4. Geometric design of the track

Grade compensation on curves :-

→ In order to avoid resistances beyond the allowable limits, the gradients are reduced on curves and this reduction in gradients is known as grade compensation for curves.

→ This curve resistance is expressed % per degree.

→ Compensation for curvature is given

0.04 % per degree of curve for BG

0.03 % " " for MG

0.02 % " " for NG.

Radious of curves in meter. 70/R for BG

52.5/R for MG

35/R for NG.

Q1 ① If the ruling gradient is 1 in 150 on a particular section of BG and at the same time a curve of 4 degree is situated on this ruling gradient, what should be the allowable ruling gradient ?

A) As per IS compensation of BG is 0.04 % per degree of curve,

$1° = 0.04\%$

Then compensation for 4° curve $= 0.04 \times 4 = 0.16\%$.

Ruling gradient 1 in 150 $= \frac{1}{150} \times 100 = 0.67\%$.

So max^m allowable gradient or actual gradient =

$0.67 - 0.16 = 0.51\%$.

$\frac{0.51}{100}$ = 1 in 196 Ans

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(8)

(Q) What should be the actual ruling gradient ?

(a) If the ruling gradient is 1 in 200 on a B.G

(b) A curve of 3° is superimposed on the above track section of B.G.

(4) Speed of the train :-

The speed of the train depends upon the strength of the track and the power of the locomotive.

For BG = 96 km.p.h

MG = 72 km p.h

NG = 40 km p.h

* With modernization of Indian Railways and use of electric traction it has now become possible to attain train speeds upto 160 km.p.h on BG routes and upto 100 km.p.h on MG routes.

Safe speed on curves :-

Safe speed for all practical purposes means a speed which is safe from the danger of overturning and derailment.

Safe speeds on curves depends upon

(1) Gauge of track (2) Radius of the curve

(3) Amount of super elevation

(4) Presence and absence of transition curves.

In india followings formula given by martin where transition curves exist :

for B.G and M.G (speed < 100 km ph)

Safe speed V in km.p.h is given by

(i) $V = 4.35\sqrt{R-67}$ or $V = 4.4\sqrt{R-70}$ — (1)-eq(1)

(ii) For N.G $V = 3.6\sqrt{r-6.1}$ or $V = 3.65\sqrt{R-6}$

* Where transition curves are absent ; on non-transitioned curves.

(i) for B.G and M.G

$V = \frac{4}{5}$ th of speed calculated in eq(1) (80% speed is allowed)

(ii) For N.G = ($\frac{4}{5}$ th of speed calculated in (B) above).

$V = 2.92\sqrt{R-6}$

(iii) for high speeds – (speeds > 100 km ph), BG, MG

$V = 4.58\sqrt{R}$, V = Speed in km.p.h.

R = Radius of curve in metres.

Cant deficiency :-

Cant deficiency = Equilibrium cant necessary for max^m permissible speed on curve – actual cant provided.

Equilibrium cant :-

when the lateral forces and wheel loads are almost equal, the cant is said to be in equilibrium. This equilibrium cant is provided on the basis of avg. speed of the trains.

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(4)

→ Max^m Cant deficiency for gauges for indian Railway are

1. B.G track – 75 mm
2. M.G track – 50 mm
3. N.G track – 40mm

Radius of Degree of curve :-

30 m Chain length

$2\pi R L = 360°$

$L = \frac{360}{2\pi R}$

for 30 m, $= \frac{360 \times 30}{2\pi R}$

$\boxed{D° = \frac{1780}{R}}$

→ Max^m degree of curvature for B.G = 10° (min R = 175 m)

→ Max^m degree of curvature for M.G = 16° (min R = 109 m)

→ Max^m degree of curvature for N.G = 40° (min R = 44 m)

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Superelevation or cant :-

To counteract the effect of centrifugal force, the level of the outer rail is raised with respect to inner rail by a certain amount to introduce the centripetal force.

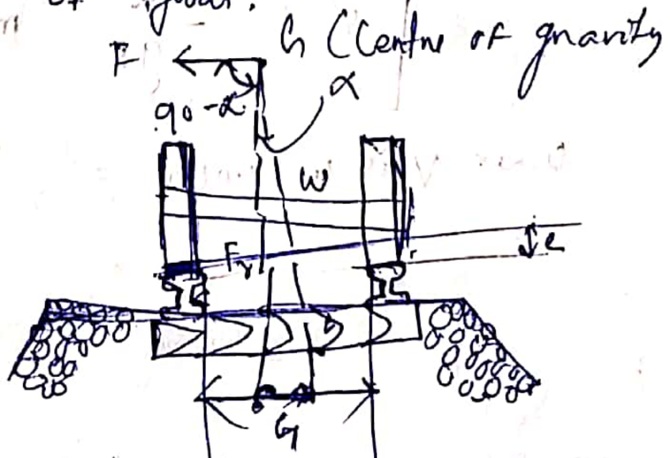
→ This raised elevation of outer rail above the inner rail of a horizontal curve is called Superelevation or cant.

Objects of providing superelevation :-

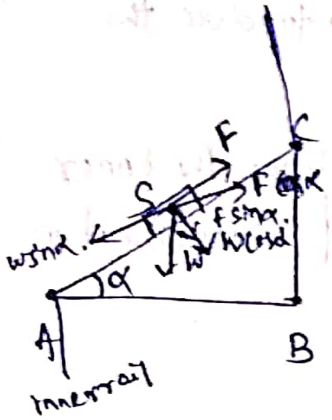
→ ① To introduce the centripetal force for counteracting the effect of centrifugal force. This will also prevent derailment and reduce the side wear and creep of rails.

② To provide equal distribution of wheel loads on two rails, so there is no tendency of track to move out of position due to more load on outer rail.

③ To provide an even and smooth running track for comfortable ride to passengers and safe movement of goods.



Relationship of super elevation (e), Gauge (G), Speed (V) and Radius of the curve (R) :–



W = weight of moving vehicle
v = Speed of vehicle m/sec
V = Speed of vehicle km per hour
R = Radius of curve (m)
G = Gauge of track (m)
g = Acceleration due to gravity in m/sec²
α = Angle of inclination.
S = Length of inclined surface in m,

- Centrifugal force = $F = m \cdot a$

Radial acceleration $a = v^2/R$

$$F = \frac{W}{g} \times \frac{v^2}{R} \quad \text{—} (1)$$

$$F = \frac{Wv^2}{gR} \quad \text{—} (1)$$

Resolving the forces weight along inclined line means AC = S

$$F \cos\alpha = W \sin\alpha$$

$\cos\alpha = \frac{b}{h}$

$\sin\alpha = \frac{P}{h}$

$$\frac{Wv^2}{gR} \times \frac{G}{S} = W \times \frac{e}{S}$$

$$e = \frac{Gv^2}{gR} \text{ metres } (v \text{ in m/s})$$

convert m/s to km

When V is in kmph $= \quad e = \frac{v^2 G}{gR}$

$$= \frac{\left(\frac{1000}{60 \times 60}\right)^2 V^2 G}{gR}$$

$$= \frac{(0.278\,V)^2 G}{9.81\,R}$$

$$e = \frac{V^2 G}{127 R} \text{ Metre}$$

∴ If R in cm $= e = \frac{V^2 G}{127 R}$

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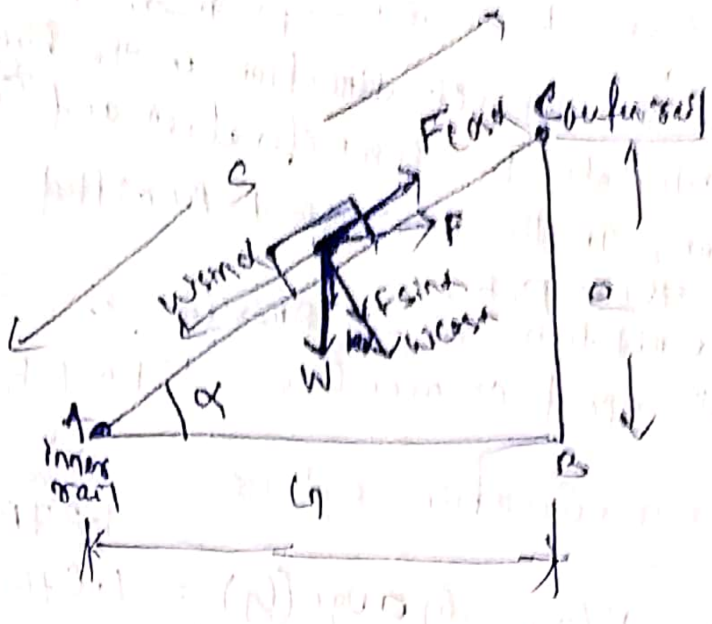
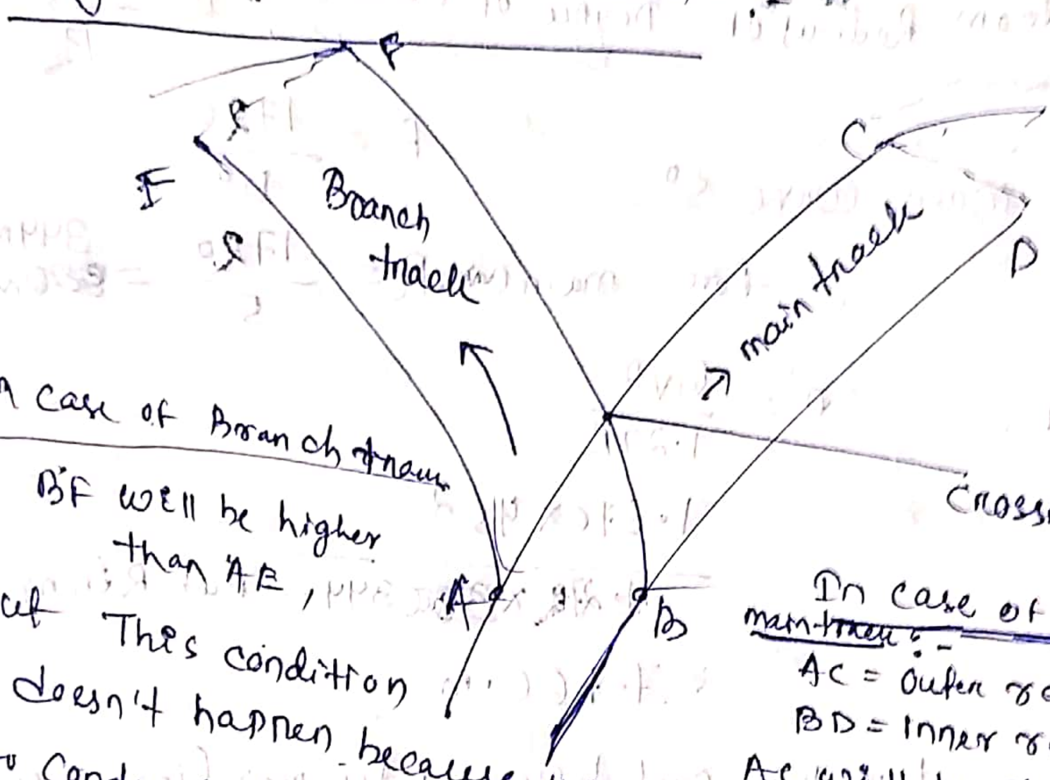


Negative super-elevation :-



In case of Branch track

B'F will be higher than A'E,

But This condition doesn't happen because this two Condradictory conditions cann't be met at same time within one lay out. Hence the inner raised AE with respect to outer-rail. This condition is known as negative Super elevation.

In case of superelevation main track :-

AC = Outer rail

BD = Inner rail

AC will be placed higher than BD.

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Ex:- 1) If a 8° curve track diverages from a main curve of 5° in an opposite direction in the layout of a B.G. yard, calculate the superelevation and speed on the branch line, if the max^m speed permitted on the main line is 45 km.p.h.

A) Full Description of a Problem :-

max^m speed on main line = 45 km.p.h

from superelevation eq^n $e = \frac{GV^2}{1.27R}$ in cm

for BG = Gauge (G) = 1.676 m

from Radius of Degree of curve $= D^\circ = \frac{1720}{R}$

$R = \frac{1720}{D^\circ}$

for main curve 5°

for main curve $R = \frac{1720}{5} = 344m$

Step - 1

$e = \frac{GV^2}{1.27R}$

$= \frac{1.676 \times 45^2}{1.27 \times 344}$ — But R in m

$= 7.76$ c.m

Step - 2 :

For BG cant deficiency for main line = 7.6 cm

Step - 3

Cant for main track = 7.76 − 7.6 = 0.16 cm

Step - 4

Therefore cant provided for branch track

= − 0.16 c.m

(Due to Negative cant)

Step - 5 For branch line =

cant deficiency = 7.6 cm which Permissible

So Cant = 7.6 + (−0.16) = 7.44 c.m

∴ speed of Branch line = $e = \frac{GV^2}{1.27R}$ $V = \sqrt{\frac{e \times 1.27R}{G}} = \sqrt{\frac{7.44 \times 1.27 \times \frac{1720}{8}}{1.676}} = 34.7$ km/h

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Example 2. A 5° curve diverges from a 3° main curve in reverse direction in the layout of a B.G. yard. If the speed on the branch line is restricted to 35 km. p.h., determine the restricted speed on the main line.

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Example 3. Find the speed for which superelevation is to be maintained if the speeds of several trains running on a main curved track are as follows :

(*i*) 15 trains at a speed of 50 km. p.h.

(*ii*) 10 trains at a speed of 60 km. p.h.

(*iii*) 5 trains at a speed of 70 km. p.h.

(*iv*) 2 trains at a speed of 80 km. p.h.

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Geometric design of Railway track

* If speed $V_{max} > 50$ km.p.h (for BG and MG)

$$\text{Average (Avg) speed} = \frac{3}{4} \times V_{max}$$

$V_{max} \leq 50$ km.p.h

* $$\text{Avg. speed} = V_{max}$$

* Some Railway weighted avg. is calculated for finding out the equilibrium speed of the trains

$$\text{equilibrium speed} = \frac{n_1 v_1 + n_2 v_2 + n_3 v_3 + \cdots}{\Sigma(n_1 + n_2 + n_3)}$$

or

$$= \frac{\Sigma n v}{N} \text{ (weighted Avg.)}$$

n_1, n_2, n_3 = no. of trains
v_1, v_2, v_3 = Speed of trains.

* **Note** – Max^m value of superelevation, according to railway Board is $\frac{1}{10}$ th of gauge.

* Max^m permissible values in india for different gauges are ① Max^m S.E (superelevation) for BG

$= \frac{1}{10} \times 1.676 = 0.167$ m
$= 16.7$ cm

② Max^m SE for M.G $= \frac{1}{10} \times 1\text{ m} = 0.1$ m
$= 10$ cm

③ Max^m SE for N.G $= \frac{1}{10} \times 0.76 =$
0.076 m
$= 7.6$ cm

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Curve :-

To change the direction or alignment (through horizontal curves) or gradient (through vertical curves) . the curve is necessary .

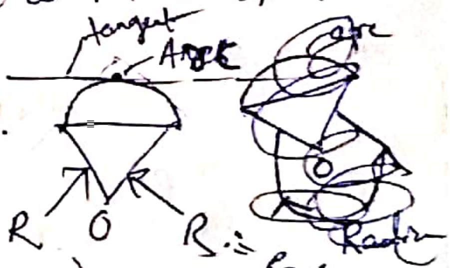
Curve is two types :-

1. Horizontal curve – It is provided , when change in direction is required.
2. vertical curve – It is provided, when change in the gradient is required

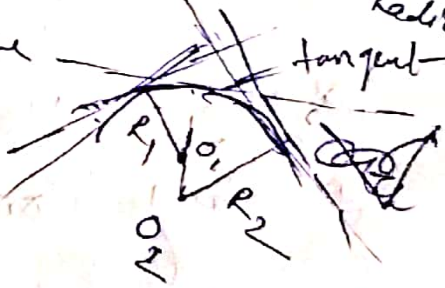
Horizontal curve is classified in to 4 types.

1. simple 2. compound 3. Reverse 4. transition

Simple curve :- → Single arc with constant radius.
→ one common tangent.



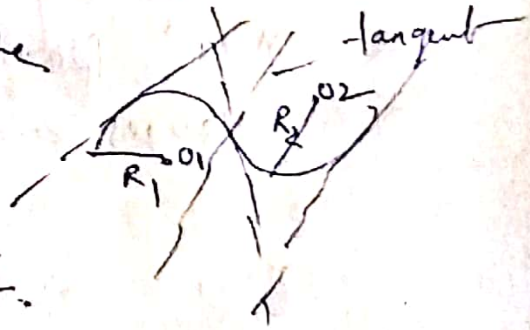
Compound :- multiple arcs with different radius.
→ The centres lies in same side of the common tangent.



Reverse :-

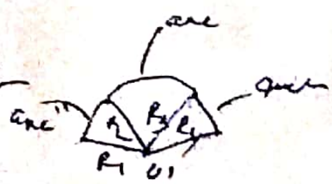
→ The curve bending in opposite direction .
→ The radius may or may not be same or equal.

→ The centres lies in the opposite side, of the common tangent.



transition curve :-

→ The curve consist of different arc with various Radius .
→ It is a non-circular curve connector of circular and straight curve



→ transition curve 3 types.

1. cubic spiral
2. cubic parabola
3. Lemniscate.

vertical curve :-

vertical curve is two types.

1. summit curves — upgradient ✕ down gradient
2. sag or valley curves. — down ✕ up.

Shift :-

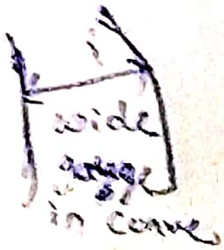
Whenever a transition curve is to fitted in between the straight and circular track, the original curve is to be shifted inwards by a certain distance.

→ This distance by which the circular curve is shifted to new position is known as 'Shift'.

$$S = \frac{L^2}{24R}$$

S = shift
L = length of transition curve
R = Radius

widening of gauge on curve :-



Due to the rigidity of wheel base the outer wheel of front axle strikes the outer rail, outer wheel of inner axle bears a gap with the outer rail. Provision of this gap is made by widening the gauge.

$$d = \frac{13(B+L)^2}{R}$$

d = extra width, R = Radius, B = base.

~ in ~

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Points and crossing

Definition :-

→ Point and crossings are arrangement used in permanent way or railway track to guide the vehicle for directional change.

→ Point and crossing assembly consists of three main components like Point, Lead, crossing element.

→ * Def^n :- A point consists of one pair of tongue rails and stock rails with necessary fittings.

→ * Def^n :- crossing is a device in the form of V-piece introduced in the track to permit movement of wheel flange at the intersection of two running lines. It has gap over which the wheel jumps.

→ * The track portion between point and crossing is called lead.

Turnout :- Turnout is the combination of points and crossing which enables one track to another track.

Tongue rail :- It is tapered moveable rail, connected at its thickest end to running rail.

Stock rail :- It is the running rail/main rail against which a tongue rail fitted.

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Switch :- A pair of tongue rail with their stock rails with necessary connections and fittings.

Points :- A pair of tongue rail with their stock rails are termed as points.

Crossing :- A crossing is a device introduced at the junction where two rails cross to permit the wheel flange of railway vehicle to pass from one track to another track.

Heel of Switch :-

It is an imaginary point on the gauge line midway between the end of lead rail and the tongue rail in case of loose heel switches in case of fixed wheel switches, it is a point on the gauge line of tongue rail opposite, the centre of heel block.

Necessity of points and crossings :-

1) Points and crossings are provided to help transfer railway vehicles from one track to another.

2) The track may be parallel to, diverging from or converging with each other.

3) Points and crossings are necessary because the wheels of railway vehicles are provided with inside flanges and therefore, they require this special arrangement in order to navigate the rails.

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Fig -

Important terms used in points and crossings :-

Facing Direction -

"If someone stands at toe of switch and looks towards the crossing, then the direction is called facing direction."

Trailing Direction -

If someone stands at the crossing and looks towards the switches, then the direction is called Trailing direction.

facing points of turnouts :-

In this turnouts, the trains pass over the switches first and then pass over the crossing.

Trailing points of turnouts :- This is the opposite side of facing points of turnouts, In this case, the trains pass over crossing first and then pass over the switches.

Right - Hand and Left hand turnouts :-

If the train from the main track is diverted to the right of the main route in the facing direction, is called as Right hand turnout. If the train from the main track is diverted to the left of the main route is called as left hand turnout.

Right Hand and left Hand switches :-

These are termed as left hand or right hand switches depending upon left or right when seen from the facing direction. (that means stand at points and look towards the crossing).

Working Principle of a turnout :-

One turnout provides facelities for turning of vehicles from one direction only and not from both the directions of the straight path or route as in the case of roads.

→ turnout works with the combinations of points and crossing. This consists of mainly a pair of points or switches, four lead rails, two clear rails and crossing.

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Heel blocks:-

→ These blocks are inserted between the heel of the tongue rail and stock rail.

→ These are made of C.I.

→ These blocks are used to provide a distance or gap for flange way between the running rail and check rail. It is also known as distance block.

Stretcher bars:-

The toes of both the tongue rails are connected together by means of stretcher bars.

Heel clearance or Heel divergence -

It is the distance between the running faces of the stock rail and running face of the tongue rail.

fig.

Flangeway Clearance:-

This is the distance between the adjacent faces of the stock rail and the check rail.

Flangeway depth:-

It is the vertical distance between the top surface of the running rails (stock rail) to the top surface of heel-block.

Switch angle (α):-

This is also known as angle of switch divergence.

→ It is the angle between the running faces of stock rail and tongue rail.

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Throw of switch :-

It is the distance through which the toe of the tongue rail moves sideways to provide a path for desired direction over the turnout.

Types of swithes :-

Two types.

1. Stub
2. Split

Stub switch. :-

In this type of switch, no separate tongue rail is provided and it is an old form of switch.

Split switch :-

In this type of switch a tongue rail is combined with the stock rail.

Split switch are two types.

(A) on the basis of fixation at heel
  1. Loose Heel type
  2. Fixed Heel type
(b)
  1. under cut
  2. over riding
  3. straight cut

Crossing (Types) :-

Two types.

(A) On the basis of shape of crossing
(B) On the basis of assembly of crossing

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(A) On the basis of shape of crossing :-

① Acute angle crossing or 'V' crossing
② Obtuse angle crossing or Diamond crossing
③ Square crossing

(B) One the basis of Assembly of crossing

① Spring or movable of crossing
② Ramped crossing

(A)

① <u>Acute angle crossing :- (or) (V crossing)</u>

Two rail gauge faces cross at acute angle. This widely used;

② <u>Obtuse angle :-</u>

Two rail gauge faces at obtuse angle.

③ <u>Square crossing :-</u>

Two tracks cross at right angle (or 90°)

(B) ① <u>Spring</u>

In spring crossing, one wing rail is movable and is held against the V of the crossing with strong helical spring while other wing rail is fixed.

② <u>Ramped :-</u>

This crossing used for safety for slow speeds.

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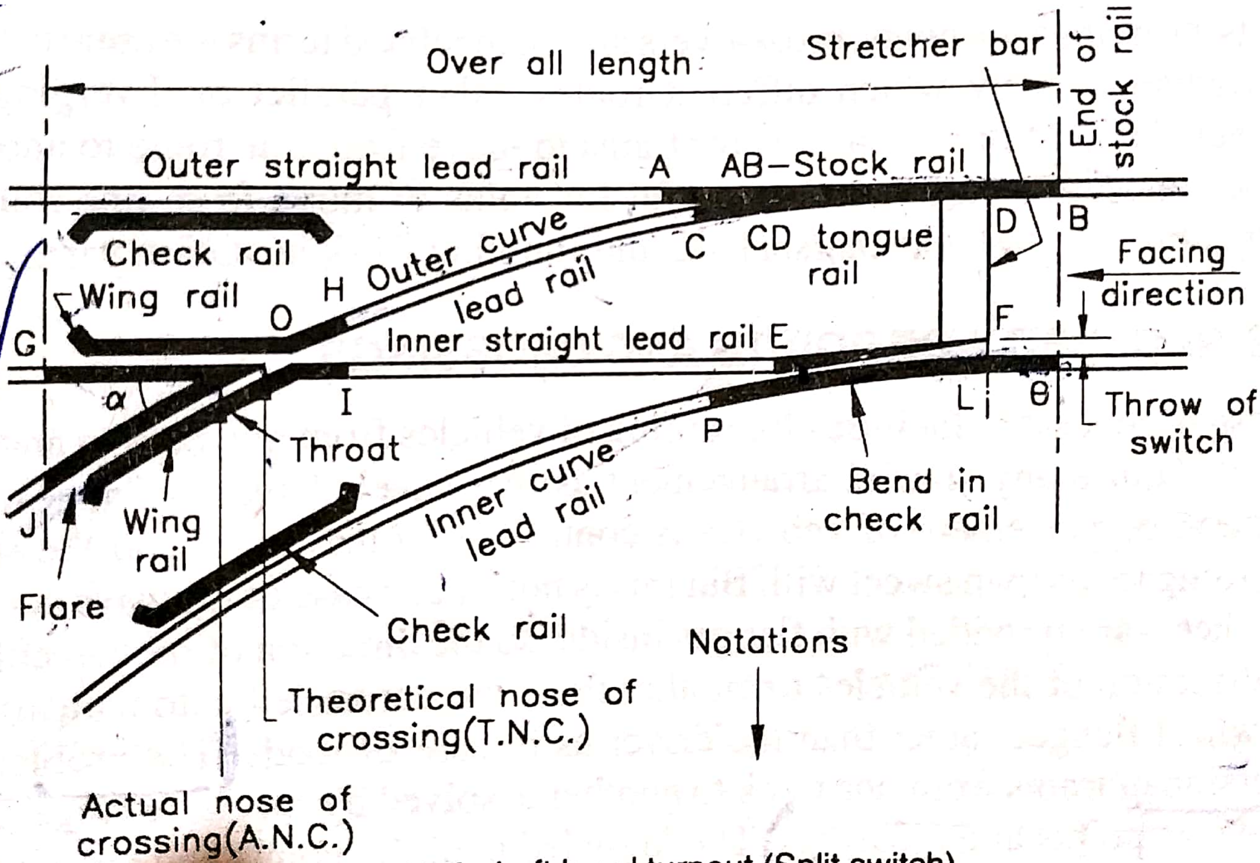

Fig. 16.1. Left hand turnout (Split switch).

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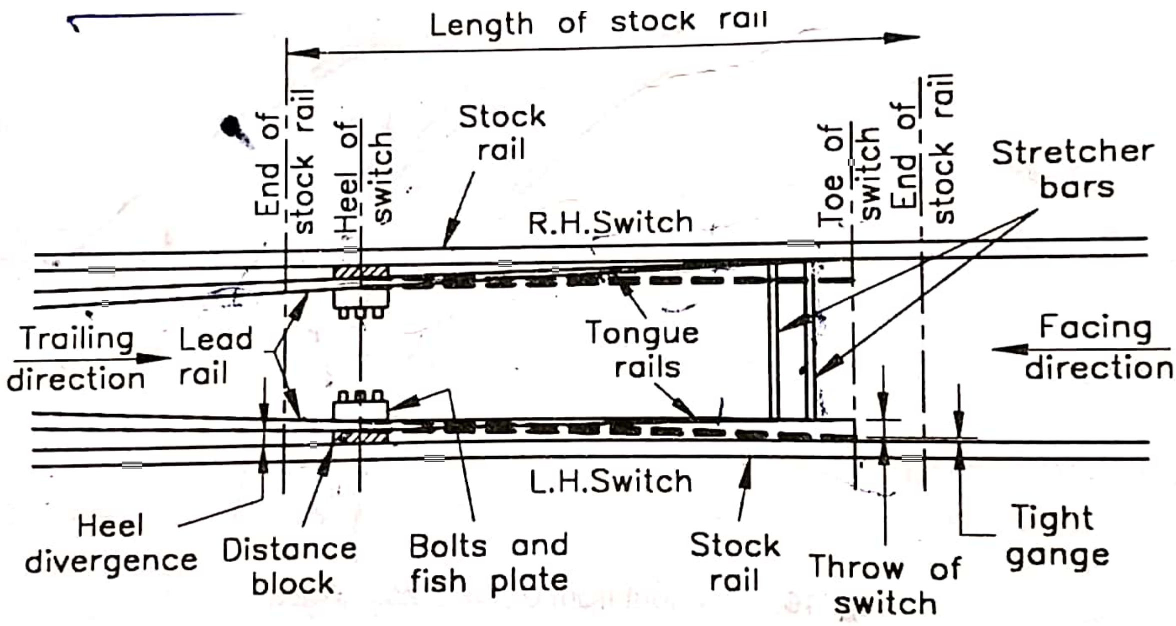

Fig. 16.5. . Fixed Heel Type Switch

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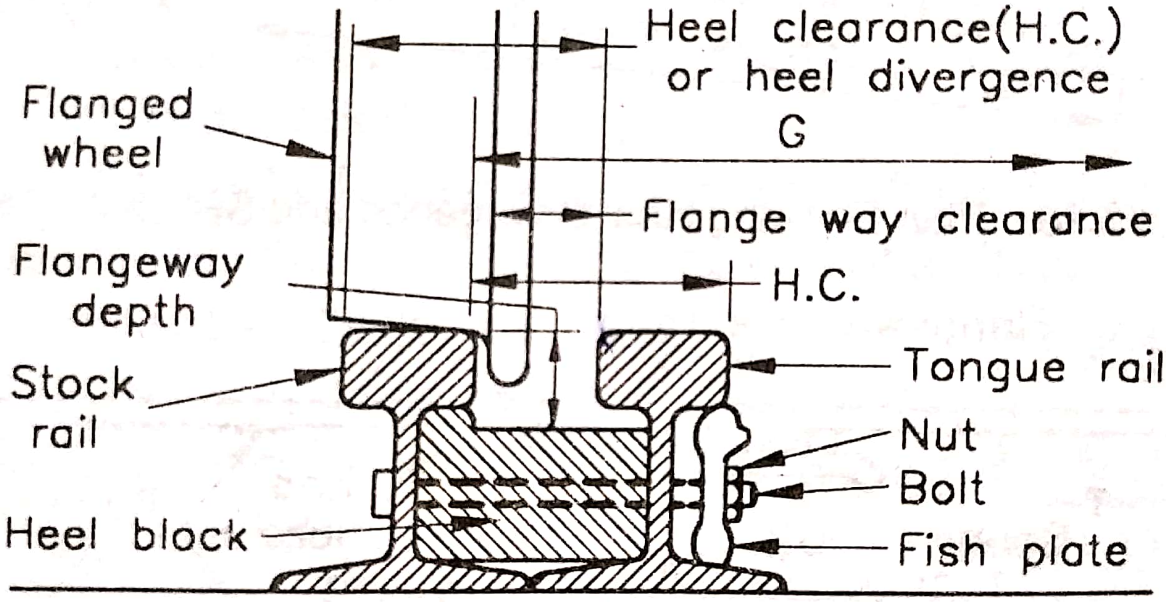

Fig. 16.8. Section at Heel of Tongue Rail.

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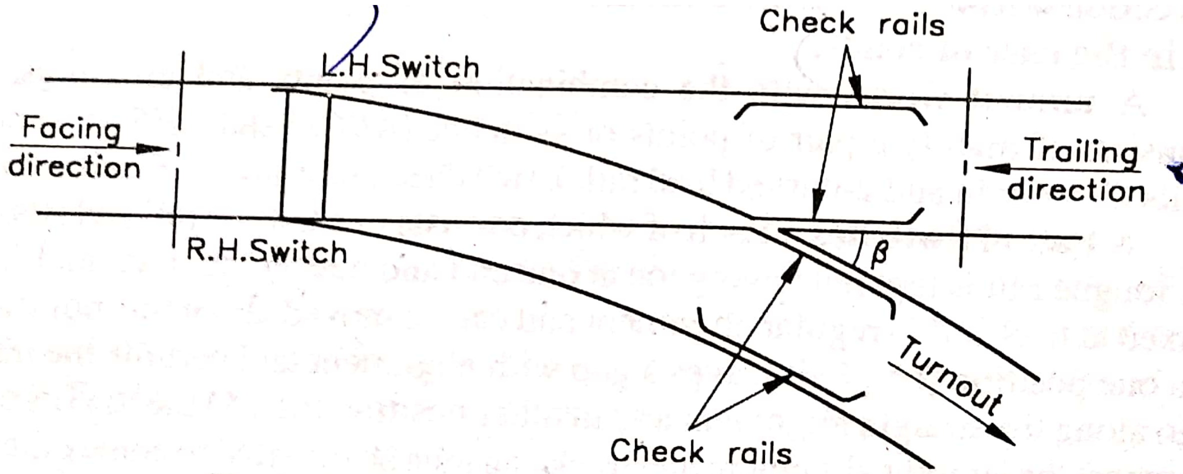

Fig. 16.2. Line Diagram of Right-hand + Turnout.

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Collection of bridge design data:-

For a complete ~~and proper~~ of the bridge project the engineer in charge of the investigation should carry out studies regarding its financial, economic, social and physical feasibility.

→ The detailed information to be collected may cover loading to be used for design based on the present and future traffic, hydraulic data based on stream characteristics, geological data, sub soil data, climatic data, alternative sites, aesthetics cost, etc.

index map :-

Index map shows the location of the bridge, existing communications, topography and important towns etc.

contour survey plan :-

The contour survey plan showing the topographical or other features that influence the location and design of the bridge.

Site plan :-

This should show the details of the site selected.

cross - sections :-

The cross-section at the site of the proposed bridge, at D/S and U/S should be plotted to the scale.

longitudinal sec :-

The longitudinal sec of the stream showing the site of the bridge with highest flood level, the ordinary flood level, the lower water level and the bed levels.

catchment Area map :-

~~The catchment~~ .

Soil profile

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Determination of flood Discharge:-

One of the essential data for the bridge design is max^m flow which could be expected to occur at the bridge site during the design period of the bridge.

-) In india for determination of flood discharge is used a convenient formula.

1) → from the rainfall and other characteristics of the catchment.

→ By use of an empirical formula applied to that region, rational method.

→ from the hydraulic characteristics of the stream such as C/s^{n}al area and slope of the stream.

→ from the records available

Emprical method !-

following are some of the most commonly used empirical methods, for flood estimation.

1) Dicken's formula
2) Ryne's formula
3) Inglis formula
4) Nawab jang Bahadur's formula
5) creager's formula
6) khosla's formula
7) Besson's formula.

empirical method:-

$Q = C \cdot M^n$

Q = Peak flow or rate of max^m discharge

C = constant for the catchment.

M = Area of the catchment

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1) **Dickens formula:-** This formula used in Northern India is

$Q = C \cdot M^{3/4}$

Q = discharge in m^3/sec
M = Area of catchment in sq-km
C = constant

2) **Ryves formula:-** This formula is used in southern india.

$Q = C \cdot M^{2/3}$

C = constant

3) **Ingles formula:-**
This formula is used in the state of Maharashtra.

→ For small area only = $Q = 123.2\sqrt{M}$

→ for all type of Area. = $Q = \frac{123.2M}{\sqrt{M} + 10.36}$

4) **Nawab Jang Bahadur's formula:-**

$Q = C\left(\frac{M}{2.59}\right)(a - b \log A)$

5) **Creager's formula:-**

$q = C \cdot M^n$

q = Peak flow per sq km of a basin.
M = Catchment area in sq.km,
C = constant.
n = some index.

6) **Khosla's formula:-**
It is a rational formula. It is based on the eqn.
R = Runoff, P = Rainfall
L = Losses

$P = R + L$
$R = P - L$

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(7) Besson's Formula:- This formula is very rational and can be used

$$Q_m = \frac{P_m \times Q_r}{P_r}$$

P_m = expected rainfall

P_r = observed rainfall

Q_m = Peak flow expected

Q_r = Some observed peak flow.

Waterway :-

The area through which the water flows under a bridge superstructure is known as the waterway of the bridge.

→ The liner measurement of this area along the bridge is known as the linear waterway.

→ This linear waterway is equal to the sum of all the clear spans. This may be called as artificial linear water way.

→ The natural waterway is the unobstructed area of the river or stream through which the water flows at the bridgesite. (c)

* While fixing the waterway of a bridge the following guiding principles must kept in mind, to ensure the safety of the structure

→ The increased velocity due to afflux should not exceed the permissible velocity under the bridge.

→ The freeboard for high level bridges should not be less than 600mm.

→ Clearance should be allowed according to navigational requirements.

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Economic span :-

The economic span of a bridge is the one which reduces the overall cost of the bridge to be a minimum.

The overall cost of a bridge depends upon the following factors.

- → cost of materials and its nature.
- → Availability of skilled labour.
- → span length.
- → Nature of stream to be bridged.
- → Climatic and other conditions.

Cost of superstructure increases and that of the sub-structure decreases with an increase in the span length.

The most economic span length is

The cost of the super structure = The cost of the sub structure.

Afflux :-

→ When a bridge is constructed, the structures such as abutment and piers cause the reduction of the natural water way area.

→ The contraction of the stream is desirable because it leads to saving the cost.

→ To carry the maxm flood discharge, the velocity under a bridge increases.

→ This increased velocity gives rise to a sudden heading up of water on the upstream side of the stream is known as afflux.

→ Greater the afflux greater will be the velocity under the downstream side of the bridge.

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Afflux is calculated by

(a) Marrimans formula :-

$$h_a = \frac{v^2}{2g}\left\{(A/Ca)^2 - (A/A_1)\right\}$$

h_a = Afflux in m.

V = velocity m/sec

A = Natural water way area at the site

a = contracted area in m^2

A_1 = The enlarge area upstream of the bridge. m^2

$$c = 0.75 + 0.35(a/A) - 0.1(a/A)^2$$

(b) Molesworth's formula :-

$$h_a = \left(\frac{v^2}{17.9} + 0.015\right)\left\{(A/a) - 1\right\}$$

Problem (1) →

Clearances :-

The horizontal clear height available for the passage of vehicular traffic is known as clearance.

Free Board :-

The vertical distance between the Afflux (HFL) to crown of bridge at its lowest point.

HFL = high flood level

free board is necessary :-

→ FB is required to allow floating debris, fallen tree trunks.

→ FB is required to allow for the afflux during HFL

→ FB is required to allow the vessels to cross the bridge in case of navigable river

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Illustrative Example 3·6·1. *A bridge has a linear waterway of 150 metres constructed across a stream whose natural linear waterway is 220 metres. If the average flood discharge is 1200 metre³/sec. and average flood depth is 3 metres, calculate the afflux under the bridge.*

Solution. The natural waterway area at the site

$$=A=220\times3=660\ \text{m}^2$$

Contracted waterway area $=a=150\times3=450\ \text{m}^2$

The velocity of approach $=V=Q/A$

Here, Q=Flood discharge=1200 m³/sec.

$V=1200/660=1{\cdot}83$ m/sec.

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Using Molesworth formula the afflux can be given by

$$ha=\left(\frac{V^2}{17{\cdot}9}+0{\cdot}015\right)\{(A/a)^2-1\}$$

$$=(0{\cdot}187+0{\cdot}015)\{(660/450)^2-1\}$$

$$=0{\cdot}202\times1{\cdot}15=0{\cdot}232 \text{ m.}$$

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3. Bridge foundation

Depth of foundation:-

The depth of bridge foundn is determined by consideration of the safe bearing capacity of the soil, taking into the effect of scour.

$$\text{min}^m \text{ depth of found}^n = h = \frac{P}{w}\left(\frac{1-\sin\phi}{1+\sin\phi}\right)^2$$

h = Depth of foundn in m.

P = bearing capacity of soil in kg/m2

w = sp. wt. of earth in kg/m3

ϕ = Angle of internal friction of the soil.

Scour depth:- (deterioration of foundn like Pier and Abutment in case of bridge.)

→ When the velocity of stream exceeds the limiting velocity which the erodable particles of bed materials can stand, the scour occurs.

→ The normal scour depth is the depth of the water in the middle of the stream when it is carrying the peak flood discharge.

Scour Depth of Alluvial stream =

$$d = 0.473\left(\frac{Q}{f}\right)^{1/3}$$

d = Normal depth of scour below H.F.L for regime condition.

Q = The design discharge in m^3

f = Lacey's silt factor = $1.76\sqrt{m}$

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Coffer dam :-

A cofferdam is a temporary structure which is built to remove water from an area and make it possible to carry on the construction work under reasonably dry conditions.

→ Cofferdams are required for projects such as dams and construction of bridge piers and abutments.

Requirements of a cofferdam :-

→ Cofferdam should be water tight.
→ The design and layout of a cofferdam should be such that the total cost of construction, maintenance is minimum.
→ It should be constructed at site of work.
→ It should be sufficiently stable against over turning and sliding under floods and loads.

Types of Cofferdams :-

1. Earth fill cofferdam.
2. Rock fill cofferdam
3. Rock fill crib cofferdam
4. Single wall cofferdam
5. Double wall cofferdam.
6. Cellular Cofferdam.

The selection of a type of cofferdam depends upon the following factors :-

1. Transportation facilities available
2. Velocity of flowing water.
3. The extent of an area to be protected by cofferdam.
4. The possibility of overtopping by floods, tides.

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1) Earth fill Coffer dam :-

→ This is the simplest form of cofferdam.
→ Its use is limited in the vicinity where the impervious earth is available and water depth is shallow.

2) Rockfill cofferdam :-

→ They are constructed by placing rock along stream.
→ They can be used for depths of water up to 3m and suitable in case of swift water.
→ They are economical in places where rock is available in plenty.

3) Rock fill crib Cofferdam :-

→ A rock-fill crib cofferdam is comprised of timber cribs.

→ A crib is frame work of wooden horizontal and cross beams.

4) Single wall cofferdam :-

→ This type of cofferdam is suitable when available working space is limited and enclosed area is small.
→ They can be used for depth of water 25m.
→ The walls of cofferdam are made up steel sheet.

5) Double wall coffer dam :-

→ Double wall coffer dams are provided to enclose a large area.
→ The Double wall gives stability to the cofferdam.

6) Cellular cofferdam :-

→ They are made of steel sheet piles and suitable for dewatering large areas.
→ In this Cofferdam the diaphragm cells series of arcs are connected to straight cross walls.
→ It can withstand overtopping of water.

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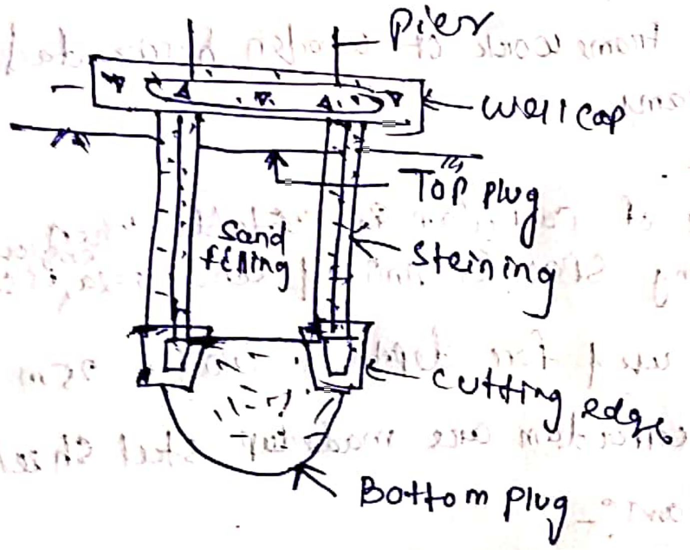
Foundations -

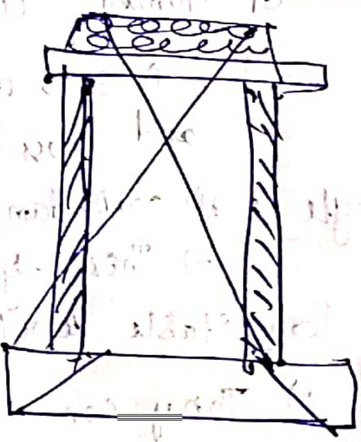
Spread foundation
Pile foundation — Types
Caisson or well foundation. Types

(Plz follow the foundation Chapter of soil Mechanics Notes-)

Sinking of foundation wells:-

In case of well sinking on dry grounds an open excavation up to half meter or 50 cm above sub soil water level is carried out and the well curb is laid and cutting edge at the required Position.





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4. Bridge substructure and approaches

The bridge structure consists of the following elements.

1. piers
2. Abutment
3. wing walls
4. foundations for the piers and abutments

→ Approaches are provided to connect the bridge, ~~[illegible]~~ to the roads on either side,

→ Piers and abutments are generally constructed with masonary, mass conc. and R.C.C.

→ composite construction with a stone masonary facing and mass concrete hearting.

→ The mass conc. used should M100 which can be made of 1:3:6.

Bridge piers:-

There are the intermediate supports of the superstructure. Piers are classified as two types.

1. Solid piers
2. Open piers.

Solid Piers :-

They may be constructed either of masonary or mass concrete.

→ features of solid bridge piers are.

* Height - from fundation to support level of girders is called height. It is kept 1 to 1.5 m above H.F.L. (High flood level,

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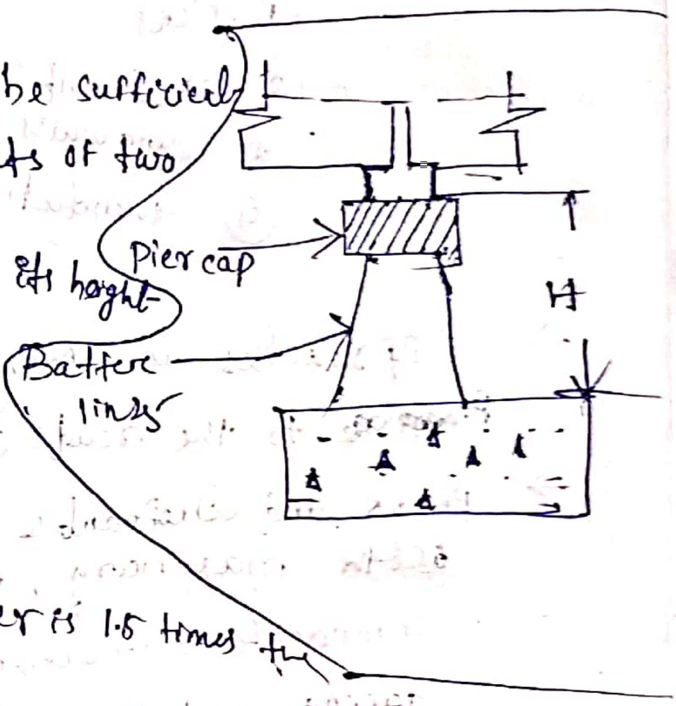
* **Pier Batter** :- Sides of pier may be vertical or battered. (1 in 12 to 1 in 25)

* **pier width** :-

Pier width should be sufficient to accomadate the seats of two bearing.

width of pier is 1/3 of its height at base and top width is equal to $\sqrt{\text{span length}}$



* **Length of Pier** :-

Generally length of Pier is 1.5 times the top width.

* **Cut and Ease water** :-

The pier ends are shaped for easy passing of water. It is called cut water at u/s and ease water at d/s.

* **pier cap** :- Top of Pier, where bearing sit and load from bearing is uniformly distributed to Pier is called pier cap.

Open Piers :-

open piers may be of multiple column, pile bent, steel cylinders filled with concrete, with bracing, trestle piers.

Special Piers :-

1. Low Piers with separate column piers
2. cellular Piers &
3. framed column Piers.

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Abutments:-

→ End supports of the superstructure of a bridge, are called as abutments. These are built either with masonary or P.C.C or R.C.C.

→ Weep holes are provided at different levels of abutment for draining off water from the retained earth.

Salient features of Abutments are :-

Height :-

The height of the abutment is kept equal to that of the Piers.

Abutment width :-

The top width of the abutment should provide enough space for the bridge seat. ~~and~~

Abutment Batter :-

Water face of the abutment is kept vertical and batter of 1 in 12 to 1 in 24.

→ face retaining earth is given a batter of 1 in 6.

Length of Abutment :-

~~The topewidth~~ The length of abutment is kept at least equal to the width of the bridge.

Abutment cap :-

The design is similar to that of Pier cap.

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Abutments are calssified in to two types -

1. Abutment with wingwalls
2. Abutment without wingwalls

Abutment with wingwalls :-

Wingwalls may be Straight or splayed or Return wingwall type.

Wing walls not only withstand earth pressure, but also the impact of live load. Basically these wingwalls are constructed with abutment main wall

Straight wingwall

Splayed wingwall

Abutment without wingwalls :-

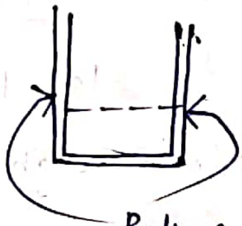
Followings are the types

1. Buried Abutments :-

   This type of abutment is constructed first and fill material is placed later. Found^n strata is hard Earth. Pr. is low.

2. Box abutment :-

   Abutment is built as a box with integral columns to act as frame to resist earth pressure.



Return wingwall

3. Tee abutments :-

   'T' shape in plan. This has become obsolete.

4. Arch abutment :-

   Used because of its economy.

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Wingwalls :-

→ These are provided both the end of the abutments to retain the earth filling of the approach road.

→ Wing walls are basically designed as retaining walls similar to abutments.

→ Length of wingwalls should not be less than the minimum required to allow approach filling.

→ The design of wing wall depends upon the nature of banks. Depending upon the material used, the wing walls are two types.

1. Masonary wingwalls
2. Reinforced concrete wing walls.

Masonary wingwalls :-

→ Their water face is kept either vertical or battered.

→ The top of wing wall is either horizontal or sloping downwards.

Reinforced concrete walls :-

→ Cantilever type or counterfort type retaining walls are used the R.C. wing walls.

→ The top of the wingwalls is horizontal or slope.

★ Here there layout in plan, wing walls are 3 types.

1. Straight wing walls
2. Splayed wing walls
3. Return wingwalls.

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① Straight wing walls :-

→ They are suitable for small bridges constructed across drains with low banks.

→ They are built for a railway bridge.

② Splayed wing walls :-

→ They are constructed generally at 45° with abutment and are straight or curve in plan.

→ They are also adopted when the road has to narrow on crossing the bridge, when two or more roads meet at the approach.

③ Return wing wall :-

→ These are walls built at right angles to the abutment at its both the ends.

→ They are designed to retain the earth filling of the approach road.

Approaches :-

→ The approaches are the length of the communication route at both ends of the bridge

→ The alignment and level of the approaches are affected by the design and layout of the bridge.

→ As per I.R.C recommendations, they should have a minimum straight length of 15m. on either side of bridge.

→ The straight length of approaches should have a minimum surface width equal to that of roadway on the bridge.

→ For high level bridge approaches are provided in filling where as for submersible bridge the causeways approaching are provided in cutting

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→ In plains top of the approach banks are kept above HFL. In urban areas where land cost is very high, approaches are made by constructing retaining walls on either side filled with earth work followed by pavement construction.

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Masonary Bridges :-

Masonary arch bridges are very commonly used for road bridges of moderate span.

→ Their simplicity, economy and ease with which pleasing appearance can be obtained make them suitable for this purpose.

→ There are three classes of masonary arches
 ① stone masonary
 ② Brick masonary
 ③ cement concrete masonary arch.

→ Arches vary in shape from very flat to very high having a rise greater than a span. The common types of arch shapes are Segmental, semi-circular, elliptical, Parabolic, pointed and multicentred.

→ The advantages of semi-circular arch and pointed arch is that they exert little or no thrust on the abutments. But give too rise and expensive approaches.

→ Elliptical and parabolic arches are not so strong as segmental type and more difficult to construct. This is popularly used

→ multicentred arches are convenient for long spans.

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②

Concrete bridge :- R.C.C Bridge :-

→ Cast iron and steel were new materials to catch the fancy of the engineers after the stone had been dominating. ~~major~~

→ With the introduction of R.C.C construction it was felt that this material would produce maintenance-free structure.

→ No cleaning and painting after five years is necessary.

→ Robert maillart wrote that " Reinforce concrete does not grow like timber, it is not rolled like steel and has no joints like masonary.

→ The durability, rigidity, economy and ease with which pleasing appearance can suitable for bridge building.

→ There are different types of R.C.C bridges.
① slab bridges, ② Girder bridges ③ balanced cantilever bridge ④ continuous bridge ⑤ Arch bridge.

Steel Bridges :-

→ Steel bridges are built for many purposes carrying a highway, a railway track for support of water pipes, gas or oil pipes etc.

→ For Railway bridges in india steel is used for very small spans to very large spans.

→ The steel bridges can be classified

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(3)

(i) **Purpose** –

Depending upon the nature of the load which the bridge is supposed to carry, the bridges are classified as railway bridges, highway or pedestrian bridges.

(ii) **Location of floor!**–

Depending upon the location of floor, bridge can be classified

(a) Deck Bridges -
(b) Through bridge
(c) semi through
(d) Double Deck &

(iii) **structural arrangement!**-

According this type of bridge, the bridges are classified beam bridges, girder bridges, truss bridges, cable bridges.

(iv) **Nature of superstructure Action!**–

simple bridges, continuous bridges balanced cantilever bridges, arch bridges, tide arch bridge, rigid Frame bridges.

(v) **connection types!**– welded bridges, bolted, pinned, riveted

(vi) **fixed or movable !**– ① swinging bridge ② lift bridge

* The main component parts of steel and iron girder bridge – ① Main girder ② flooring ③ Bracing

* Depending upon the main girder ① Beam, ② Plate girder ③ Truss bridge.

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Chapter - 6 — Culvert and causeways

Causeways:-

→ A road causeway is a Pucca dip which allows floods to pass over it.

→ It may or may not have opening or vents for low water to flow.

→ If it has vents for low water to flow, then it is known as high level causeway or submersible bridge.

Types of causeways:-

① Low level causeways.
② High level causeways.

Low level causeways:-

The bed of small rivers or streams, which remain dry for most part of the year, are passable without a bridge.

→ This involves heavy earth work in cutting for bridge approaches,

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→ The low level causeway could be provided with openings formed by concrete hume pipes if there is continuous flow stream during monsoon periods.

High level causeway :-

→ A high level causeway is submersible road bridge designed to be overtopped in floods. Its formation level is fixed in such a way as not to cause interruption to traffic during floods for more than three days at a time.

→ A sufficient number of opening are provided to allow the normal flood discharge to pass through them with required clearance.

→ Temporary causeway used for an emergency military operations are formed either by using timber stringers.

Culvert :-

→ A culvert is a small bridge for carrying water, beneath a road or railway.

→ It is used when the linear waterway does not exceed 12m.

→ The waterway is provided in 1 to 3 spans.

There are 4 types of culvert.

1. Arch culvert
2. Slab culvert
3. Pipe culvert
4. Box culvert

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(1) Arch culvert :-

→ An arch culvert consists of abutments wing walls, arch, parapets and found^ns.

→ The construction materials used are brick or conc..

→ An artificial floor is provided below the arch, or the floor may not be provided depending upon the nature of found^n and velocity of flow.

Box culvert :-

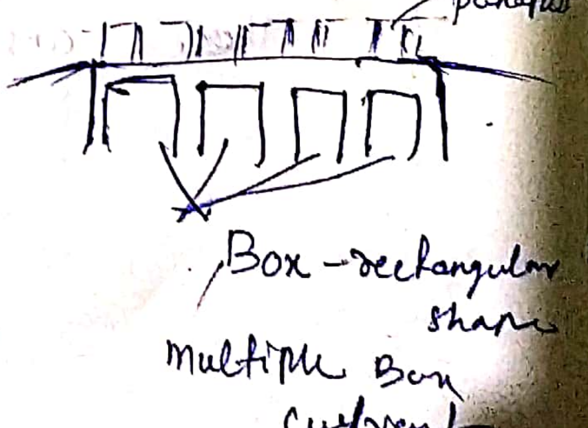
→ Box culverts are in rectangular shape and constructed by concrete.

→ Reinforcement is also provided in the construction of box culvert.

→ These are used to dispose the rain water, so these are not useful in the dry period.

→ They can also used passages to cross the rail or roadway during dry period.

→ Box culverts can also be provided in multiple numbers.



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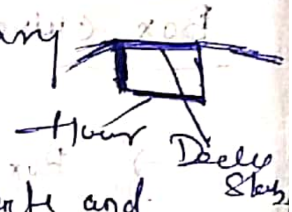
Slab culvert :-

→ A slab culvert consist of R.c.c slab with or without beams or a stone slab, with or without steel girders, to cover the span across the abutments and piers.

→ The parapet, wingwalls, found^n are also provided.

→ The deck slab should be designed as one way slab.

→ Slab culvert can replace box culverts if no artificial flooring is necessary.



Pipe culvert :-

→ Pipe culverts are widely used culverts and rounded in shape.

→ The culverts may be of single in number or multiple.

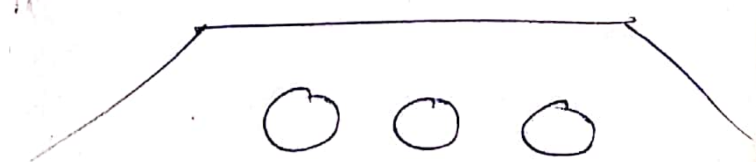
→ If single pipe culvert is used then larger diameter culvert is installed.

→ If the width is large then we go for multiple pipe culvert.

→ They are suitable for larger flows very well.

→ The dia ranges from 1 m to 6 m.

→ These are made of conc. or steel.



Bridges

Chapter-1 Introduction:-

Q.1. What is bridge?

2. What are the components of bridge?

3. What are the classification of bridge?

4. What are the requirement of an ideal bridge?

Chapter-2

Q.1. What considerations are to be taken into consideration for the selection of bridge site?

Q. What are the essential information required to be collected for the design of a bridge?

Q. Discuss briefly the characteristics of an ideal site for a bridge?

Q. What is bridge allignment, write its types.

Q. Define the following terms :- (Short notes on)

1. Waterway
2. Economic span
3. Afflux
4. Clearance
5. free board

(Q) What are the Principal requirements of subsurface investigation for a bridge found?

(Q) Write down the formula for
1. Dicken's formula
2. Ryve's formula
3. Inglis formula

} others formula etc.

Chapter-3

Q.1. Write short notes on i) scour depth (iii) sinki
ii) Minimum depth of foundn.

Q.2. What are the types of Bridge foundn, write its types ?

Q.3. Describe each foundn with suitable figure..

Q.4 What is coffer dam ? Describe briefly its types ?

chapter-4

Q.1. Defn of Piers and its classification?

Q.2 Defn of Abutments, its features and its classification ?

Q.3 Defn of wingwall and its classification ?

Q.4. Write short notes on 1) Approaches
2) Causeways.

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