* Component of Bridge:

(i) Super structure → wearing course, railing, footpath (kerb)
→ Deck slab
→ Primary member (long. girder)
→ Secondary member (cross girder)

Bearing
↳ It is a mechanical device which safely transmits all vertical and lateral load to substructure allowing some translational and rotational movement.

(ii) Sub-structure → Pier, abutment, cap
→ foundation cap, foundation.
→

* Various Types of Bridge:

(i) Based upon material use
→ Rcc, steel, masonry, timber, pre-stressed, composite

(ii). Based upon span
→ As per Nepal Bridge standard 2067.

Minor bridge: span ≤ 25m ~~no. of span~~ (total) ≤ 50m

Major Bridge: span ≥ 25m total length > 50m

Special Bridge: (span ≥ 100m)

(iii) Based upon Type of structural system:

- → Beam system (T-Beam)
- → Arch system
- → Frame system
- → Truss system
- → Cable ~~stayed~~ system
- →

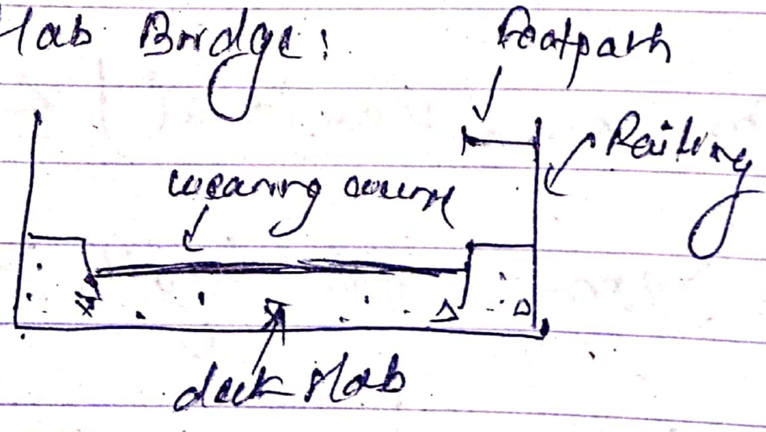
(iv) Based upon type of superstructure:

- → Slab Bridge
- → T-Beam Bridge
- → Box Girder
- → Arch Bridge
- → Truss Bridge
- → Cable Stayed
- → Suspension

In the context of Nepal?

* Selection of Bridge Type:

(1) Slab Bridge:



Positive Aspects

→ ~~eco~~ technically feasible and economically viable upto 15m (RCC) span

→ vertical clearance is more (AB)

→ uniform lateral load distribution

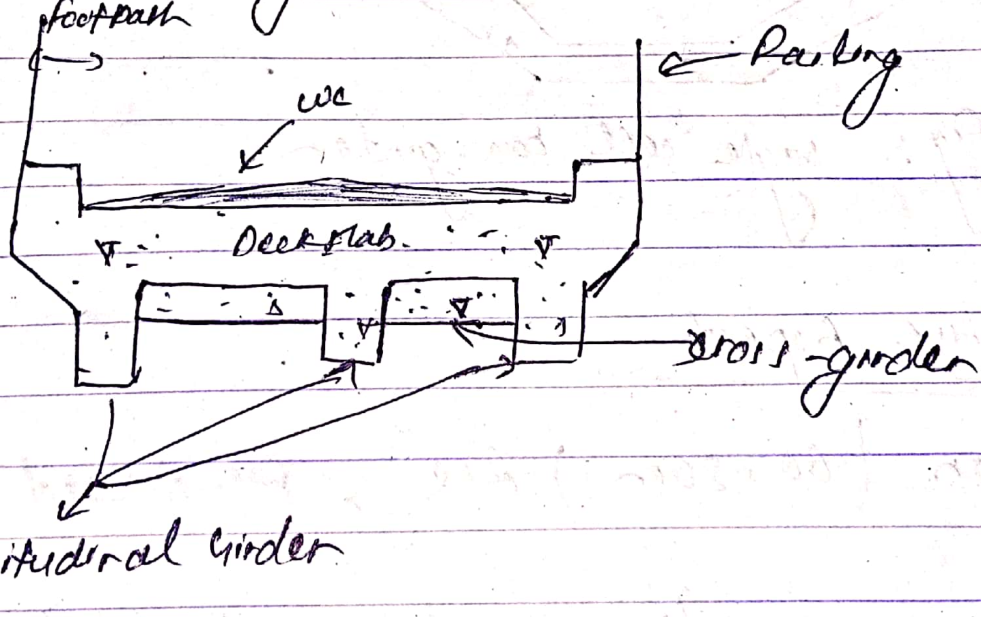
→ good appearance

Negative aspect:

→ not feasible for long span.

→ no. of lane of bridge more than 2.

(II) T- Beam Bridge:



Positive Aspect:

→ technically feasible and economically viable upto 25m (RCC) span

→ Due to monolithic construction it has better rigidity.

→ easier to construct

Negative
→ Less vertical clearance
→ Bulky in appearance.

(iii). Box Girder Bridge:

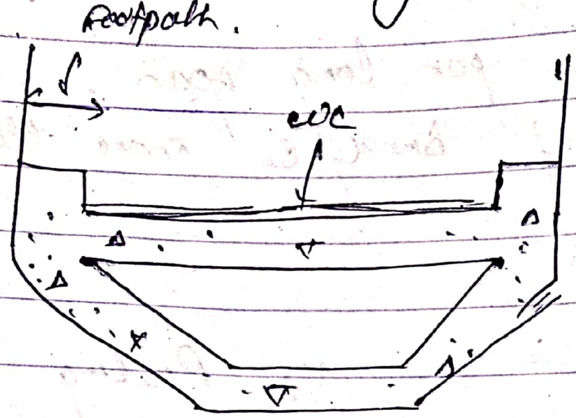


Fig: single cell box-girder

Positive Aspect
→ span (60-80m) RCC, Pre-stressed (100m)
→ curve profile can be made
→ has good lateral load distribution capacity.
→ good appearance
→ generally used in flyover

Negative Aspect
→ cast incurred is difficult
→ Highly skilled manpower needed.
→ advance technology.

(IV) Arch Bridge:

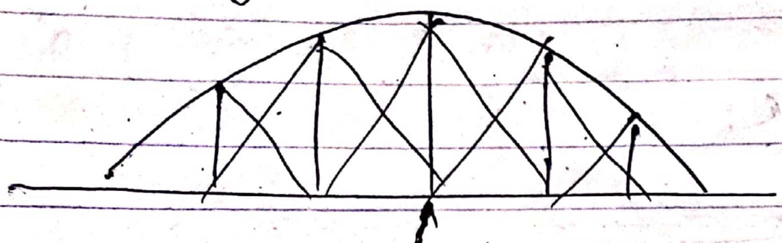


Fig: Through Type arch

(bow बिजुली बजार)

(V).

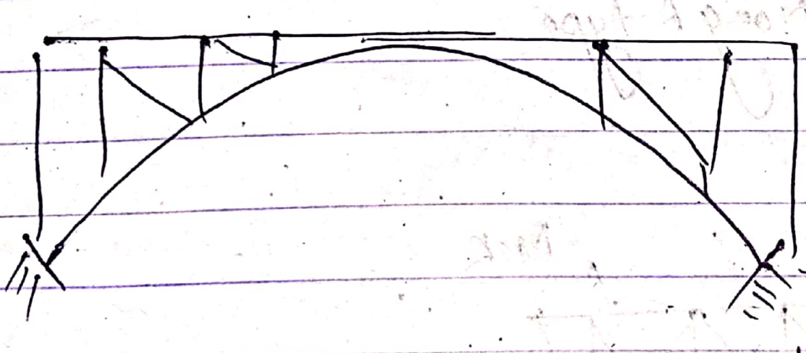


Fig: Deck Type Arch

(मै. ग्रल्टीज)

Positive Aspect:

→ upto span 6100 m for RCC
→ aesthetically pleasing.
→ economical (section (small section can resist high loading).

Negative Aspect

→ strong abutment on sub-soil constr- required (high bearing capacity)

→ difficult to shape the arch ⇒ workmanship difficult.

(V) Truss Bridge:

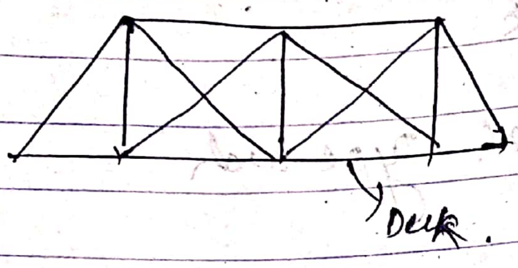


fig: Through type

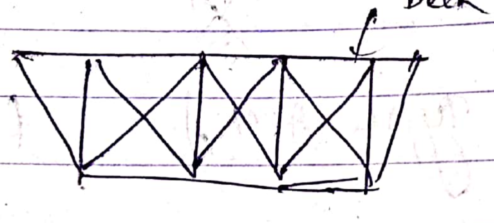


fig: Deck Type

Positive Aspect:

→ economical & viable upto 150 m.

→ rigid structure good lateral load distri- bution characteristics.

→ high speed of fabrication. used in emergency case.

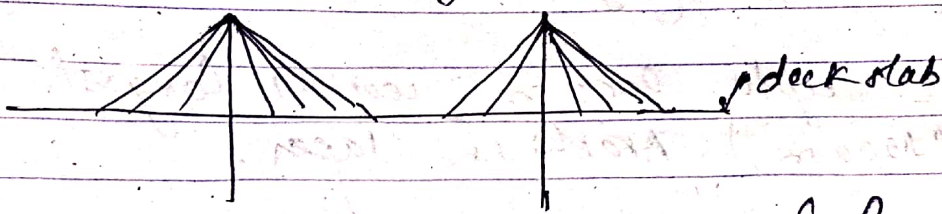
Negative

→ Bulky

→ regular maintainenance needed

→ Less vertical clearance for deck type.

(vi). Cable stayed Bridge.



Positive Aspect:

निवेदिता (500 m)
non-symm क्षे।

→ span upto (600 m - 800 m) RCC
prestressed - 1000 - 1200

→ Has good lateral load distribution

→ main cable anchored into deck slab.

→ Better aesthetic appearance.

→ Less no. of piers, foundation.

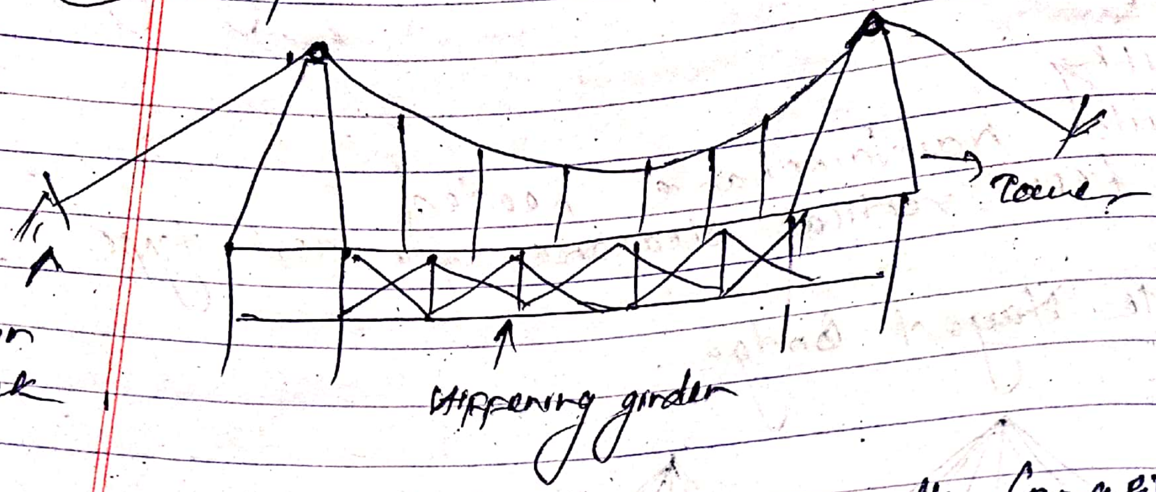
Negative:

→ Taller tower

→ Skilled manpower

→ Advanced technology.

(VII) Suspension cable Bride :



→ viable upto 2000 m. world's Longest (1200 m) Akashi in Japan.

→ good lateral load distribution
→ main cable on ute and deck slab.
→ better aesthetic

*Imp #

How live load are considered for design of bridge in Nepal? Also explain how seismic forces are incorporated in the design of Bridge.

=> Nepal Bridge Standard (2067), all bridge design are designed as per AASHTO or IRC. Unless and otherwise specified, IRC shall be used (IRC 6:2024

→ IRC Bridge loading.

IRC live load
(vehicular load)

- Normal load (wheel vehicle)
  - → IRC class 'A' Loading
  - → IRC class 'B' Loading
- Abnormal load (Military and industrial vehicle)
  - → IRC class 70 R Loading
    - a) wheel loading
    - b) Track Loading
  - → IRC class AA Loading
    - a) wheel loading
    - b) Track loading

lengthy [illegible] /

Design of Bridge:

- Introduction.

(i) Choice of location of Bridge site
(ii) Bridge classification and its selection
(iii) Characteristics of Bridge superstructure
(iv) Data required for Analysis and Design of Bridge (Basic Design Data Requirement / Parameter
(v) Factors Affecting selection of Bridge Type
(vi) component of Bridge

Second Part (Imp)

(i) Load Calculation and its structural Analysis (BM, SF using ILD).

*Imp → method of lateral load distribution (Analysis of Bridge Deck)

(i) Courbon's Method (T-beam Bridge Design

*Imp. (70-8.04. T-beam Nepal TT)

3rd Part. Structural Design

→ design of slab Bridge

→ design of T-beam Bridge

Date
Page

II. Explain briefly how live loads are considered in the design of bridges in Nepal. Also explain how seismic forces are incorporated.

→ Nepal Bridge Standard 2067

<u>Road Bridge Loading</u>

All permanent road bridge in Nepal shall be designed as per IRC loading or AASTHO loading. All design shall be carried out using in accordance to IRC standard for bridge unless otherwise specified.

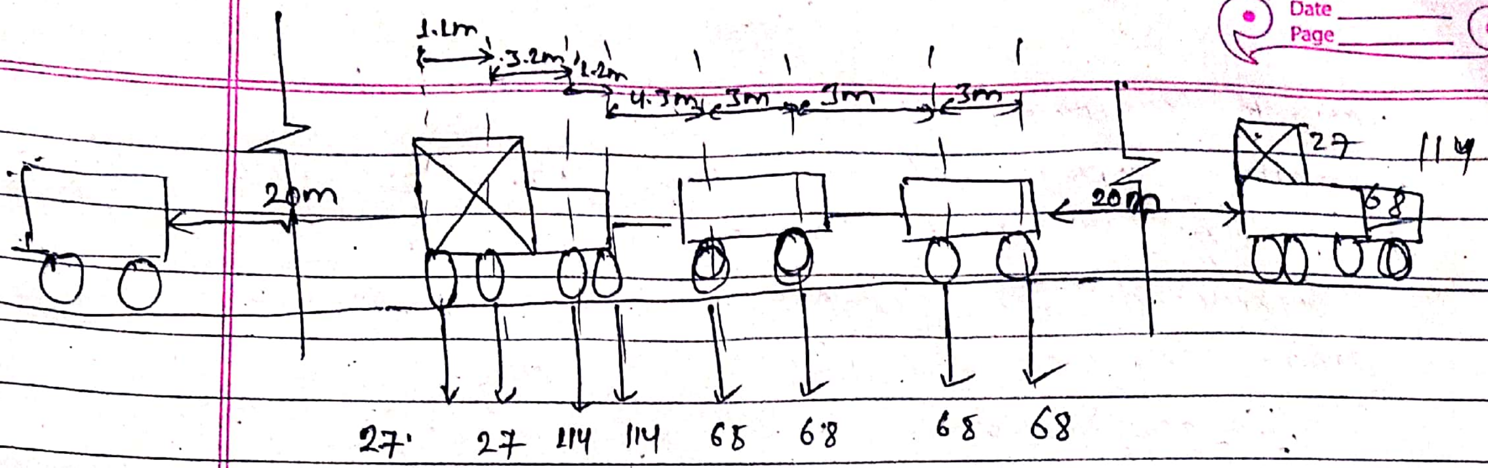
<u>IRC Live Loading:</u>

(1) IRC Class A Loading:

It consists of wheel load train comprising a truck (driving unit) and trailer of specified axle spacing and load.

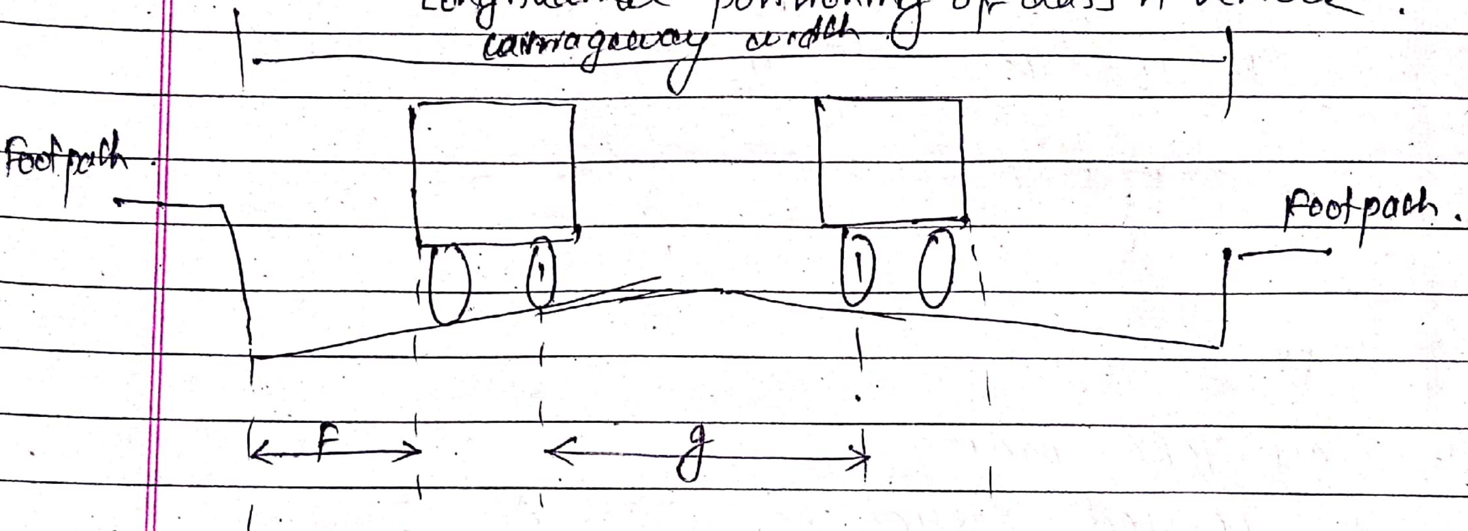
→ normally adopted for design of all roads on which permanent bridge and culvert are constructed.

27 27 114 114



Total load = 554 KN
= (27+27+114+114+68+68+68+68)

Longitudinal positioning of class A vehicle.

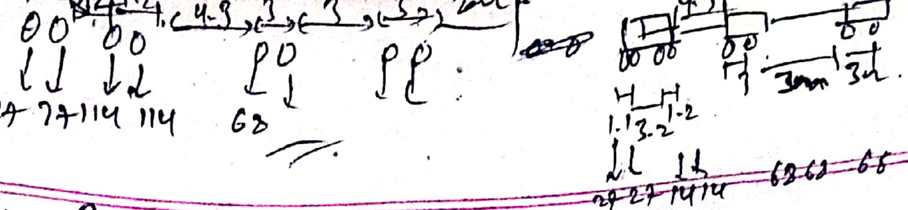


$f \geq 150$ mm

$g \geq 1.2$m for two lane.

→ For one train of class A vehicle occupies one lane of carriageway of bridge!

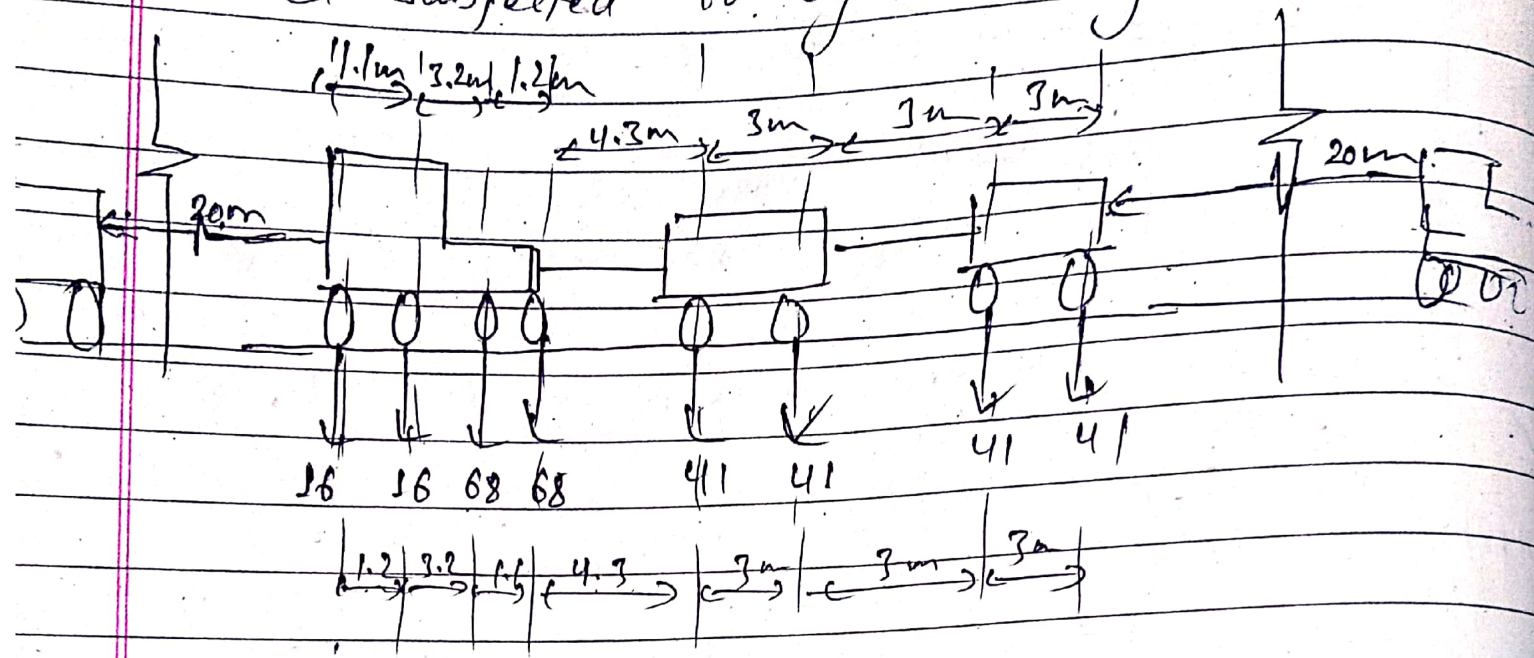
→ Bridge designed for class A loading should be checked for class 70R loading and class AA loading. ? why ⇒ to identify the most critical loading condition.



(ii) Class B loading:

→ comprises of wheel load train similar to class A loading but with smaller axle load.

→ considered for temporary bridge in specified area subjected to light loading.



~~27 27 114 114~~

68

(iii). Class 70R Loading:

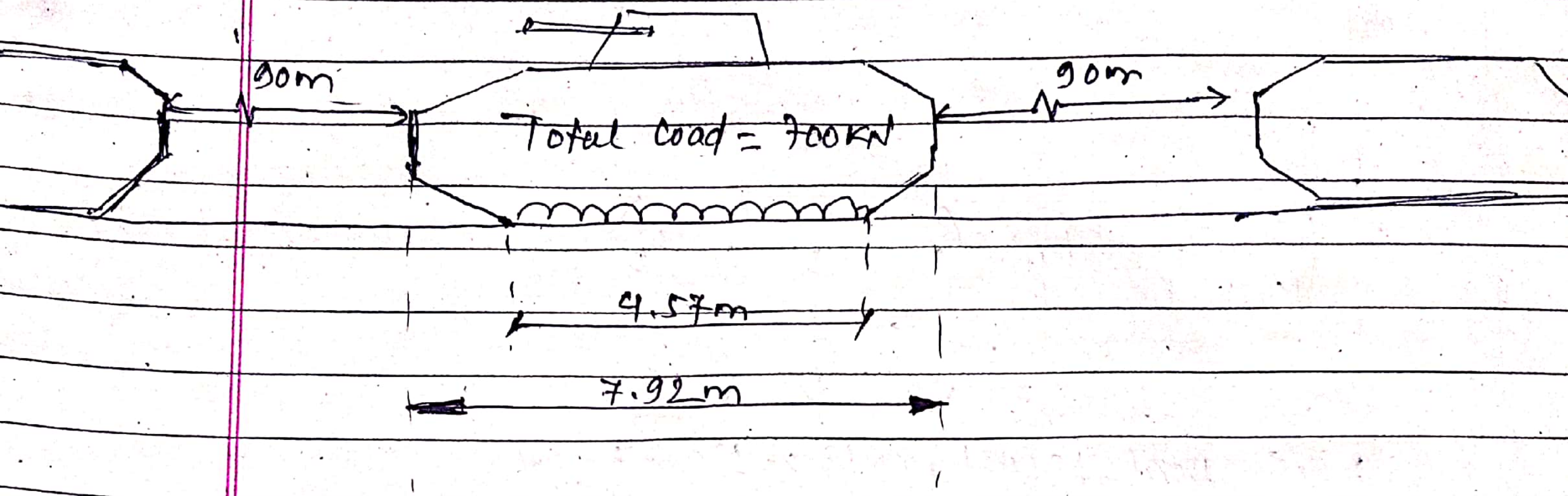
→ revised version of class 'AA' loading and consist of tracked and wheel load.

→ IRC class 70R loading is adopted on all road where permanent bridge is constructed.

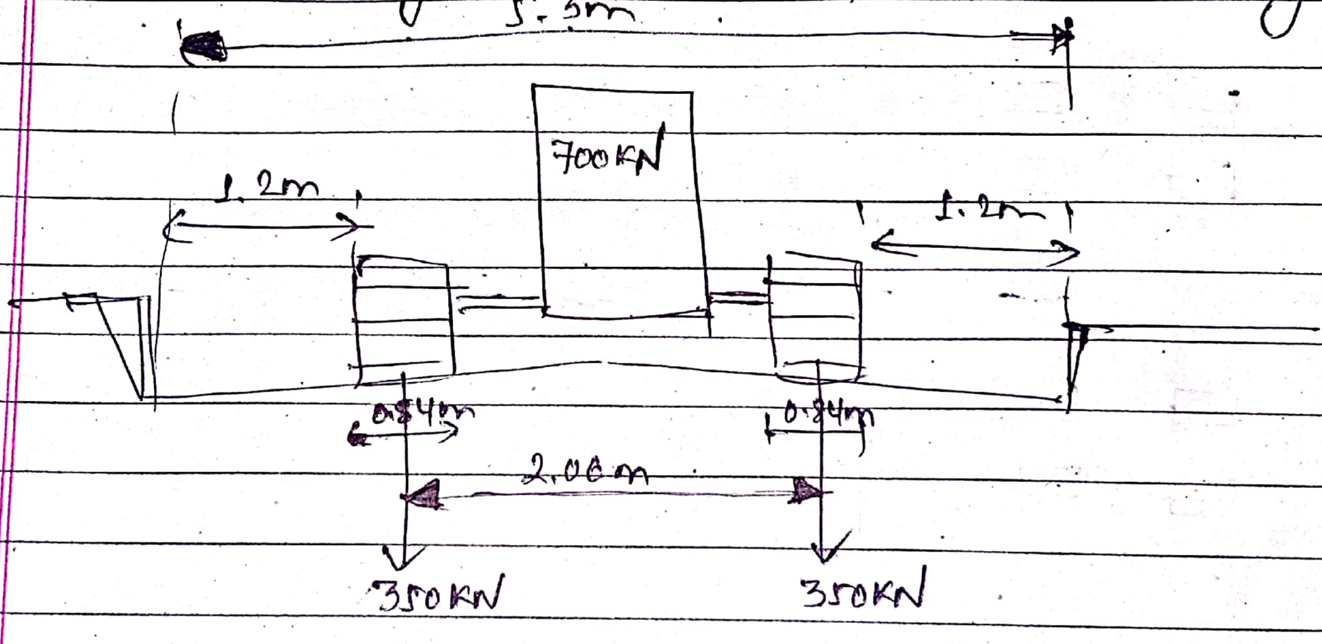
→ Bridge design for IRC class 70R loading should be checked for class A loading.

→ One class of 70R loading occupies two lane of bridge carriageway.

(a) Track ~~wheel~~ loading:



Longitudinal section of class 70R loading.

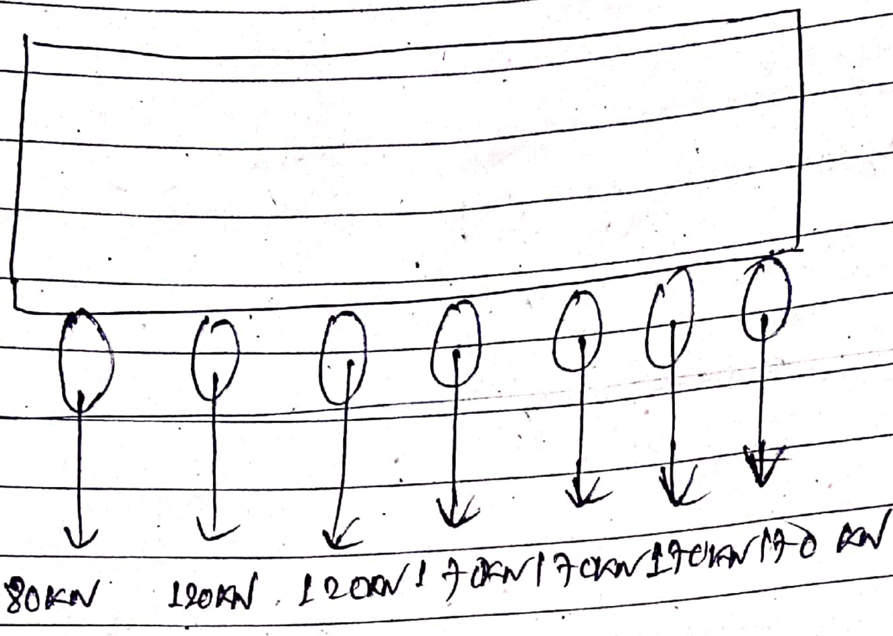


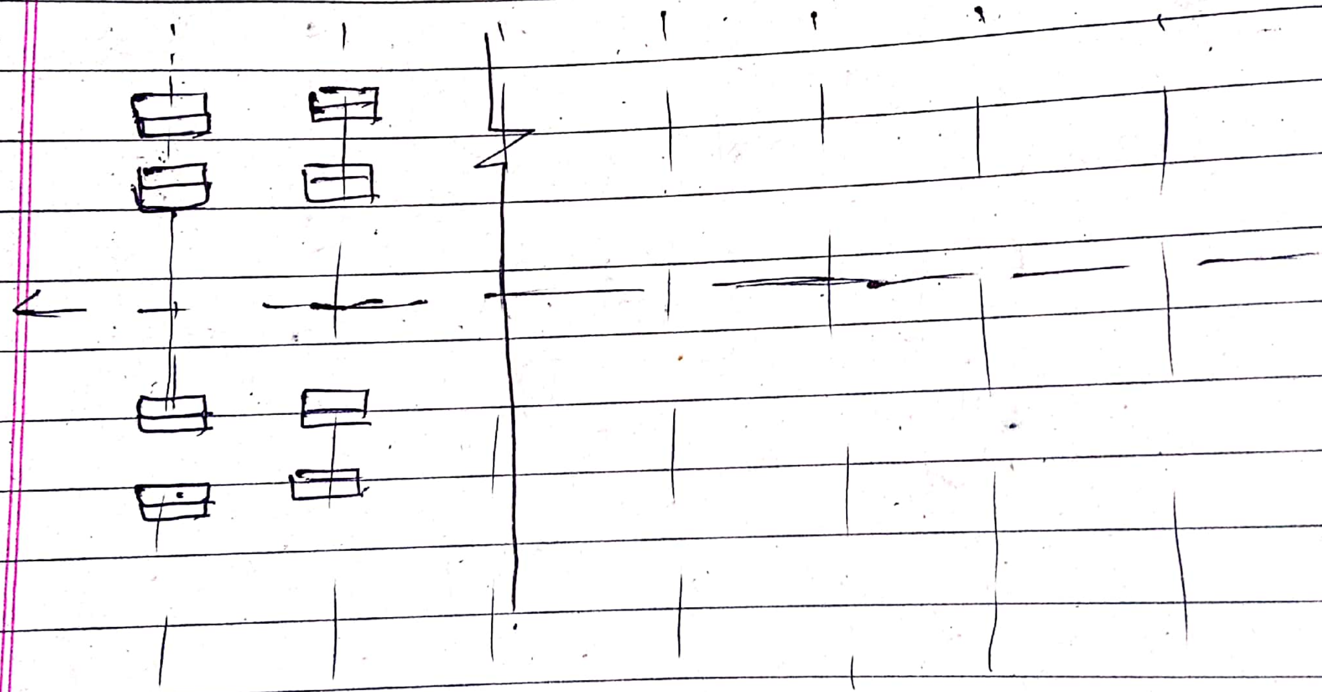
Transverse-section

(ii). ~~Class AA Loading~~ :

(b). Wheel Loading (class 70R)

→ seven axle wheel load.



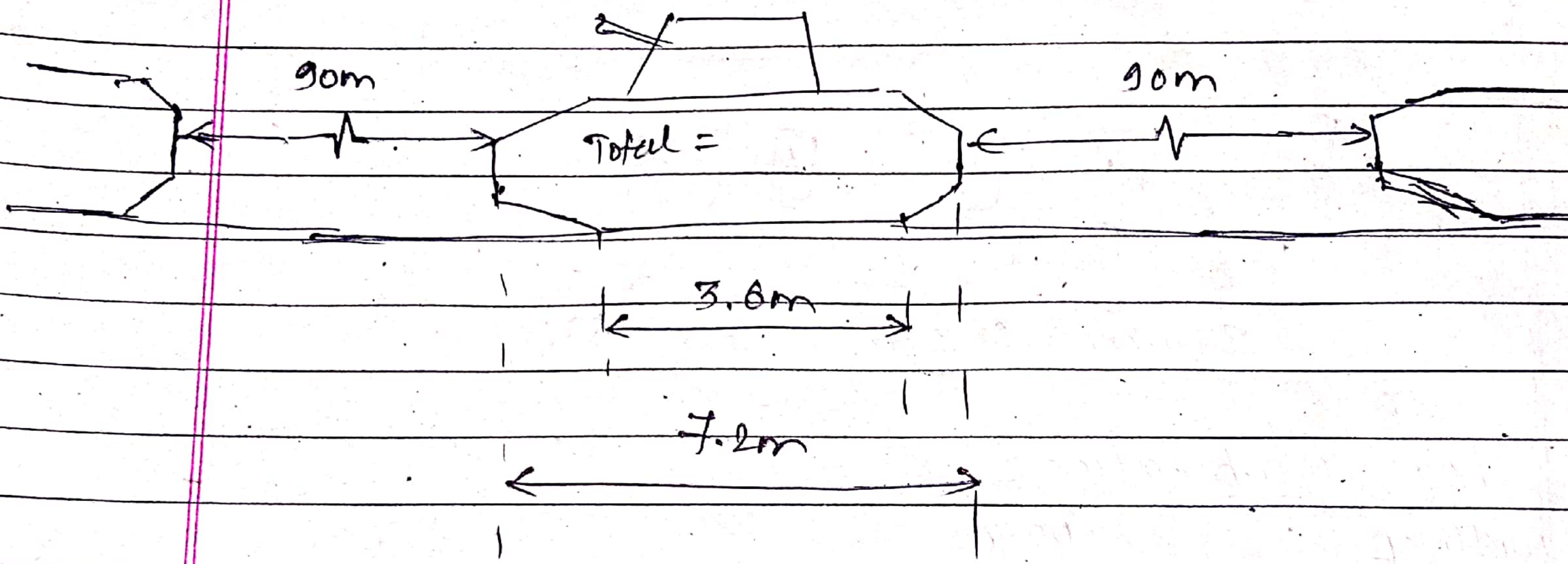


(iv) class AA Loading:

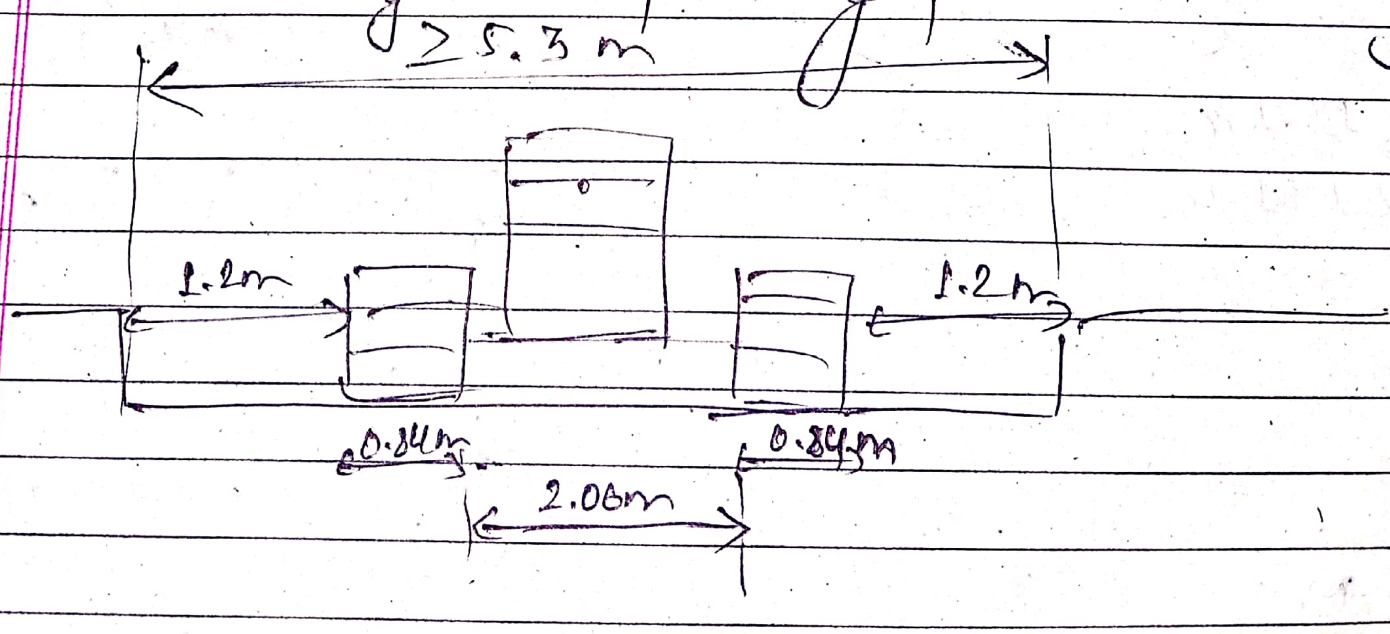
(a). → consists of either a tracked vehicle or wheeled vehicle

→ normally bridge on national highway are designed for class 'AA' loads.

→ Bridge design for class AA loading should be checked for class A loading (under certain condition, heavier stress might be obtained under class A loading).

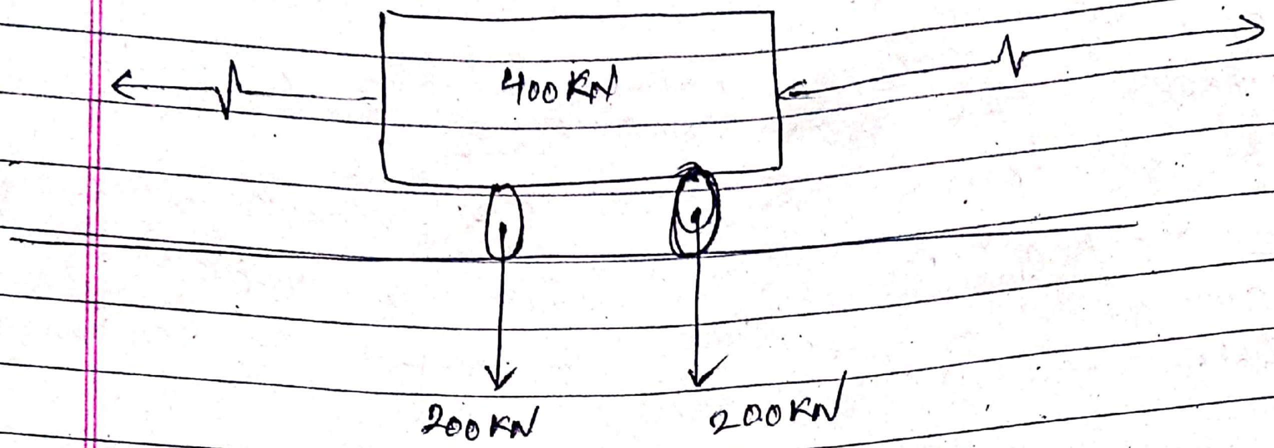


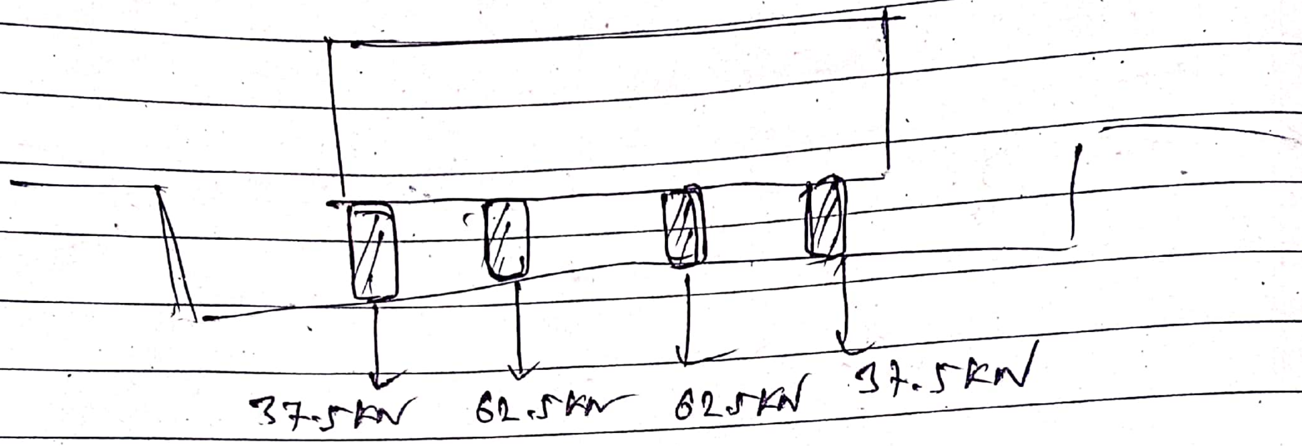
Longitudinal positioning of class AA loading



V_r = Anc

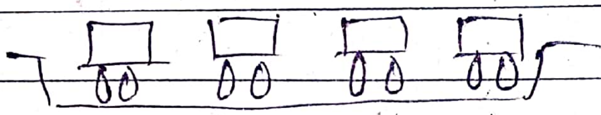
(b) wheeled vehicle.





*. Load combination :-

width of carriageway of bridge	No. of lane	Load combination
		combination ①
		class A vehicle (4).
> 13.1m < 16.1m	4	



combination (ii).
nos.
2 class A vehicle +
class 70R or class AA
Ⓔ 1 nos.
combo (3)

Si.Rm

Class 70R or class A
2 lanes.

most critical taken.

Seismic wave consideration:

(i) Linear Static Method (Seismic coefficient method)

(ii) Non-Linear Static (Pushover Analysis)

(iii) Linear Dynamic Analysis Response Spectrum Method

(iv) Non-Linear Dynamic (Time History method)

(i) Linear Static Method:

$$V_B = A_h W$$

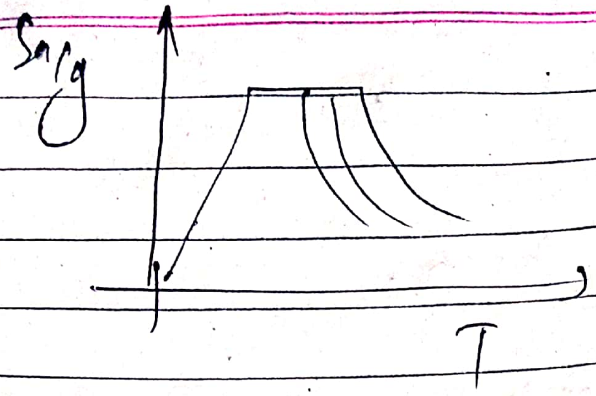
$$A_h = \left(\frac{Z}{2}\right)\left(\frac{S_a}{g}\right)\left(\frac{I}{R}\right)$$

I = importance factor = 1.5 for national highway bridge

= 1 for other bridge.

R => Response Reduction factor = 2.5 (ductile detailing).

Z => depends on seismic zone

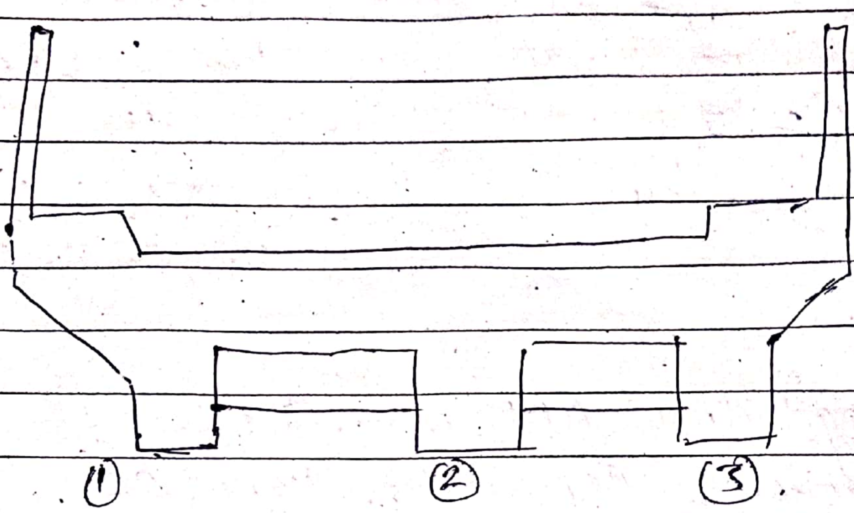


depends on fundamental time period.

T beam, slab bridge

Counterfort

* Structural Analysis of T-beam and Slab Bridge:
→ method of lateral load distribution in deck slab and girder. (long. girder मा कति load आउँछ)

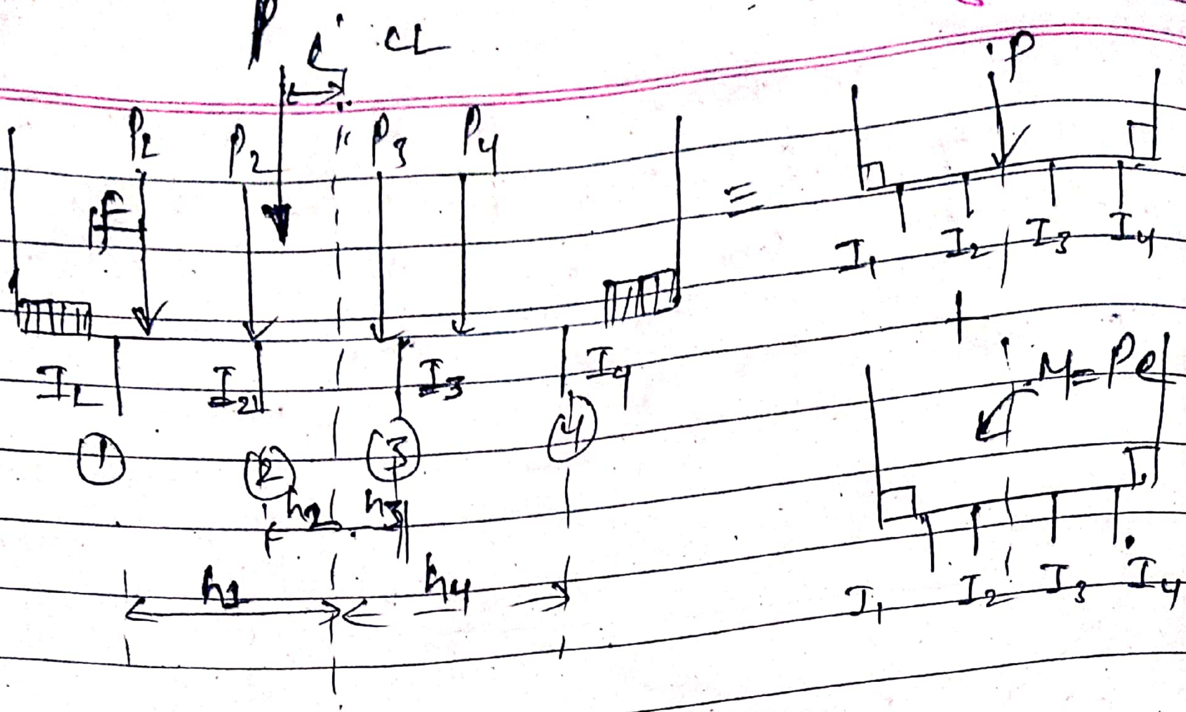


①. Courbon's Method of lateral load distribution:
→ used in the analysis of T-beam and composite bridge

Requirement:

(i) ratio of span to width > 2
(ii) minm No. of cross-beams (girder) interconnecting the longitudinal girder shou = 5 (adequate stiffeners)
(iii). Depth of cross girder should at least be 3/4th (0.75) of the depth of longitudinal ~~beam~~. girder.

simple, highly popular and powerful tool for lateral load distribution in T-beam



Analysis:

→ max. longitudinal BM, max. long SF

→ max. transverse BM, max. trans. SF

. To get max^m longitudinal BM and SF due to Live Load, transverse positioning of Live Load is such that it produces maximum eccentricity.

Load shared by each girder:

1^st girder $R_1 = \dfrac{P I_1}{\Sigma I} + \dfrac{M I_1 h_1}{\Sigma I h^2}$

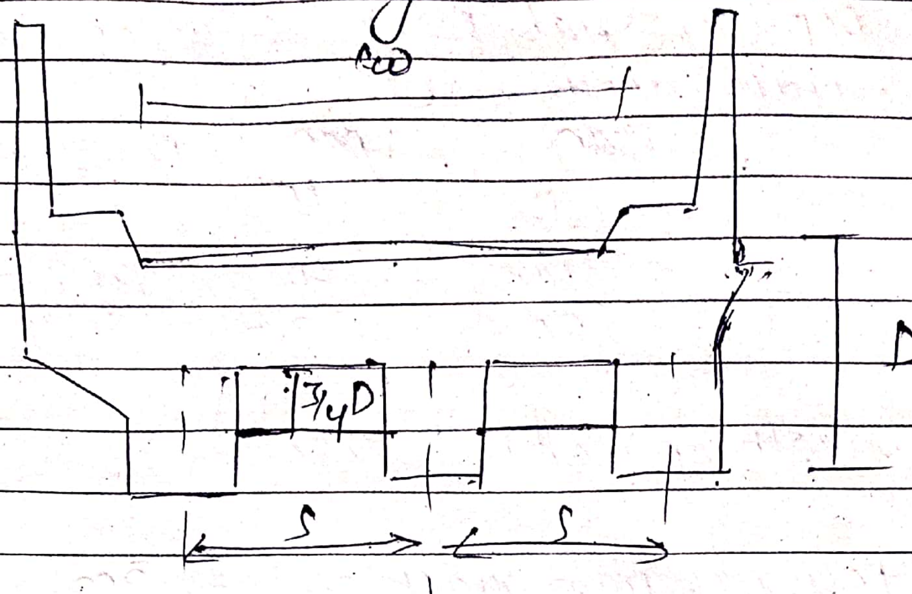
$R_2 = \dfrac{P I_2}{\Sigma I} + \dfrac{M I_2 h_2}{\Sigma I h^2}$

$R_3 = \dfrac{P I_3}{\Sigma I} - \dfrac{M I_3 h_3}{\Sigma I h^2}$

$R_4 = \dfrac{P I_4}{\Sigma I} - \dfrac{M I_4 h_4}{\Sigma I h^2}$

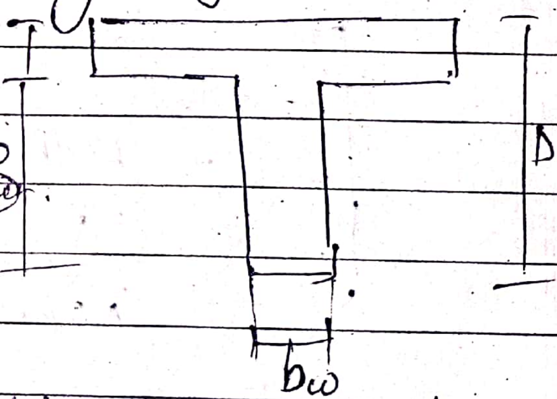
$R_2 = \frac{P I_2}{\Sigma I} + \frac{M I_2 h_2}{\Sigma I h^2}$ $\quad R_4 = \frac{P I_4}{\Sigma I_4} - \frac{M I_4 h_4}{\Sigma I h^2}$

* Design of T-beam bridge :



→ Main load Resisting member
(i) Deck slab
(ii). Main girder
(iii) cross girder.

STEP (I) : planning and preliminary design



Planning :

For single lane : 4.25m
For double lane : 7-7.5m
width of carriageway :

ht. of railing ⇒ ≥ 1.1 - half width of railing
width of kerb ⇒ ≥ 0.225 m
depth of kerb = 0.225 m
width of footpath = ≥ 0.6m

Preliminary design:

a) Depth of slab/flang $\geq 200mm$

b) overall depth $\Rightarrow$

$= \frac{span}{10} - \frac{span}{15}$ for simply supported.

$= \frac{span}{20} - \frac{span}{25}$ for continuous.

c) breadth of web (b_w) $\geq 250mm$

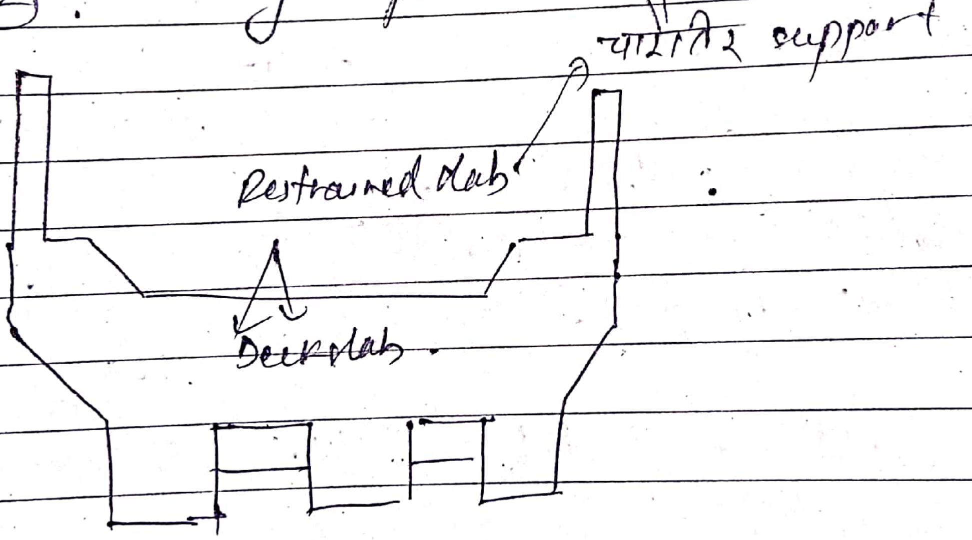
d) spacing of main girder $\Rightarrow$ 2–3m

e) spacing of cross girder $\Rightarrow$ 3–5m

f) min^m no. of cross girder $\Rightarrow \geq 5$ nos.

g) depth of cross girder $\Rightarrow \geq \frac{3}{4} D$.

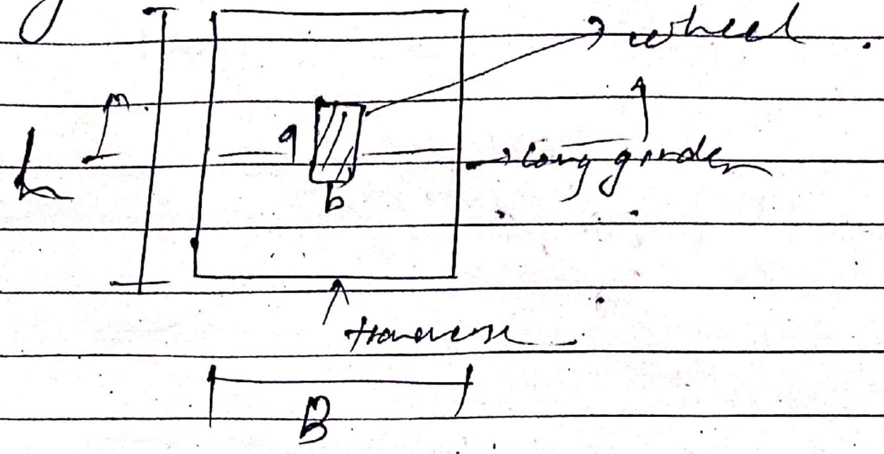
STEP 2 : Analysis of ~~deck~~ cantilever slab and its design.

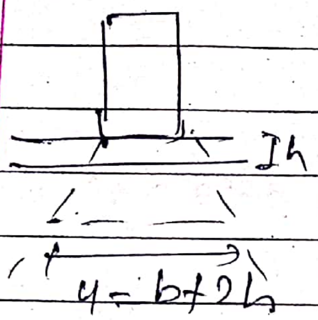


→ using effective width method

STEP 3: Analysis and design of restrained slab.

→ using Pigeaud method.



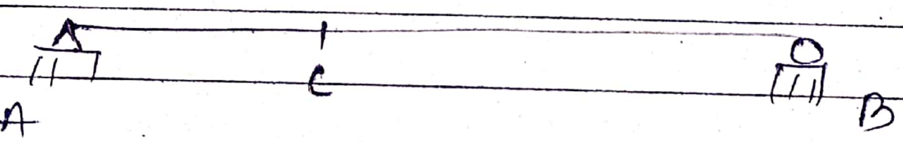


$$M_1 = (m_1 + \mu m_2) P$$
$$M_2 = (m_2 + \mu m_1) P$$

m_1, m_2 ⇒ coeff. for moments along short and long spans.

M_1, M_2 ⇒ moment along short and long spans.

STEP 4: Analysis and Design of main girder due to moving load.

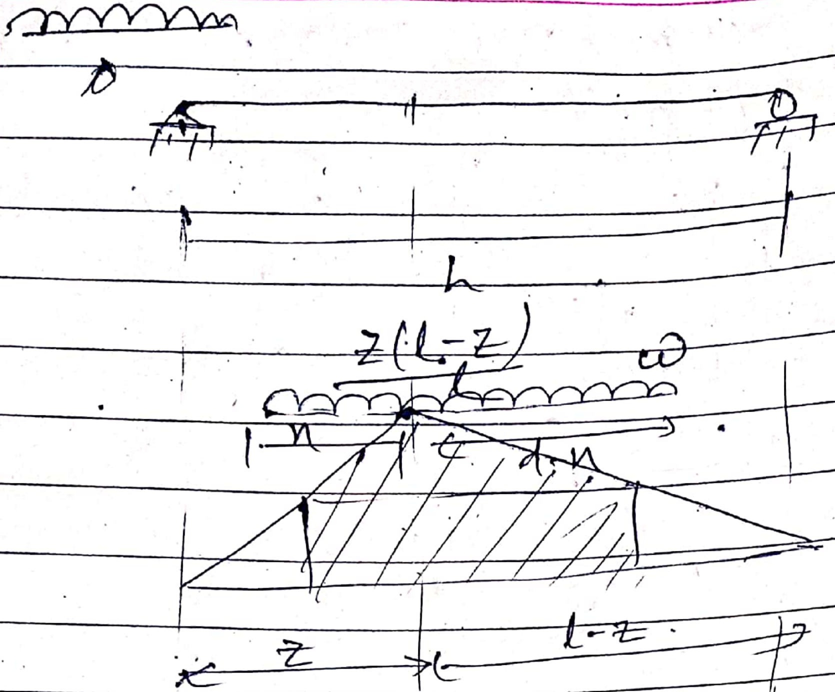


max. BM at section C. for

a) track load.

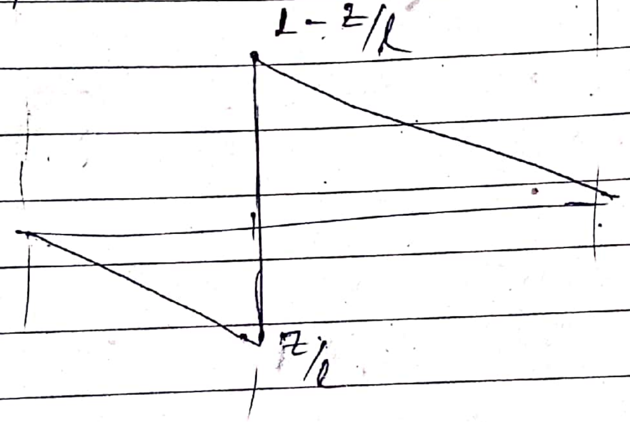
$\frac{700}{4.57\ m}$

Date
Page



ILD for BM at C

→ using ILD we have to calculate max^m value of BM and SF

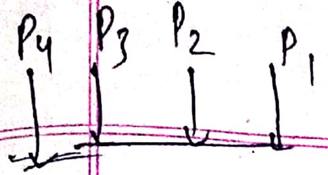


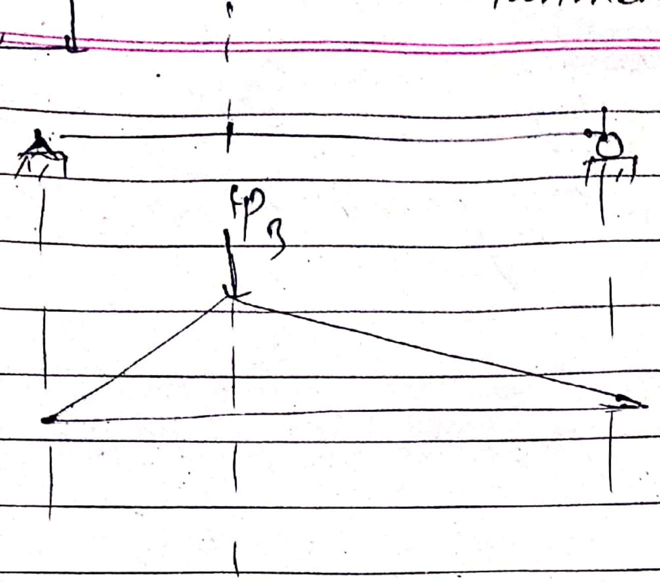
BM max at C occurs when $\frac{x}{d} = \frac{Z}{L}$

M^C_{max} = $w \times$ Area of shade part.

(B) wheel load

span बिच आसपासको गर्दा curtailment done.





Max when one of the load at C and. Eg.

(B_1) P_2 मा हुँदा

(B_2) P_3 C मा आउदा अघि.

$$\left(\frac{P_1}{Z}\right) > \frac{R_2}{(L-Z)}$$

$\Downarrow$ changes sign.

$$\left(\frac{R_1}{Z}\right) < \frac{R_2}{(l-Z)}$$

$$M_{max}^{C} = P_1y_1 + P_2y_2 + P_3y_3 + P_4y_4$$

similarly SF.

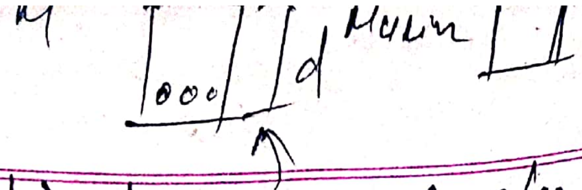
STEP 5 : calculation of steel reinforcement.

$$M_{max} = 0.87 f_y A_{st}\, d \left(1 - \frac{f_y A_{st}}{f_{ck}\, b \times d}\right)$$

$A_{st} = \text{- - - -}$ f_e 500 Se

Also, check $M_{ulim} = 0.133 f_{ck} b d^2$

$$d_{balance} = \sqrt{\frac{M}{0.133 f_{ck} b}}$$



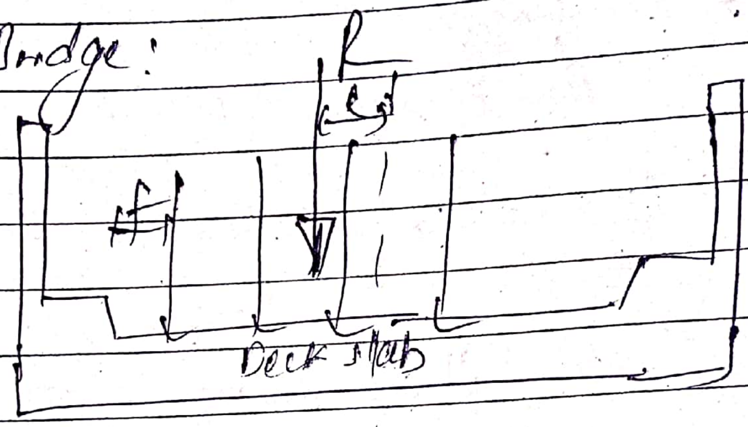
$d > d_{bal}$ $\Rightarrow$ singly reinforced

If $d < d_{bal}$ $\Rightarrow$ doubly reinforced.

STEP 6: Detailing:

See notes.

II) Slab Bridge:



main loading taken by slab..

Planning and preliminary design.

1 lane $\Rightarrow$ 4.25m

2 lane = 7 - 7.5m.

Kerb width = 0.225m

height of footpath = 0.225m

Preliminary Design:

Depth of slab (Deflection control criteria)

$$D = \frac{span}{15} - \frac{span}{12} \quad \text{simply supported}$$

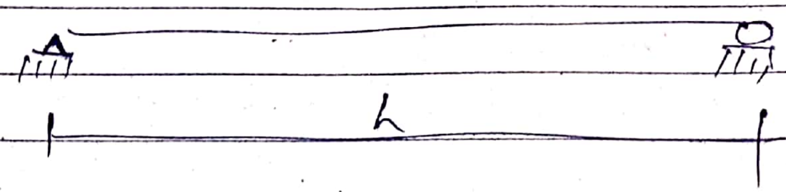
$$= \frac{span}{20} - \frac{span}{25} \quad \text{continuous.}$$

STEP (2): Analysis of deck slab

Positioning of live load when

$\Rightarrow M_{max\ long} \rightarrow e_{max}$

M_{max} transverse $\Rightarrow$ when e_{min}.

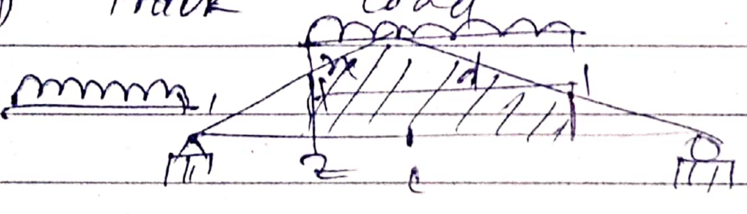


assume unit (1m) width beam.

यदि effective width multiply

using ILD determine. BM_{max} and SF_{max} for (a) track load and (b) wheel load..

(a) Track Load



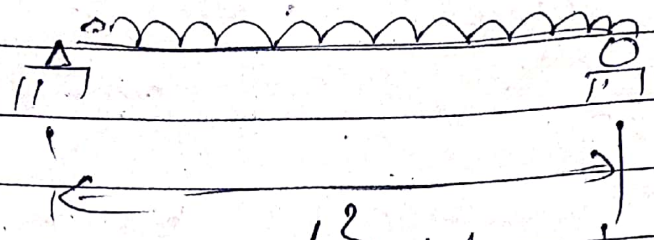
B_{max} when $\frac{x}{d} = \frac{z}{l}$

B_{max} = w X Area of shaded.

(b) wheel load

Tem reinforcement आदि रखना |

Dead Load



$M_{max} = \frac{wl^2}{8}$ (long) → Long. reinforcement.

For BMmax in transverse

$$M_{trans/max} = 0.3\,LLBM + 0.2\,DLBM$$

$$= 0.3\,(M_{max})_{LL} + 0.2\,(M_{max})_{DL}$$

→ Trans reinforcement.

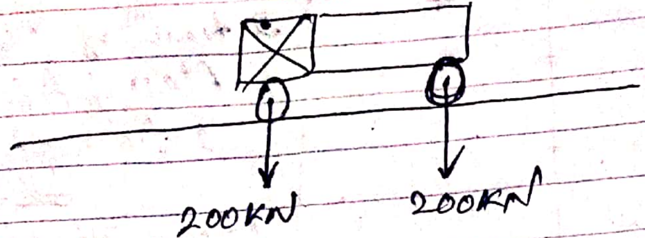


Fig: Longitudinal section.

* **Bridge Load combination :**

	carriageway width	No. of lane.	Live Load	
1.	< 5.3m > 4.75m	1	class 'A' loading for 2.3 m width	
2.	$5.3 \leq x < 9.6m$	2	class 'A' train 2 number	class 70R / class AA load one train
3.	$9.6 \leq x < 13.1$ m	3	class 'A' train 3 number	class 70R / class AA load one train + class A one train
4.	$13.1 \leq x < 16m$	4	class A train 4 no.	2 train of class 70R / 'AA' or 1 train class 70R/class AA + 2 class A

5.	≥16.6 m	<20.1m	5	2 train of class AOR Class AA + 1 train of class A OR 1 train of class AA OR + 3 train of class A
6.	≥20.1m	<23.6m	6	

* Seismic Analysis of Bridge:

- Static Loading
  - Linear static analysis (Seismic coefficient method)
  - Non-Linear Static analysis (Pushover analysis)
- Dynamic Loading
  - Linear dynamic (Response spectrum method)
  - Non-Linear dynam (Time History Analysis) (most accurate)

Horizontal seismic force [Base shear (V_b)]

$= A_h * W$

$$h = \frac{S_a}{g} * \left(\frac{Z}{2}\right) * \left(\frac{I}{R}\right)$$

ere

=) Zone factor

=) importance factor (1.5 for national road 1 for feeder

=) Response reduction factor (2.5)

$\frac{S_a}{g}$ =) spectral acceleration at 5% damping.

* list out and discuss the loads, forces and stresses which are to be considered in the designing of a road bridge.

⇒ Loads to be considered for appropriate combination to carry out the necessary checks for the design of road bridges as per IRC: 6-2017 are as follows:

1) Dead Load
2) Snow Load
3) Super-imposed dead load such as hand rail, crash barrier, foot path & service loads
4) Surfacing or Wearing coat
5) Back fill weight
6) Earth Pressure
7) Primary and secondary effect of prestress
8) Secondary effects such as creep, Shrinkage and settlement
9) Temperature effects including restraint and bearing forces
10) Carriage way live load, foot path live load, construction live load
11) Associated carriageway live load such as braking, tractive and centrifugal forces.
12) Accidental forces such as vehicle collision load, barge impact due to floating bodies and accidental wheel load on mountable footway
13) Wind
14) Seismic Effect
15) Construction dead loads such as weight of launching girder, truss or Cantilever construction equipments
16) Water Current forces
17) Wave Pressure
18) Buoyancy
19) Hydrodynamic Effect

(16–19) Hydraulic Loads.

CamScanner

1. Dead Load

→ It is the self weight of the structure and any permanent loads fixed there on
→ The dead load of a member depends upon the type of materials made of.

2. Live Load

→ Road bridges are divided into classes according to the loadings they are designed to carry.

(i) IRC Class 70R Loading (Wheeled and Tracked Type)

(ii) IRC Class AA Loading (Wheeled and Tracked Type)

(iii) IRC Class A Loading

(iv) IRC Class B Loading → timber bridges

(v) IRC Class Special Vehicle (SV) Loading

For bridges classified above, the design live load shall consist of standard wheeled or tracked vehicles or trains of vehicles as illustrated below.

(i)

(a)

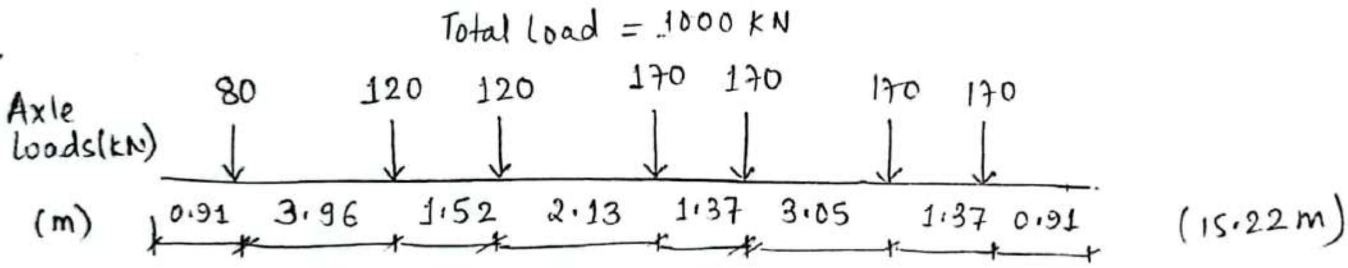


fig: Class 70R (Wheeled) - longitudinal Position.

(b)

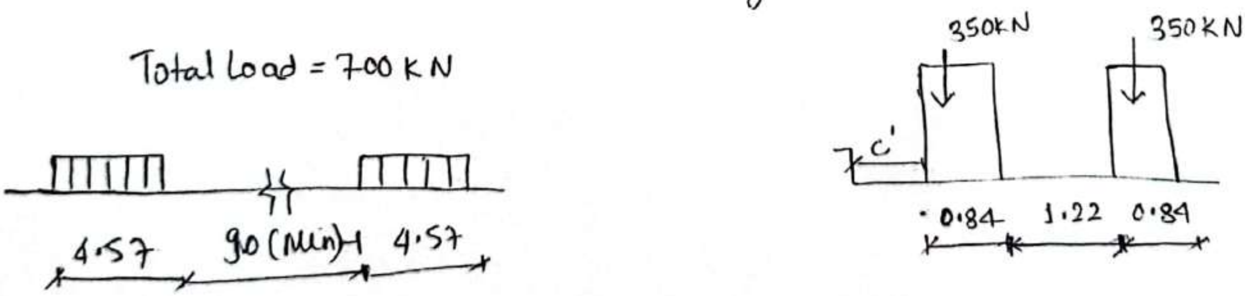
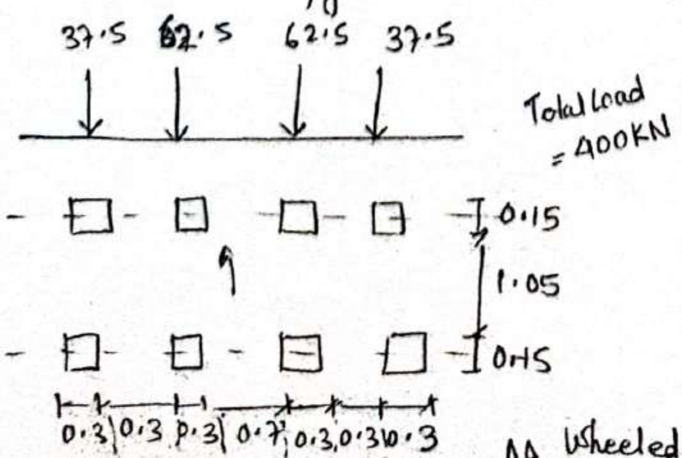
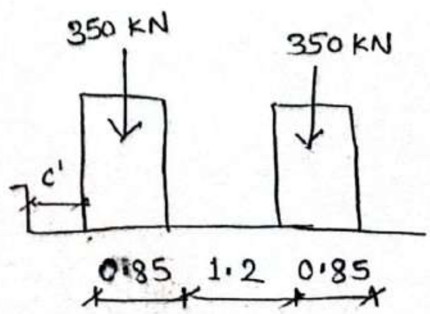


fig: Class 70R (Tracked) Vehicle

(ii)



AA Wheeled



AA Tracked

(iii)

Total Load = 554 KN

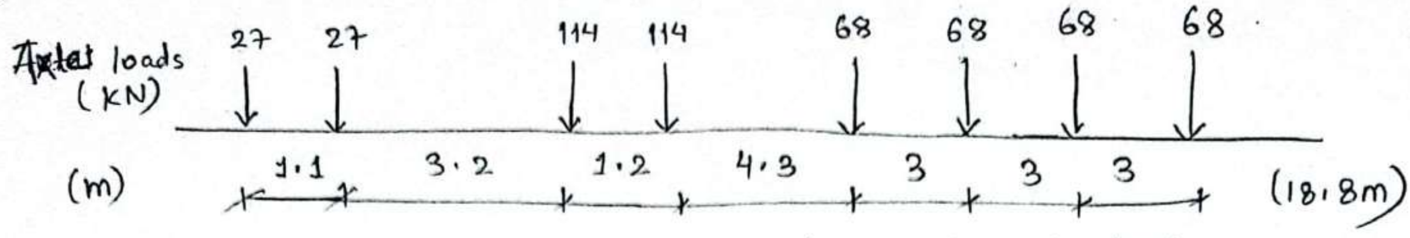


fig : Class A Vehicle (Longitudinal Position)

→ Bridges designed for class AA loading and class 70 R loading should be checked for class A loading also, as under certain conditions, heavier stresses may occur under class A loading.

3. Impact

→ Provision for impact or dynamic action shall be made by an increment of the live load by an impact allowance expressed as a fraction or a percentage of applied live load.

For Class A or B Loading (3m to 45m)

(i) Impact factor fraction for RCC bridges $= \dfrac{4.5}{6+L}$

(ii) Impact factor fraction for steel bridges $= \dfrac{9}{13.5+L}$

where; L is span in meters.

For 70R Loading or Class AA Loading.

i) for span less than 9m

Tracked vehicles = 25% for span up to 5m & linearly reducing to 10% for span up to 9m.

Wheeled Vehicles = 25%.

ii) for Span ~~gr~~ of 9m or more.

RCC Bridges

Tracked vehicles = 10% up to span of 40m

Wheeled Vehicles = 25% up to span of 12m

} for ~~greater~~ excess, in accordance with curve of IRC code

Steel Bridges

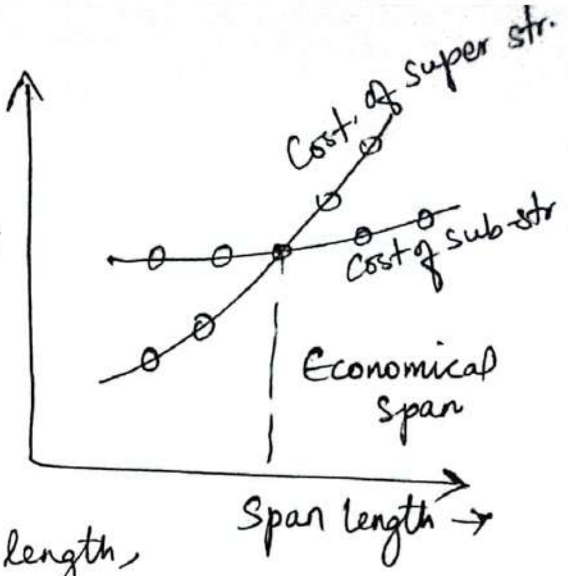
Tracked Vehicles = 10% for all spans

Wheeled Vehicles = 25% up to span of 23m.

* Economic Span Length

→ depend upon cost of substructure & Superstructure

Total cost of bridge = Total cost of superstructure + total cost of sub-structure.



→ When the span length of bridge increases, cost of sub str. decreases while cost of super str. increases.

→ Cost of main girders & cross girders per unit length, directly proportional to span.

→ Economic span is span for which overall cost of bridge is minimum, For this, cost of super str. = cost of sub str.

Total cost of bridge = Cost of abutments + no. of pier * cost of each pier + length * cost of flooring per unit length + length * cost of main & cross girders per meter length.

$$\therefore \quad C = C_A + nC_p + LC_F + LC_T \qquad L = \text{total length}$$

n = no. of piers.
l = length of one span

Here,

$$C_T \propto l$$
$$C_T = Kl$$

Also, $n = \frac{L}{l} - 1$

$$\therefore \; C = C_A + C_p\left(\frac{L}{l} - 1\right) + LC_F + L * Kl$$
$$= C_A + \frac{L}{l}C_p + LC_F + LKl - C_p$$

for total cost to be min^m; $\frac{dC}{dl} = 0$

$$0 = 0 - \frac{L}{l^2}C_p + 0 + LK$$

or, $K = \frac{C_p}{l^2}$ or, $lK = \frac{C_p}{l}$

$$\boxed{\therefore \; l = \sqrt{C_p/K}}$$

or, $C_p = lC_T$ ✓ So when cost of pier is equal to cost of main girders & cross girder of the span, the total cost of bridge will be minimum.

Thus, we can conclude that, most economical span length is that for which cost of superstructure equals the cost of sub-structure.

* Selection of bridge type.

① Geometric Condition of site.

→ depend on horizontal and vertical alignment of the highway route and on clearances above and below the roadway.

eg. alignment is on curve, box & slab type bridges are best option

② Subsurface conditions of site.

→ foundations soils
→ Scour depth
} governs the type of substructure & foundation.

→ Weak sub soil = Simply supported spans instead of continuous spans

③ Functional requirements

→ future widening or replacement of bridge deck is a concern, girder type bridge is best option.

→ type of traffic – restrict the choice of bridge type.

④ Aesthetics

⑤ Economic and ease of maintenance.

⑥ Construction and erection considerations.

→ Availability of skilled & unskilled labours, specified materials.

⑦ Legal considerations

→ Environmental consideration