $k_b = \frac{x}{d}$:

$$k_b = \frac{m\ \sigma_{cbc}}{\sigma_{st} + m\ \sigma_{cbc}} = \frac{11.0 \times 8.5}{190.0 + 11.0 \times 8.5} = 0.329 \quad (44)$$

$$j_b = 1 - \frac{k_b}{3} = 1 - \frac{0.329}{3} = 0.890 \quad (45)$$

(H) Analysis of reinforced concrete section - WSM

(j) Moment of resistance of the section due to concrete :

$$\begin{aligned} M_c &= \frac{1}{2}\,\sigma_{cbc}\;k_b\;j_b\;b\;d^2 \\ &= \frac{1}{2}\times 8.5\times 0.329\times 0.890\times \\ &\quad 1000.0\times 417.5^2\times 10^{-6}\;kNm \\ &= 216.914\;kNm \end{aligned} \tag{46}$$

NPTEL

(k) Compressive force in balanced section :

$$
\begin{aligned}
C_b &= \frac{1}{2}\,\sigma_{cbc}\ b\ x \\
&= \frac{1}{2}\,\sigma_{cbc}\ k_b\ b\ d \\
&= \frac{1}{2} \times 8.5 \times 0.329 \times 1000.0 \times 417.5 \times 10^{-3}\ kN \\
&= 583.769\ kN
\end{aligned} \tag{47}
$$

(l) Balanced area of steel :

$$
\begin{aligned}
A_{st,b} &= \frac{C_b}{\sigma_{st}} \\
&= \frac{583.769 \times 10^3}{190.0} \\
&= 3072.5\ mm^2
\end{aligned} \tag{48}
$$

NPTEL

(k) Area of longitudinal steel (main reinforcment) required :

$$A_{st,reqd} = \frac{M}{\sigma_{st}\ j_b\ d} = \frac{140.143 \times 10^6}{190.0 \times 0.890 \times 417.5} = 1985.1\ mm^2 \quad (49)$$

(l) Area of each bar of diameter, 25 mm $= \pi \frac{25^2}{4} = 490.9\ mm^2$

(m) Spacing of bars required :

$$\frac{1000 \times 1985.1}{490.9} = 247.3\ mm \quad (50)$$

(n) Longitudinal reinforcement provided : Bar of 25 mm dia @ 200 mm C/C (2454.4 mm^2)

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Summary

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Summary

- Design of slab bridges is shown in step by step.

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References

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References

IRC 21 : 2000 Standard specifications and code of practice for road bridges, Section III : Cement concrete (plain and reinforced) (Indian Roads Congress, New Delhi)

IRC 112 : 2011 Code of practice for concrete road bridges (Indian Roads Congress, New Delhi)

IS 456 : 2000 Indian Standard Plain and Reinforced Concrete (Bureau of Indian Standards, New Delhi)

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Thank you

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Reinforced Concrete Road Bridges

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Lecture-13

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Overview

1. Design of Slab Bridge
2. Summary
3. References

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Design of Slab Bridge

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Problem statement

Problem : 1 Design a deck slab bridge for the following parameters :

- Clear span: 5.500 m
- Width of carriage way : 7500.0 mm
- Width of the foot path : 1000.0 mm on either side
- Wearing coat: 100 mm
- Loading : IRC 70R (tracked)
- Materials : Concrete : M25, Steel : Fe415

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(A) Design parameters

(i) Effective span of the bridge

- Assume clear span by overall depth as 12
- Estimated overall depth of the slab :

$$D_{estim} = \frac{5.500}{12.0} = 0.458m \tag{1}$$

- Overall depth of the slab (assumed) = 460.0 mm
- Assume width of the bearing = 400.0 mm
- Effective span, L = 5.500 + 0.400 = 5.900 m

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(B) Dead Load

(i) Dead Load :

- Dead load of the slab:

$$q_{slab} = 0.460 \times 24.0 = 11.040 \; kN/m^2 \tag{2}$$

- Dead load of the wearing coat:

$$q_{wc} = 0.100 \times 22.0 = 2.200 \; kN/m^2 \tag{3}$$

- Dead load:

$$q_{dl} = 11.040 + 2.2 = 13.240 \; kN/m^2 \tag{4}$$

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(B) Dead Load

(ii) Dead Load : Bending Moment

- Dead load bending moment :

$$
\begin{aligned}
M_{dl} &= \frac{q_{dl} \times L^2}{8} \\
&= \frac{13.240 \times 5.900^2}{8} \qquad (5) \\
&= 57.611\ kNm/m\ width\ of\ slab
\end{aligned}
$$

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(B) Dead Load

(iii) Dead Load : Shear Force

- Dead load shear force :

$$
\begin{aligned}
V_{dl} &= \frac{q_{dl} \times L}{2} \\
&= \frac{13.240 \times 5.900}{2} \\
&= 39.058 \; kN/m \; width \; of \; slab
\end{aligned}
\tag{6}
$$

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(C) Effective width for Live Load Bending Moment

(i) Effective width for single track for Live Load BM :

- As per IRC 6: 2014, the size of each track of IRC 70R (tracked) vehicle : 4570.0 $mm \times 840.0\ mm$
- Thickness of wearing coat : 100.0 mm
- Therefore, at top of concrete deck, the effective size of each track

$$\begin{aligned} b &= 0.840 + 2 \times 0.100 = 1.040\ m \\ l &= 4.570 + 2 \times 0.100 = 4.770\ m \end{aligned} \tag{7}$$

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(ii) Width of deck slab :

$$B = 7.500 + 2 \times 1.000 = 9.500\ m \tag{8}$$

Therefore,

$$\frac{B}{L} = \frac{9.500}{5.900} = 1.610 \tag{9}$$

Therefore,

$$\alpha = 2.880 + \frac{2.920 - 2.880}{0.1}(1.610 - 1.600) = 2.884 \tag{10}$$

NPTEL

(C) Effective width for Live Load Bending Moment

(iii) The effective width of load parallel to support :

$$b_{ef} = \alpha \; x \; (1 - \frac{x}{L}) \; + \; b \tag{11}$$

where

$$\begin{aligned} L &= 5.900 \\ x &= \frac{5.900}{2} = 2.950 \; m \\ b &= 0.840 + 2 \times 0.100 = 1.040 \; m \end{aligned} \tag{12}$$

NPTEL

(C) Effective width for Live Load Bending Moment

- Effective width of dispersion for single load:

$$
\begin{aligned}
b_{ef} &= \alpha\ x\ \left(1 - \frac{x}{L}\right)\ +\ b \\
&= 2.884\ \times\ 2.950\ \times\ \left(1 - \frac{2.950}{5.900}\right)\ +\ 1.040 \qquad (13) \\
&= 5.294\ m
\end{aligned}
$$

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(C) Effective width for Live Load Bending Moment

(iv) Effective width for IRC 70R (tracked) vehicle for Live Load BM :

(iv-a) Left part of dispersion

- The center of left track from the left end of bridge :

$$1.000 \; + \; 1.200 \; + \; \frac{0.840}{2} \; = \; 2.620 \; m \tag{14}$$

- The half of the effective width of dispersion :

$$\frac{5.294}{2} = 2.647 \; m \tag{15}$$

- Therefore, the left part of dispersion will be extended upto : 2.620 m from the center of left wheel

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(C) Effective width for Live Load Bending Moment

(iv-b) Right part of dispersion :

- The center of right wheel from the left end of bridge :

$$1.000 \ + \ 1.200 \ + \ 2.900 \ - \ \frac{0.840}{2} \ = \ 4.680 \ m \qquad (16)$$

- The center of right track from the right end of bridge :

$$9.500 \ - \ 4.680 \ = \ 4.820 \ m \qquad (17)$$

- The half of the effective width of dispersion :

$$\frac{5.294}{2} = 2.647 \ m \qquad (18)$$

- Therefore, the right part of dispersion will be extended upto : 2.647 m from the center of right wheel

(C) Effective width for Live Load Bending Moment

(iv-c) Effective width for IRC 70R (tracked) vehicle for Live Load BM :

- The total width of dispersion has three parts :
  - (a) The left part of dispersion is extended upto : 2.620 m from the center of left wheel
  - (b) The center to center distance of wheels :

$$2.900 - 2 \times \frac{0.840}{2} = 2.060m \tag{19}$$

  - (c) The right part of dispersion is extended upto : 2.647 m from the center of right wheel
- Therefore, the effective width of dispersion for shear force :

$$b_{ef} = 2.620 + 2.060 + 2.647 = 7.327\ m \tag{20}$$

NPTEL

(C) Effective width for Live Load Bending Moment

(v) Effective length of dispersion for Live Load BM :

- Effective length of dispersion :

$$l_{ef} = 4.570 + 2 \times 0.460 + 2 \times 0.100 = 5.690\ m \quad (21)$$

NPTEL

(D) Effective width for Live Load Shear Force

(i) Effective length of dispersion for Live Load SF :

- Effective length of dispersion for SF will be same as effective length for BM :

$$l_{ef} = 4.570 + 2 \times 0.460 + 2 \times 0.100 = 5.690\ m \quad (22)$$

NPTEL

(D) Effective width for Live Load Shear Force

(ii) Width of the deck slab :

$$B = 7.500 + 2 \times 1.000 = 9.500 \; m \tag{23}$$

Therefore,

$$\frac{B}{L} = \frac{9.500}{5.900} = 1.610 \tag{24}$$

Therefore,

$$\alpha = 2.880 + \frac{2.920 - 2.880}{0.1}(1.610 - 1.600) = 2.884 \tag{25}$$

NPTEL

(D) Effective width for Live Load Shear Force

(iii) The effective length of dispersion : 5.690 m

Therefore, the load will be placed from the left support itself for getting maximum shear force in left support

The effective width of load parallel to support :

$$b_{ef} = \alpha \; x \; (1 - \frac{x}{L}) \; + \; b \tag{26}$$

where

$$\begin{aligned} L &= 5.900 \\ x &= \frac{5.690}{2} = 2.385 \; m \\ b &= 0.840 + 2 \times 0.100 = 1.040 \; m \end{aligned} \tag{27}$$

NPTEL

(D) Effective width for Live Load Shear Force

- Effective width of dispersion for single load:

$$
\begin{aligned}
b_{ef} &= \alpha \ x \ \left(1 - \frac{x}{L}\right) \ + \ b \\
&= 2.884 \ \times \ 2.385 \ \times \ \left(1 - \frac{2.385}{5.900}\right) \ + \ 1.040 \qquad (28) \\
&= 5.138 \ m
\end{aligned}
$$

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(D) Effective width for Live Load Shear Force

(iv) Effective width for IRC 70R (tracked) vehicle for Live Load SF:

(iv-a) Left part of dispersion

- The center of left track from the left end of bridge :

$$1.000 + 1.200 + \frac{0.840}{2} = 2.620 \; m \tag{29}$$

- The half of the effective width of dispersion :

$$\frac{5.138}{2} = 2.569 \; m \tag{30}$$

- Therefore, the left part of dispersion will be extended upto : 2.569 m from the center of left wheel

(D) Effective width for Live Load Shear Force

(iv-b) Right part of dispersion :

- The center of right wheel from the left end of bridge :

$$1.000 + 1.200 + 2.900 - \frac{0.840}{2} = 4.680\ m \tag{31}$$

- The center of right track from the right end of bridge :

$$9.500 - 4.680 = 4.820\ m \tag{32}$$

- The half of the effective width of dispersion :

$$\frac{5.138}{2} = 2.569\ m \tag{33}$$

- Therefore, the right part of dispersion will be extended upto : 2.569 m from the center of right wheel

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(D) Effective width for Live Load Shear Force

(iv-c) Effective width for IRC 70R (tracked) vehicle for Live Load SF :

- The total width of dispersion has three parts :
  - (a) The left part of dispersion is extended upto : 2.569 m from the center of left wheel
  - (b) The center to center distance of wheels :

$$2.900 - 2 \times \frac{0.840}{2} = 2.060m \tag{34}$$

  - (c) The right part of dispersion is extended upto : 2.569 m from the center of right wheel
- Therefore, the effective width of dispersion for shear force :

$$b_{ef} = 2.569 + 2.060 + 2.569 = 7.198 \ m \tag{35}$$

NPTEL

(E) Impact Factor for Vehicle Load

(i) Impact percentage for Class AA Loading and Class 70R Loading for RCC bridges

- (1) For spans less than 9 m, the value of the impact percentage shall be taken as follows:
  - (a) For tracked vehicles : 25 percent for spans upto 5 m linearly reducing to 10 percent for spans upto 9 m
  - (b) For wheeled vehicles : 25 percent
- (2) For spans of 9m or more, the value of the impact percentage shall be taken as follows:
  - (a) For tracked vehicles : 10 percent upto a span of 40 m and in accordance with the curve in Fig. 5 of IRC 6 : 2014 for spans in excess of 40 m
  - (b) For wheeled vehicles :25 percent for spans upto 12 m and in accordance with the curve in Fig. 5 of IRC 6 : 2014 for spans in excess of 12 m.

(E) Impact factor for Vehicle Load

(ii) Impact factors for Class AA Loading and Class 70R Loading

- For RCC bridges of span, 5.900 m and class IRC 70R (Tracked) loading
  - Impact percentage (for span greater than 5m but less than 9m) $= 25 - \frac{5.900 - 5}{9-5} \times (25 - 10) = 21.625$
  - Impact factor : 1.216

NPTEL

(F) Bending moment due to Live Load

(i) Intensity of loading due to vehicle load :

$$\frac{1.216 \times 700.000}{7.327 \times 5.690} = 20.421 \; kN/m^2 \qquad (36)$$

(ii) Maximum live load bending moment :

$$\frac{20.421 \times 5.690}{2} \times \frac{5.900}{2} - 20.421 \times \frac{5.900}{2} \times \frac{5.900}{2} \qquad (37)$$
$$= 82.533 \; kNm$$

(iii) Design bending moment = Dead load BM + Live load BM

$$57.611 + 82.533 = 140.143 \; kNm \qquad (38)$$

NPTEL

(G) Shear force due to Live Load

(i) Intensity of loading due to vehicle load :

$$\frac{1.216 \times 700.000}{7.198 \times 5.690} = 20.787 \ kN/m^2 \tag{39}$$

(ii) Maximum live load shear force :

$$20.787 \times 5.690 \times \frac{(5.900 - 5.690/2)}{5.900} = 61.245 \ kN \tag{40}$$

(iii) Design shear force = Dead load SF + Live load SF

$$39.058 + 61.245 = 100.303 \ kN \tag{41}$$

NPTEL

(H) Analysis of reinforced concrete section - WSM

(i) Applied bending moment : 140.143 kNm

- **(a)** Concrete grade : M25
- **(b)** Steel grade : Fe415
- **(c)** Overall depth provided : 460.0 mm
- **(d)** Clear cover : 30.0 mm
- **(e)** Dia. of longitudinal bars : 25 mm
- **(f)** σ_{cbc} : 8.5 N/mm^2
- **(g)** σ_{st} : 190.0 N/mm^2
- **(h)** Modular ration, m :

$$\frac{280}{3\sigma_{cbc}} = \frac{280}{3 \times 8.5} = 11.0 \tag{42}$$

NPTEL

(H) Analysis of reinforced concrete section - WSM

(i) Effective depth (d) provided :

$$D - cc - \frac{\phi_t}{2} = 460.0 - 30.0 - \frac{25.0}{2} = 417.5 \; mm \quad (43)$$

For balanced section, $k_b = \frac{x}{d}$:

$$\begin{aligned} k_b &= \frac{m \; \sigma_{cbc}}{\sigma_{st} + \; m \; \sigma_{cbc}} \\ &= \frac{11.0 \times 8.5}{190.0 + 11.0 \times 8.5} \\ &= 0.329 \end{aligned} \quad (44)$$

$$j_b = 1 - \frac{k_b}{3} = 1 - \frac{0.329}{3} = 0.890 \quad (45)$$

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(j) Moment of resistance of the section due to concrete :

$$\begin{aligned} M_c &= \frac{1}{2}\,\sigma_{cbc}\;k_b\;j_b\;b\;d^2 \\ &= \frac{1}{2} \times 8.5 \times 0.329 \times 0.890 \times \\ &\quad 1000.0 \times 417.5^2 \times 10^{-6}\;kNm \\ &= 216.914\;kNm \end{aligned} \tag{46}$$

NPTEL

(H) Analysis of reinforced concrete section - WSM

(k) Compressive force in balanced section :

$$\begin{aligned} C_b &= \frac{1}{2}\,\sigma_{cbc}\;b\;x \\ &= \frac{1}{2}\,\sigma_{cbc}\;k_b\;b\;d \\ &= \frac{1}{2}\;\times\;8.5\;\times\;0.329\;\times\;1000.0\;\times\;417.5\;\times\;10^{-3}\;kN \\ &= 583.769\;kN \end{aligned} \tag{47}$$

(l) Balanced area of steel :

$$\begin{aligned} A_{st,b} &= \frac{C_b}{\sigma_{st}} \\ &= \frac{583.769\;\times\;10^3}{190.0} \\ &= 3072.5\;mm^2 \end{aligned} \tag{48}$$

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(k) Area of longitudinal steel (main reinforcment) required :

$$\begin{aligned} A_{st,reqd} &= \frac{M}{\sigma_{st}\ j_b\ d} \\ &= \frac{140.143 \times 10^6}{190.0 \times 0.890 \times 417.5} \\ &= 1985.1\ mm^2 \end{aligned} \quad (49)$$

(l) Area of each bar of diameter, 25 mm $= \pi\ \frac{25^2}{4} = 490.9\ mm^2$

(m) Spacing of bars required :

$$\frac{1000 \times 1985.1}{490.9} = 247.3\ mm \quad (50)$$

(n) Longitudinal reinforcement provided : Bar of 25 mm dia @ 200 mm C/C (2454.4 mm^2)

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Summary

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Summary

- Design of slab bridges is shown in step by step.

References

References

IRC 21 : 2000 Standard specifications and code of practice for road bridges, Section III : Cement concrete (plain and reinforced) (Indian Roads Congress, New Delhi)

IRC 112 : 2011 Code of practice for concrete road bridges (Indian Roads Congress, New Delhi)

IS 456 : 2000 Indian Standard Plain and Reinforced Concrete (Bureau of Indian Standards, New Delhi)

Thank you

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Reinforced Concrete Road Bridges

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Lecture-14

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Overview

1. Design of Slab Bridge
2. Summary
3. References

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Design of Slab Bridge

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Problem statement

Problem : 1 Design a deck slab bridge for the following parameters :

- Clear span: 5.500 m
- Width of carriage way : 7500.0 mm
- Width of the foot path : 1000.0 mm on either side
- Wearing coat: 100 mm
- Loading : IRC 70R (tracked)
- Materials : Concrete : M25, Steel : Fe415

NPTEL

(A) Design parameters

(i) Effective span of the bridge

- Assume clear span by overall depth as 12
- Estimated overall depth of the slab :

$$D_{estim} = \frac{5.500}{12.0} = 0.458m \quad (1)$$

- Overall depth of the slab (assumed) = 460.0 mm
- Assume width of the bearing = 400.0 mm
- Effective span, L = 5.500 + 0.400 = 5.900 m

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(B) Dead Load

(i) Dead Load :

- Dead load of the slab:

$$q_{slab} = 0.460 \times 24.0 = 11.040\ kN/m^2 \tag{2}$$

- Dead load of the wearing coat:

$$q_{wc} = 0.100 \times 22.0 = 2.200\ kN/m^2 \tag{3}$$

- Dead load:

$$q_{dl} = 11.040 + 2.2 = 13.240\ kN/m^2 \tag{4}$$

NPTEL

(B) Dead Load

(ii) Dead Load : Bending Moment

- Dead load bending moment :

$$
\begin{aligned}
M_{dl} &= \frac{q_{dl} \times L^2}{8} \\
&= \frac{13.240 \times 5.900^2}{8} \\
&= 57.611 \; kNm/m \; width \; of \; slab
\end{aligned} \tag{5}
$$

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(B) Dead Load

(iii) Dead Load : Shear Force

- Dead load shear force :

$$
\begin{aligned}
V_{dl} &= \frac{q_{dl} \times L}{2} \\
&= \frac{13.240 \times 5.900}{2} \\
&= 39.058 \; kN/m \; width \; of \; slab
\end{aligned} \tag{6}
$$

NPTEL

(C) Effective width for Live Load Bending Moment

(i) Effective width for single track for Live Load BM :

- As per IRC 6: 2014, the size of each track of IRC 70R (tracked) vehicle : $4570.0\ mm \times 840.0\ mm$
- Thickness of wearing coat : 100.0 mm
- Therefore, at top of concrete deck, the effective size of each track

$$\begin{aligned} b &= 0.840 + 2 \times 0.100 = 1.040\ m \\ l &= 4.570 + 2 \times 0.100 = 4.770\ m \end{aligned} \tag{7}$$

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(ii) Width of deck slab :

$$B = 7.500 + 2 \times 1.000 = 9.500\ m \tag{8}$$

Therefore,

$$\frac{B}{L} = \frac{9.500}{5.900} = 1.610 \tag{9}$$

Therefore,

$$\alpha = 2.880 + \frac{2.920 - 2.880}{0.1}(1.610 - 1.600) = 2.884 \tag{10}$$

NPTEL

(iii) The effective width of load parallel to support :

$$b_{ef} = \alpha\ x\ (1 - \frac{x}{L})\ +\ b \tag{11}$$

where

$$\begin{aligned} L &= 5.900 \\ x &= \frac{5.900}{2} = 2.950\ m \\ b &= 0.840 + 2 \times 0.100 = 1.040\ m \end{aligned} \tag{12}$$

NPTEL

(C) Effective width for Live Load Bending Moment

- Effective width of dispersion for single load:

$$
\begin{aligned}
b_{ef} &= \alpha\ x\ \left(1 - \frac{x}{L}\right)\ +\ b \\
&= 2.884\ \times\ 2.950\ \times\ \left(1 - \frac{2.950}{5.900}\right)\ +\ 1.040 \qquad (13) \\
&= 5.294\ m
\end{aligned}
$$

NPTEL

(C) Effective width for Live Load Bending Moment

(iv) Effective width for IRC 70R (tracked) vehicle for Live Load BM :

(iv-a) Left part of dispersion

- The center of left track from the left end of bridge :

$$1.000 + 1.200 + \frac{0.840}{2} = 2.620\ m \tag{14}$$

- The half of the effective width of dispersion :

$$\frac{5.294}{2} = 2.647\ m \tag{15}$$

- Therefore, the left part of dispersion will be extended upto : 2.620 m from the center of left wheel

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(C) Effective width for Live Load Bending Moment

(iv-b) Right part of dispersion :

- The center of right wheel from the left end of bridge :

$$1.000 \; + \; 1.200 \; + \; 2.900 \; - \; \frac{0.840}{2} \; = \; 4.680 \; m \qquad (16)$$

- The center of right track from the right end of bridge :

$$9.500 \; - \; 4.680 \; = \; 4.820 \; m \qquad (17)$$

- The half of the effective width of dispersion :

$$\frac{5.294}{2} = 2.647 \; m \qquad (18)$$

- Therefore, the right part of dispersion will be extended upto : 2.647 m from the center of right wheel

(C) Effective width for Live Load Bending Moment

(iv-c) Effective width for IRC 70R (tracked) vehicle for Live Load BM :

- The total width of dispersion has three parts :
  - (a) The left part of dispersion is extended upto : 2.620 m from the center of left wheel
  - (b) The center to center distance of wheels :

$$2.900 - 2 \times \frac{0.840}{2} = 2.060m \tag{19}$$

  - (c) The right part of dispersion is extended upto : 2.647 m from the center of right wheel
- Therefore, the effective width of dispersion for shear force :

$$b_{ef} = 2.620 + 2.060 + 2.647 = 7.327\ m \tag{20}$$

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(C) Effective width for Live Load Bending Moment

(v) Effective length of dispersion for Live Load BM :

- Effective length of dispersion :

$$l_{ef} \;=\; 4.570 + 2 \times 0.460 + 2 \times 0.100 \;=\; 5.690\ m \quad (21)$$

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(D) Effective width for Live Load Shear Force

(i) Effective length of dispersion for Live Load SF :

- Effective length of dispersion for SF will be same as effective length for BM :

$$l_{ef} = 4.570 + 2 \times 0.460 + 2 \times 0.100 = 5.690\ m \quad (22)$$

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(D) Effective width for Live Load Shear Force

(ii) Width of the deck slab :

$$B = 7.500 + 2 \times 1.000 = 9.500\ m \tag{23}$$

Therefore,

$$\frac{B}{L} = \frac{9.500}{5.900} = 1.610 \tag{24}$$

Therefore,

$$\alpha = 2.880 + \frac{2.920 - 2.880}{0.1}(1.610 - 1.600) = 2.884 \tag{25}$$

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(D) Effective width for Live Load Shear Force

(iii) The effective length of dispersion : 5.690 m

Therefore, the load will be placed from the left support itself for getting maximum shear force in left support

The effective width of load parallel to support :

$$b_{ef} = \alpha \; x \; (1 - \frac{x}{L}) \; + \; b \qquad (26)$$

where

$$L = \; 5.900$$
$$x = \frac{5.690}{2} = \; 2.385 \; m \qquad (27)$$
$$b = \; 0.840 \; + \; 2 \; \times \; 0.100 \; = \; 1.040 \; m$$

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(D) Effective width for Live Load Shear Force

- Effective width of dispersion for single load:

$$
\begin{aligned}
b_{ef} &= \alpha\ x\ \left(1 - \frac{x}{L}\right)\ +\ b \\
&= 2.884\ \times\ 2.385\ \times\ \left(1 - \frac{2.385}{5.900}\right)\ +\ 1.040 \qquad (28) \\
&= 5.138\ m
\end{aligned}
$$

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(D) Effective width for Live Load Shear Force

(iv) Effective width for IRC 70R (tracked) vehicle for Live Load SF:

(iv-a) Left part of dispersion

- The center of left track from the left end of bridge :

$$1.000 + 1.200 + \frac{0.840}{2} = 2.620\ m \tag{29}$$

- The half of the effective width of dispersion :

$$\frac{5.138}{2} = 2.569\ m \tag{30}$$

- Therefore, the left part of dispersion will be extended upto : 2.569 m from the center of left wheel

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(D) Effective width for Live Load Shear Force

(iv-b) Right part of dispersion :

- The center of right wheel from the left end of bridge :

$$1.000 + 1.200 + 2.900 - \frac{0.840}{2} = 4.680\ m \qquad (31)$$

- The center of right track from the right end of bridge :

$$9.500 - 4.680 = 4.820\ m \qquad (32)$$

- The half of the effective width of dispersion :

$$\frac{5.138}{2} = 2.569\ m \qquad (33)$$

- Therefore, the right part of dispersion will be extended upto : 2.569 m from the center of right wheel

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(D) Effective width for Live Load Shear Force

(iv-c) Effective width for IRC 70R (tracked) vehicle for Live Load SF :

- The total width of dispersion has three parts :
  - (a) The left part of dispersion is extended upto : 2.569 m from the center of left wheel
  - (b) The center to center distance of wheels :

$$2.900 - 2 \times \frac{0.840}{2} = 2.060m \qquad (34)$$

  - (c) The right part of dispersion is extended upto : 2.569 m from the center of right wheel
- Therefore, the effective width of dispersion for shear force :

$$b_{ef} = 2.569 + 2.060 + 2.569 = 7.198 \ m \qquad (35)$$

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(E) Impact Factor for Vehicle Load

(i) Impact percentage for Class AA Loading and Class 70R Loading for RCC bridges

- (1) For spans less than 9 m, the value of the impact percentage shall be taken as follows:
  - (a) For tracked vehicles : 25 percent for spans upto 5 m linearly reducing to 10 percent for spans upto 9 m
  - (b) For wheeled vehicles : 25 percent
- (2) For spans of 9m or more, the value of the impact percentage shall be taken as follows:
  - (a) For tracked vehicles : 10 percent upto a span of 40 m and in accordance with the curve in Fig. 5 of IRC 6 : 2014 for spans in excess of 40 m
  - (b) For wheeled vehicles :25 percent for spans upto 12 m and in accordance with the curve in Fig. 5 of IRC 6 : 2014 for spans in excess of 12 m.

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(E) Impact factor for Vehicle Load

(ii) Impact factors for Class AA Loading and Class 70R Loading

- For RCC bridges of span, 5.900 m and class IRC 70R (Tracked) loading
  - Impact percentage (for span greater than 5m but less than 9m) $= 25 - \frac{5.900 - 5}{9-5} \times (25 - 10) = 21.625$
  - Impact factor : 1.216

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(F) Bending moment due to Live Load

(i) Intensity of loading due to vehicle load :

$$\frac{1.216 \times 700.000}{7.327 \times 5.690} = 20.421\ kN/m^2 \tag{36}$$

(ii) Maximum live load bending moment :

$$\frac{20.421 \times 5.690}{2} \times \frac{5.900}{2} - 20.421 \times \frac{5.900}{2} \times \frac{5.900}{2} \tag{37}$$
$$= 82.533\ kNm$$

(iii) Design bending moment = Dead load BM + Live load BM

$$57.611 + 82.533 = 140.143\ kNm \tag{38}$$

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(G) Shear force due to Live Load

(i) Intensity of loading due to vehicle load :

$$\frac{1.216 \times 700.000}{7.198 \times 5.690} = 20.787 \; kN/m^2 \tag{39}$$

(ii) Maximum live load shear force :

$$20.787 \times 5.690 \times \frac{(5.900 - 5.690/2)}{5.900} = 61.245 \; kN \tag{40}$$

(iii) Design shear force = Dead load SF + Live load SF

$$39.058 + 61.245 = 100.303 \; kN \tag{41}$$

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(H) Analysis of reinforced concrete section - WSM

(i) Applied bending moment : 140.143 kNm

(a) Concrete grade : M25

(b) Steel grade : Fe415

(c) Overall depth provided : 460.0 mm

(d) Clear cover : 30.0 mm

(e) Dia. of longitudinal bars : 25 mm

(f) σ_{cbc} : 8.5 N/mm^2

(g) σ_{st} : 190.0 N/mm^2

(h) Modular ration, m :

$$\frac{280}{3\sigma_{cbc}} = \frac{280}{3 \times 8.5} = 11.0 \tag{42}$$

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(H) Analysis of reinforced concrete section - WSM

(i) Effective depth (d) provided :

$$D - cc - \frac{\phi_t}{2} = 460.0 - 30.0 - \frac{25.0}{2} = 417.5\ mm \quad (43)$$

For balanced section, $k_b = \frac{x}{d}$:

$$\begin{aligned} k_b &= \frac{m\ \sigma_{cbc}}{\sigma_{st} + m\ \sigma_{cbc}} \\ &= \frac{11.0 \times 8.5}{190.0 + 11.0 \times 8.5} \quad (44) \\ &= 0.329 \end{aligned}$$

$$j_b = 1 - \frac{k_b}{3} = 1 - \frac{0.329}{3} = 0.890 \quad (45)$$

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(j) Moment of resistance of the section due to concrete :

$$
\begin{aligned}
M_c &= \frac{1}{2}\,\sigma_{cbc}\; k_b\; j_b\; b\; d^2 \\
&= \frac{1}{2} \times 8.5 \times 0.329 \times 0.890 \times \\
&\quad 1000.0 \times 417.5^2 \times 10^{-6}\; kNm \\
&= 216.914\; kNm
\end{aligned}
\tag{46}
$$

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(k) Compressive force in balanced section :

$$\begin{aligned} C_b &= \frac{1}{2}\,\sigma_{cbc}\;b\;x \\ &= \frac{1}{2}\,\sigma_{cbc}\;k_b\;b\;d \\ &= \frac{1}{2}\times 8.5 \times 0.329 \times 1000.0 \times 417.5 \times 10^{-3}\;kN \\ &= 583.769\;kN \end{aligned} \tag{47}$$

(l) Balanced area of steel :

$$\begin{aligned} A_{st,b} &= \frac{C_b}{\sigma_{st}} \\ &= \frac{583.769 \times 10^3}{190.0} \\ &= 3072.5\;mm^2 \end{aligned} \tag{48}$$

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(H) Analysis of reinforced concrete section - WSM

(k) Area of longitudinal steel (main reinforcment) required :

$$A_{st,reqd} = \frac{M}{\sigma_{st}\ j_b\ d} = \frac{140.143 \times 10^6}{190.0 \times 0.890 \times 417.5} = 1985.1\ mm^2 \tag{49}$$

(l) Area of each bar of diameter, 25 mm $= \pi\ \frac{25^2}{4} = 490.9\ mm^2$

(m) Spacing of bars required :

$$\frac{1000 \times 1985.1}{490.9} = 247.3\ mm \tag{50}$$

(n) Longitudinal reinforcement provided : Bar of 25 mm dia @ 200 mm C/C (2454.4 mm^2)

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Summary

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Summary

- Design of slab bridges is shown in step by step.

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References

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References

IRC 21 : 2000 Standard specifications and code of practice for road bridges, Section III : Cement concrete (plain and reinforced) (Indian Roads Congress, New Delhi)

IRC 112 : 2011 Code of practice for concrete road bridges (Indian Roads Congress, New Delhi)

IS 456 : 2000 Indian Standard Plain and Reinforced Concrete (Bureau of Indian Standards, New Delhi)

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Thank you

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Reinforced Concrete Road Bridges

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Lecture-15

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Overview

1. Abutment
2. Bridge abutment
3. Selection of abutments
4. Forces on abutments
5. Bridge data
   - Cross-section of the abutment
6. Stability of abutments

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Abutment

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Abutments

- The structure upon which the ends of a bridge rests is referred to as an Abutment.
- A retaining wall is used to hold back an earth embankment or water and to maintain a sudden change in elevation.

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Abutments (contd ...)

Abutment serves following functions

- Distributes the loads from bridge ends to the ground
- Withstands any loads that are directly imposed on it
- Provides vehicular and pedestrian access to the bridge

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Bridge abutment

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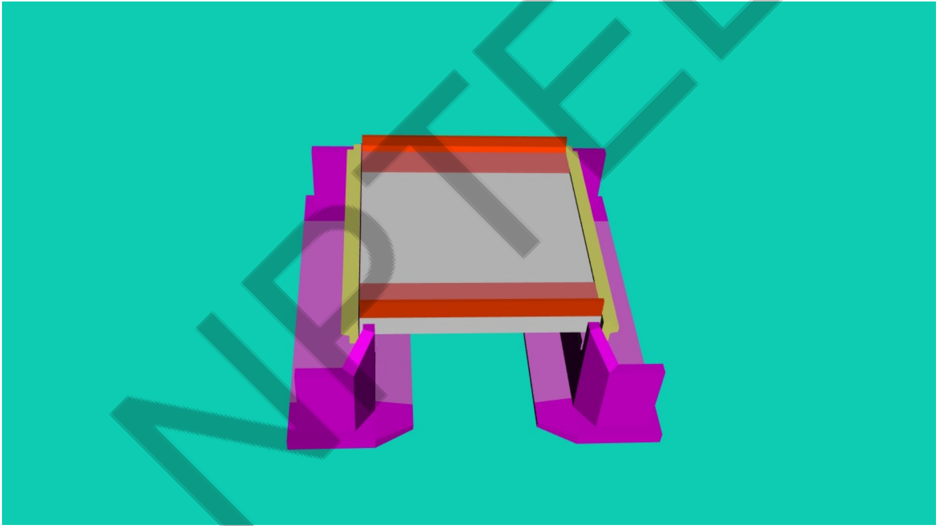
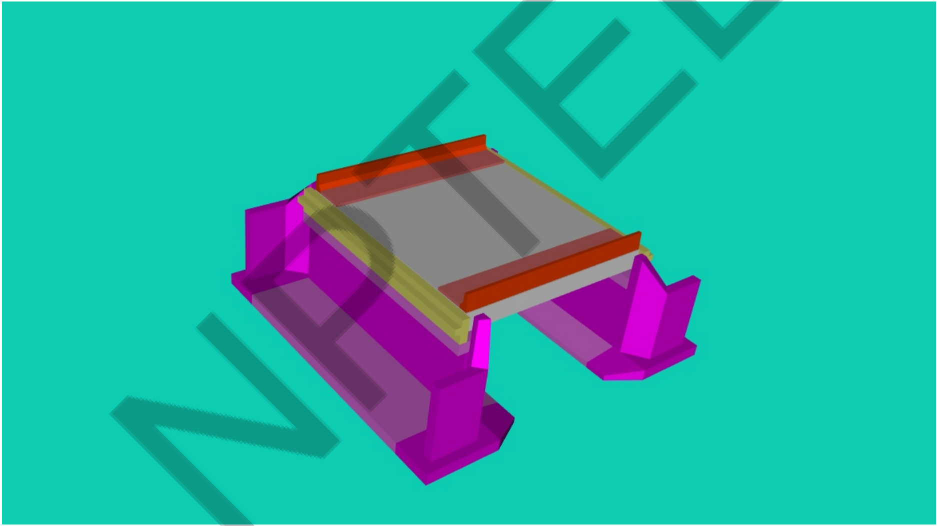
Bridge abutment



Bridge abutment



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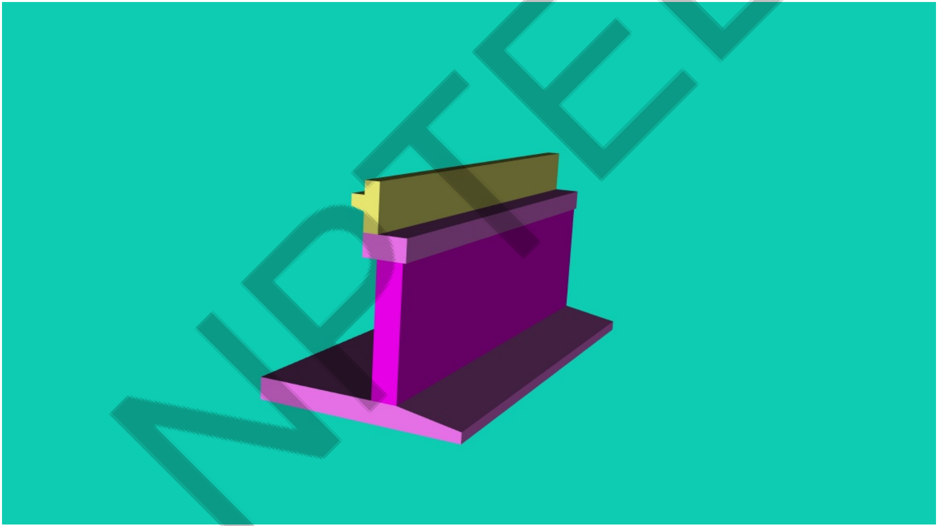

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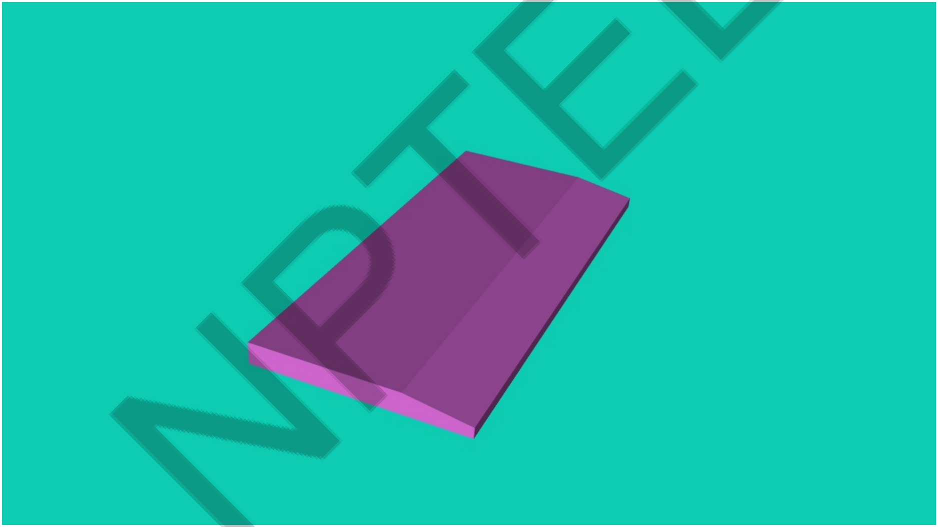

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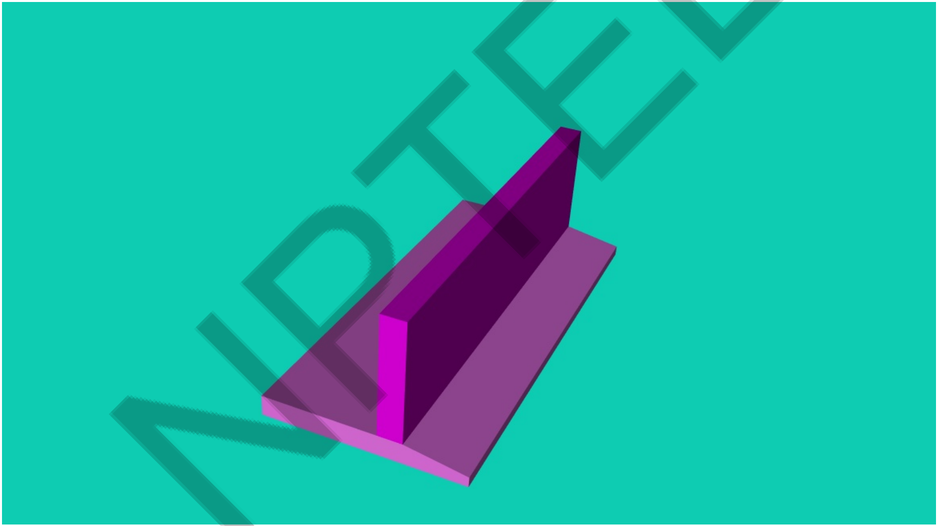
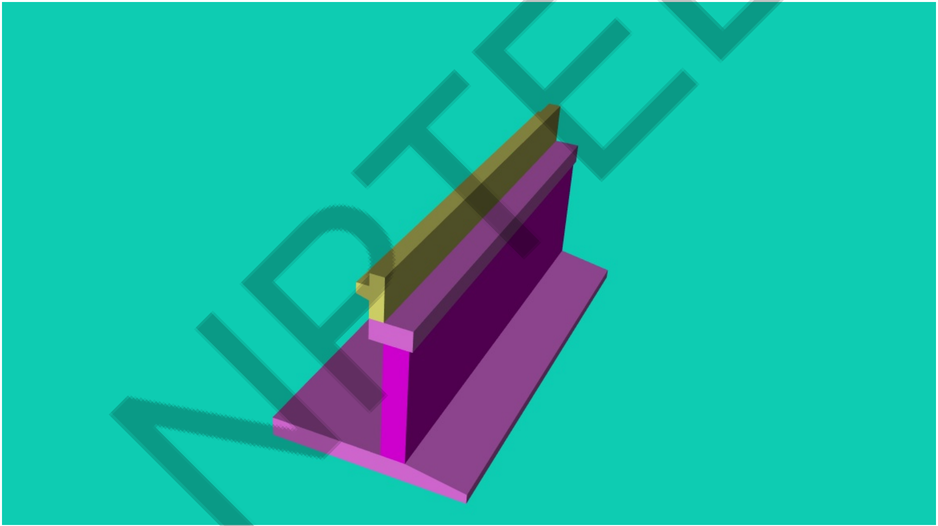
Bridge abutment



Bridge abutment



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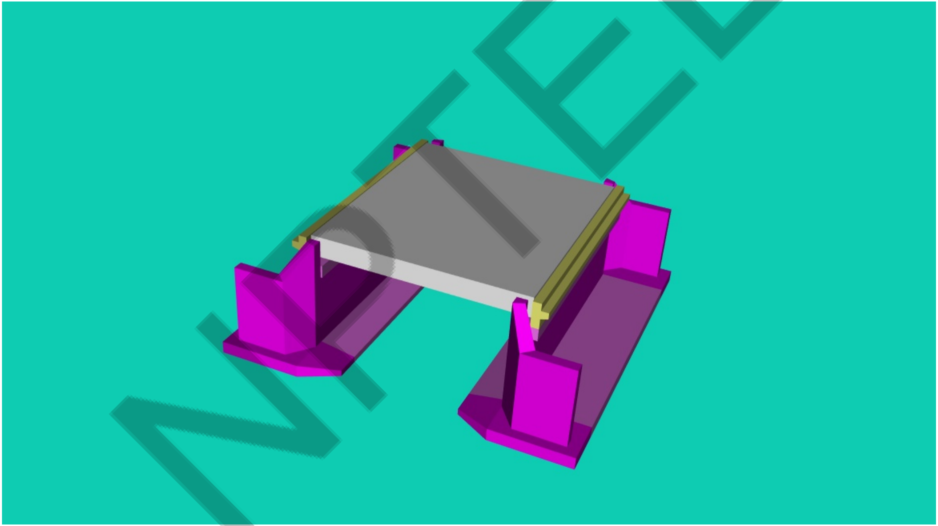
Bridge abutment



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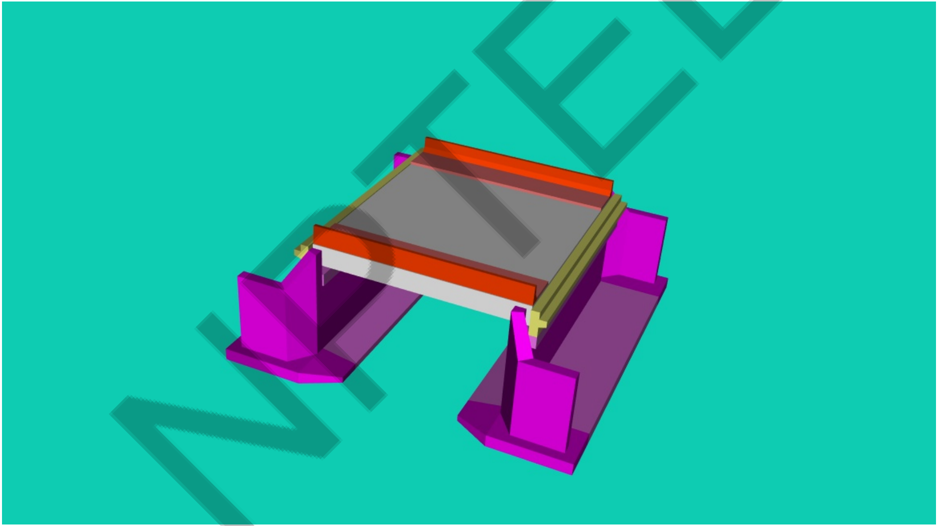
Bridge abutment



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Selection of abutments

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Selection of abutments

The procedure of selecting the most appropriate type of abutments can be based on the following consideration:

- Construction and maintenance cost
- Cut or fill earthwork situation
- Traffic maintenance during construction
- Construction period
- Safety of construction workers
- Availability and cost of backfill material
- Superstructure depth

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Selection of abutments (contd ...)

- Size of abutment
- Horizontal and vertical alignment changes
- Area of excavation
- Aesthetics and similarity to adjacent structures
- Previous experience with the type of abutment
- Ease of access for inspection and maintenance.
- Anticipated life, loading condition, and acceptability of deformations.

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Forces on abutments

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Forces on abutments

Earth pressures exerted on an abutment can be classified according to the direction and the magnitude of the abutment movement.

- At-rest Earth Pressure

When the wall is fixed rigidly and does not move, the pressure exerted by the soil on the wall is called at-rest earth pressure.

- Active Earth Pressure

When a wall moves away from the backfill, the earth pressure decreases (active pressure)

- Passive Earth Pressure

When it moves toward the backfill, the earth pressure increases (passive pressure).

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Bridge data

Cross-section of an abutment

[1]Chainage=$43 + 910$
[2]Span, C/C bearing=10.4 m
[3]Characteristics strength of concrete=30 N/mm^2
[4]Characteristics strength of reinforcing steel=415 N/mm^2

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Cross-section of an abutment

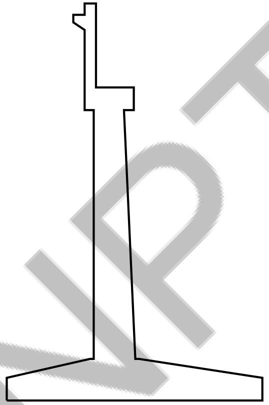

Fig.1.1 : Cross section of the abutment

Stability of abutments

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Stability of abutments

- An abutment may fall in any of the following ways:
  - It may overturn about its toe
  - It may slide along the base
  - It may fail due to the loss of bearing capacity of the soil supporting the base
  - It may undergo deep-seated shear failure
  - It may go through excessive settlement

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Thank you

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