Railway Engineering

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RAILWAY ENGINEERING

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1 RAIL, RAILWAY AND RAIL JOINT

1.1. Introduction

These are steel girders for the purpose of carrying axle load made up of high carbon steel which convert **moving wheel** loads of train into point load which then acts on sleepers.

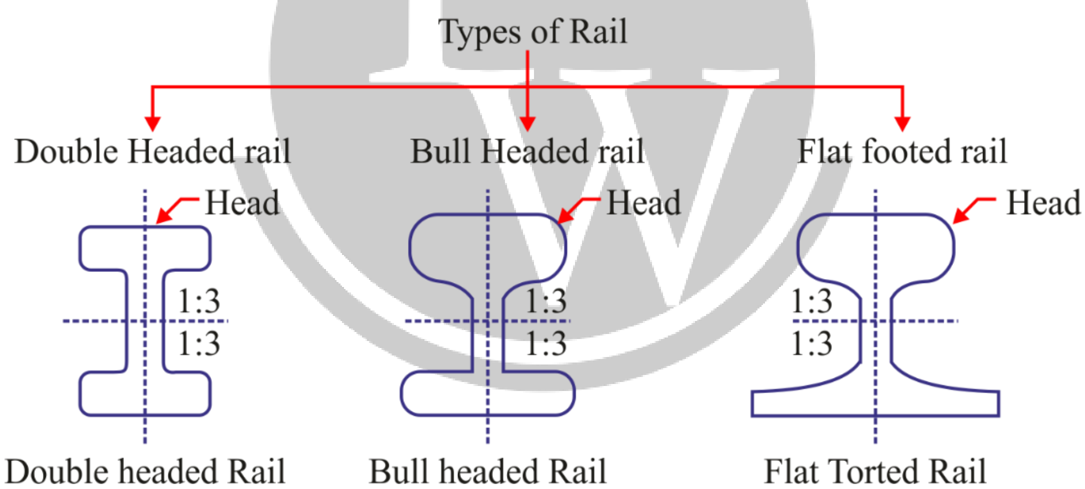
Requirement of Rails:

(i) Rails are tested by falling weight text.

(ii) Rails are manufactured by open heart or duplex process.

(iii) Maximum wear of head allowed is 10 mm

(iv) Minimum tensile strength needed 72 kg/m^2



Note: 52 kg rail (i.e. 52kg/m F.F) is suitable upto 130 kmph and 60 kg rail is suitable upto speed of 160 kmph.

Length of Rail: Rails of larger length are always preferred as they will have less no. of joints. Rail length of 12.8m for BG tracks and rail length of 11.8 gm for MG tracks are used in Indian railways.

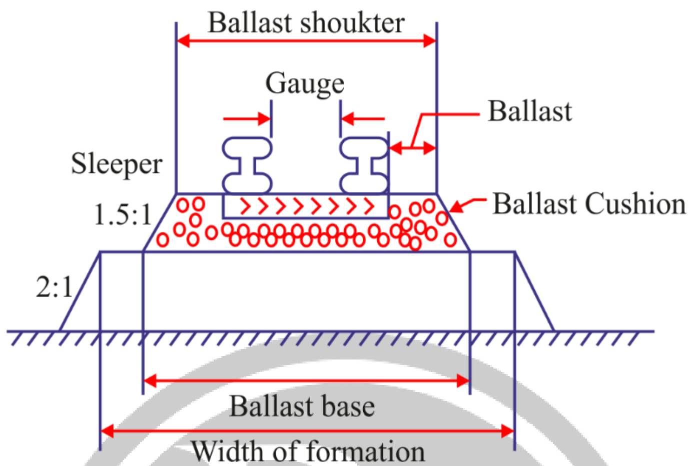
Note : $\frac{\text{wt. of Rail}}{\text{wt. of locomotive}} \approx \frac{1}{510}$

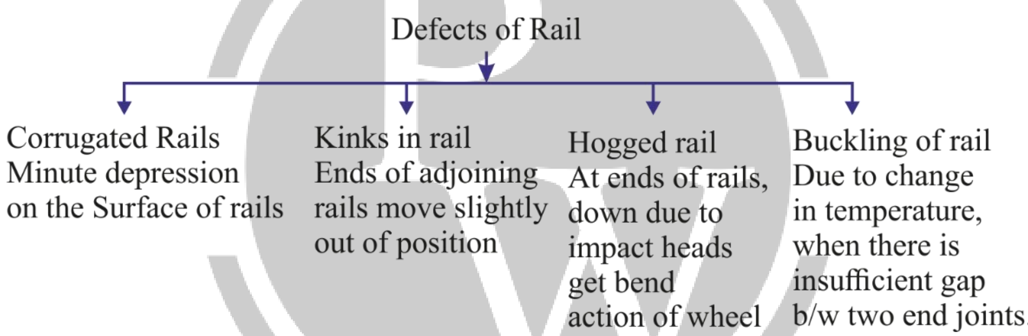
When wear of head exceeds 5% of total weight, the rail is to be replaced.

1.1.1. Permanent Way OR Railway Track

⇒ Sometimes temporary tracks are laid down for material transportation. Hence, word permanent way is coined for railway track.

⇒ It is **Semi-elastic in** nature due to packing of ballast cushion.





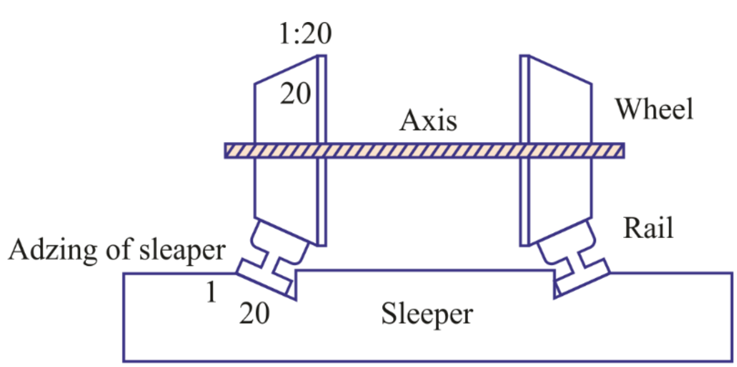
Ganges in Railway Track: It's the clear distance between inner faces of two track rails.

Broad Gauge = l.676m Narrow Gauge = 0.762m Meter Gauge = l.Om

Standard gauge = l.435m (Delhi metro)

Coning of Wheels: Wheels of the train are made at a slope of 1:20. Thus is known as coning of wheels.

Adzing of Sleepers: For effective use of coning of wheels, the rails are also laid at the slope of 1in 20 on the sleepers.



Rail Joints: Are needed to hold together the adjoining ends of the rail. They are the weakest part of the track.

Types of Rail joints

- Supported → Rail ends rests on a single sleeper
- Supported → Rail ends are projected beyond sleepers
- Supported → projected rail ends are connected by a flat or plate
- Supported → Two different rail sections are joined by fish plates.
- Supported → Gap is provided for thermal expansion
- Welded → Most perfectand strongesttype of Joints.

Welded Rails: Rails are welded to provide sufficient restrain at the ends of rail and better degree of fixity of rail to the sleeper so that the stresses produced are resisted by sleeper fasteners.

- Short welded Rail (SWR) → 3 rail lengths are welded (by standards of Indian Railways
- Long welded Rail (LWR) → Minimum length of 200m(BG) or 300m (MG) is welded at both ends
- Continuous welded Rail (CWR) → Rail longer than 1 km and extending from 1 station to another

Length of welded Rail:

$$\boxed{L = (n-1)S}$$

$$\boxed{n = \frac{\alpha T E_S A_S}{R}}$$

S = Sleeper Spacing

n = No. of sleepers required

α = Coefficient of thermal expansion

T = Rise in temperature

E_S = Modulus of elasticity

A_S = Cross. sectional area of rail

R = Resisting force/sleeper

Breathing Length: Minimum length of rail required to be welded at the end of track, so the portion of rail between welded rail does not undergo any thermal expansion or contraction.

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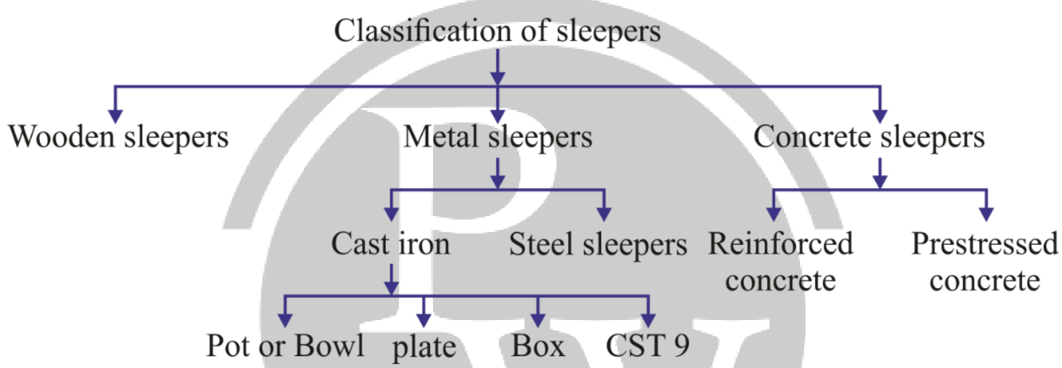
2 SLEEPERS AND TRACK FASTENERS

1.2. Introduction

Sleepers are the members which support the rail and are laid transverse to it. They act as elastic medium for providing longitudinal and lateral stability to the track.



- Wooden sleepers are best sleepers but they have maximum life of 12-15 years.
- C.I sleepers are used more than steel sleepers as they are less prone to corrosion.
- C.I sleepers can be used with every type of ballast but are not suitable for track circuiting.
- ST 9 sleeper has inverted triangular pot on either side of the rail section and a plate with the projecting rib and a box on top of the plate.
- Steel sleepers are light in weight, require less no. of fasteners but get easily rusted.
- Concrete sleepers have high track modulus, hence used for developing high speed tracks.

Note: Serviceable portion of the spiked killed wooden sleepers is cut and used with tie bars in station yards is known as check sleepers.

Composite Sleeper Index (C.S.I.) Used to measure the mechanical strength of timber.

$$\boxed{CSI = \frac{S+10H}{20}}$$

S = Strength Index. **H** = Hardness Index.

Both Index are measured at 12% moisture content.

Track fasteners:

(i) Fish plates: used to join two rail joints.

(ii) Spiker: hold's rail on wooden sleepers.

(iii) Bolts: used where sleepers rest on steel girders.

(iv) Chair: support bull headed rails on sleepers.

(v) Keys :fix rails to chairs on metal sleepers.

(vi) Bearing plates: used below F.F. rails to distribute load over wooden sleeper.

Sleeper Density: Number of sleepers per rail length. Its M + x,

Where **M** = Rail length (13 for BG)

x = Varies b/w 3 to 7

for BG sleeper density is M + 5 i.e. 18 sleepers/rail.

Squaring of Sleeper: Adjusting ballast under the sleepers to space them parallel to each other.

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3 BALLAST, SUB-GRADE AND TRACK ALIGNMENT

3.1. Introduction

- **Ballast:** It's high Quality crushed stone with desired specifications placed immediately beneath the sleepers.
- **Ballast Cushion:** Depth of ballast below the bottom of the sleeper, normally measured under the rail seat. On the curved track super- elevation is maintained by ballast cushion.

Types of Ballast:

(i) Broken stone: Best material as ballast, has maximum stability.

(ii) Gravel or River pebble: Smooth and round so poor packing and interlocking.

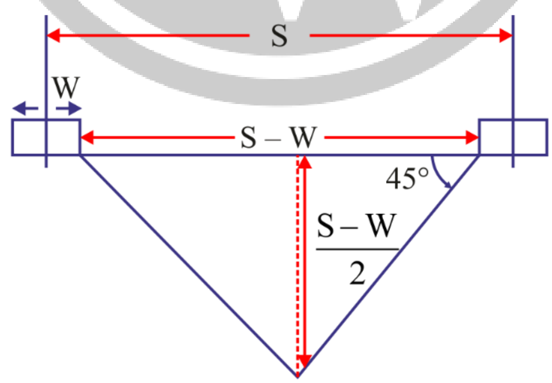
(iii) Sand: Good drainage, provides silent track, blown off due to vibrations

(iv) Asher or girders: Excellent drainage property, Excellent ballast material for station yards.

Minimum Depth of Ballast Layer = D

$$D_{min} = \frac{S-W}{2}$$

3.1.1. Depth of Ballast-Section



- **Packing:** Process of ramming the ballast underneath the sleeper.
- **Boxing:** Loosely filled ballast above the packed layer.
- **Subgrade:** Naturally occurring soil prepared to receive the ballast.

The ideal material for subgrade is soil containing gravel, sand, clay and siltin equal proportion withmoisture cont.entjust above the plastic limit.

Subgrades can be improved by

(i) adding mixture of sand, silt and clay

(ii) providing blanket of non-cohesive soil over poor cohesive soil.

(iii) injecting mixture of cement and sand under pressure.

(iv) providing concrete mats to stabilise poor subgrade.

Survey works for alignment of track.

(i) Traffic survey

(ii) Reconnaissance survey

(iii) Preliminary survey

(iv) Detailed or location survey

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4 Track Stresses and Creeps of Rail

4.1. Introduction

Track Modulus (μ): Load per unit length of the rail reoccurred to produce unit deformation or depression in the track.

Note: Elasto-plastic theory is used to define tack modulus.

- **Stresses on the Rail:** Torsional stresses are developed due to eccentric vertical loads while max shear stress below the contact surface of rail and diesel locomotive is 36.25 kg /mm^2.
- **Hammer Blow Effect:** Alternate lifting and sudden pressing is called hammer blow

$$Hammer\ blow = 0.14 \times \frac{M}{g} \times (2\pi n)^2 \sin\theta$$

Where, M = Net over weight in kg

r = Crank pin diameter in m

n = Number of revolutions of wheel per sec

θ = Crank angle

- **Steam Effect:** The vertical component of pressure of steam acting on piston is given in F.P.S units as

$$P_\upsilon = \left(\frac{\pi}{4} d^2\right) p \left(\frac{r\sin\theta \pm h}{L}\right)$$

Where, L = Length of connecting rod in inches

d = diameter of piston in inches

H = height of cross head above the centre line of driving wheel in inches.

= Crank angle.

4.1.1. Inertia of Reciprocating Forces

$$F_\upsilon = \frac{m}{g} r (2\pi n)^2 \left(\cos\theta + \frac{r}{L}\cos 2\theta\right)\left(\frac{r\sin\theta \pm h}{L}\right)$$

Stresses on Sleeper

Deflection under newly Constructed sleepers | Depression at ends due to repeated action of loads.

Method of calculating longitudinal bending stress inrail.

(i) $$X_i = 42.33\sqrt{\frac{I}{\mu}}$$

X_i = Distance from the load to the point of contrafiexure of the rail in cm.

I = Vertical moment of inertia of rail section in cm^4

μ = Track modulus in kg/cm^2.

(ii) $$\sigma_{comp} = \frac{m_0}{Z_{comp}} tonnes/cm^2 \qquad \sigma_{tension} = \frac{m_0}{Z_{tension}} tonnes/cm^2$$

m_0 = B.M. in tonne cm immediately under an isolated load p tonne on one rail.

$Z_{comp}/Z_{tension}$ = Section modulus of rail in compression/tension

$\sigma_{comp}/\sigma_{tension}$ = consequent compressive/tensile stress in the rail head/ foot under the load p in tonne per square cm.

(iii) $$d = \frac{9.25p}{4\sqrt{I\mu^3}}$$

d = deflection of track in cm

P = load on one rail in tonnes.

Creep of the Rail: It's the longitudinal movement of rail with respect to sleepers in a tack.

Theories of creep

- Wave Action theory ⇒ Vertical reverse curve due to longitudinal movement in the traffic direction.
- Precursion theory ⇒ due to horizontal component of the resultant impact force at the rail end
- Drag theory ⇒ Drag of driving wheel of locomotive have opposite effect with respect to direction of creep.

Prevention of Creep:

(i) Pulling back rails to original position

(ii) Using steel sleepers

(iii) By providing sufficient crib ballast

Factors Governing Creep of the Rail:

(i) Alignment of track: observed greater on curves

(ii) Grade of track: more creep in downward steep gradients.

(iii) Type of rails: old rails have more creep

(iv) More creep in the direction of heaviest traffic.

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5 GEOMETRIC DESIGN OF THE TRACK

5.1. Introduction

Gradient: Any rise or fall in track level is called gradient.

- **Ruling Gradient**
  ⇒(a) In plain regions 1 in 150 to 1 in 200
  (b) In hilly regions 1 in 100 to 1 in 150
- **Momentum Gradient**
  ⇒It's sleeper than ruling gradient and come only after a falling gradient
- **Helper or pusher**
  ⇒Gradient A Hel per or pusher engine is used.
- **Gradients at station yard**
  ⇒1 in 400 to 1 in 1000
  ⇒Provided to drain off the water

Grade Compensation: Due to curvature on the grade, the gradients on the curves are to be reduced to reduce the resistance in motion of train.

	% Per Degree of Curve
BG	0.04
MG	0.03
NG	0.02

Safe speed of train as per Martin's Formula

- For low speed (<100 kmph) (>100 kmph)
  - Transitioned curve
    - on BG & MG: $V_{max} = 4.35\sqrt{R - 6.7}$
    - on NG: $V_{max} = 3.6\sqrt{R - 6.1}$
  - Non-trasitioned curve 80% of speed on transitioned curve.
- For high speed: $V_{max} = 4.58\sqrt{R}$ BG

Degree of Curve:

For 30m Chain	$\frac{1720}{R}$
For 20m Chain	$\frac{1150}{R}$

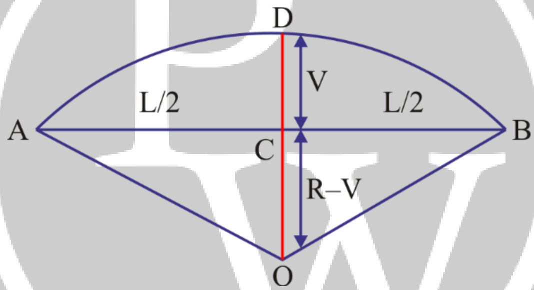
As per Indian Railways,

	Maximum Degree of Curve	Minimum Radius
BG	10°	175m
MG	100°	109m
NG	50°	44m

Versine of Curve: Used to check the accuracy of the curve.

$$\text{Versine} = \frac{L^2}{8R} \quad V = \text{cm}$$

$$L, R = \text{m}$$

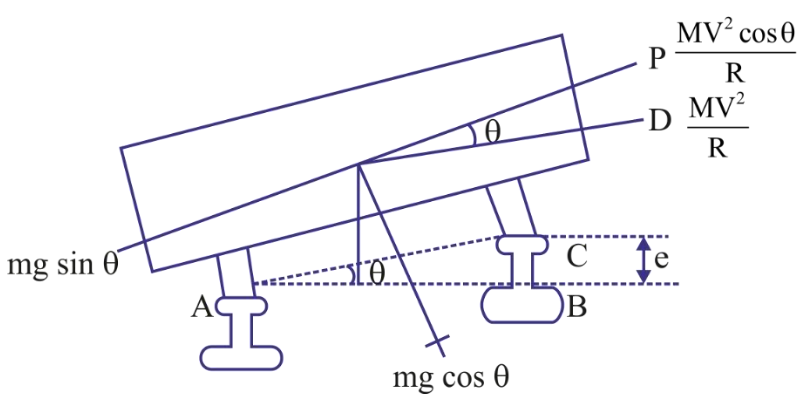


Super Elevation or Cant

$$\tan\theta = \frac{e}{G} = \frac{\upsilon^2}{gR}$$

$$\boxed{e = \frac{G\upsilon^2}{127R}} \quad \text{V in kmph, R in m}$$

G → Gauge (in m)



Equilibrium Speed

Maximum Limit of Super Elevation

Track	Speed<120kmph	>120 kmph
BG	16.5 cm	18.5 cm
MG	10 cm	x
NG	7.6 cm	x

Equilibrium speed

When sanction speed > 50 kmph

$$V_{equ} = \min \begin{cases} \frac{3}{4} V_{max} \\ \text{safe speed by martin} \end{cases}$$

When sanction speed < 50 kmph

$$V_{equ} = \min \begin{cases} 50 \text{ kmph} \\ \text{safe speed by martin} \end{cases}$$

$$\boxed{\text{Weighted average speed} = \frac{\Sigma N_i V_i}{\Sigma N_i}}$$

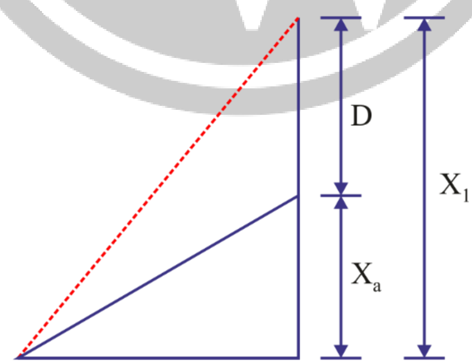
N_i = Number of train's having speed V_i

Can't Deficiency: For trains running with higher speed than equilibrium speed actual can't requirement is more than provided. This shortage is known as can't deficiency.

$$\boxed{\text{can't deficiency} = X_1 - X_A}$$

X_1 = Can't required for higher speed train

X_A = Actual can't provided as per average speed

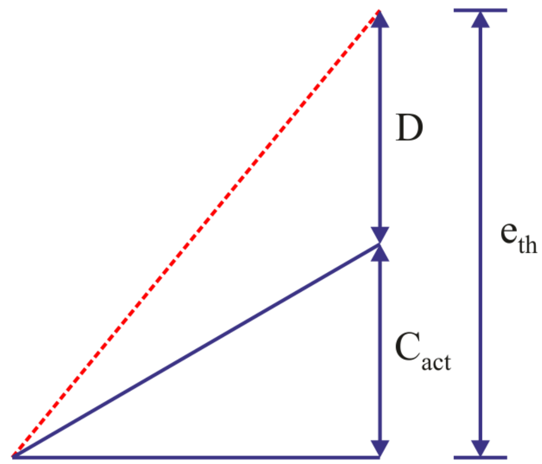


$$\boxed{e_{th} = e_{act} + D}$$

e_{th} = Theoretical can't

e_{act} = Actual can't

D = can't deficiency



Limit on D_{max}

	B.G. Track		M.G.	N.G.
	< 100 kmph	> 100 kmph		
D_{max}	7.6 cm	10 cm	5.1 cm	3.8 cm

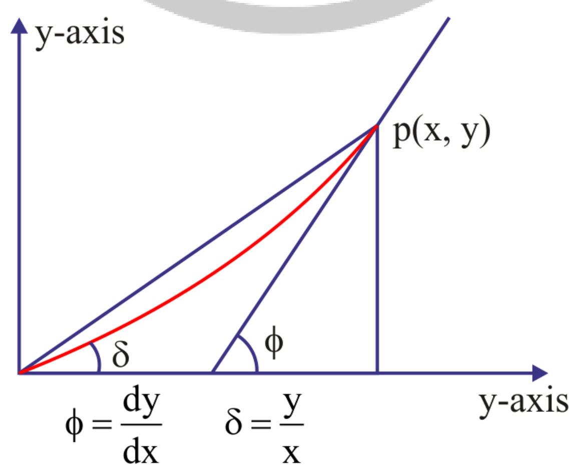
Transition Curve: Cubic parabola is used as transition curve.

(i) Equation of deflection $y = \dfrac{x^3}{6RL}$

(ii) Spiral angle $\phi = \tan^{-1}\left(\dfrac{x^2}{2RL}\right)$

(iii) Deflection angle $\delta = \tan^{-1}\left(\dfrac{1}{3}\tan\phi\right)$

(iv) Shift $s = \dfrac{L^2}{24R}$



Note: Transition curve are early set out by offset method. Cubic parabola is also known as Froude's curve.

Length of transition curve

I approach

$$L = \max \begin{cases} 7.2e \\ 0.03e\,V_{max} \\ 0.073D\,V_{max} \end{cases}$$

E = S.E in cm

D = can't deficiency in com

V_{max} in kmph

II approach

Maximum of the following

(i) Railway board formula

$L = 4.4\sqrt{R}$

L, R → m

(ii) Change of radial acceleration

$$L = \frac{3.28V^3}{R} \quad V \rightarrow \text{m/sec}$$

(iii) Rate of change of super elevation

L = 3.6e

Maximum speed based on length of transition curve

Speed < 100 kmph

$$V_{max} = 134\frac{L}{e}$$

L → m

e → mm

speed > 100 kmph

$$V_{max} = 198\frac{L}{e}$$

Gauge Widening on Curves

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

B = Rigid wheel base in meters

For **BG** = 6m For **MG** = 4.88m

R = Radius of curve (in m)

$$L = 0.02\sqrt{h^2 + Dh}$$

L = Lap of flange

h = depth of wheel flange below rails in cm

D = Diameter of wheel in cm

W_C = Widening of gauge in cm

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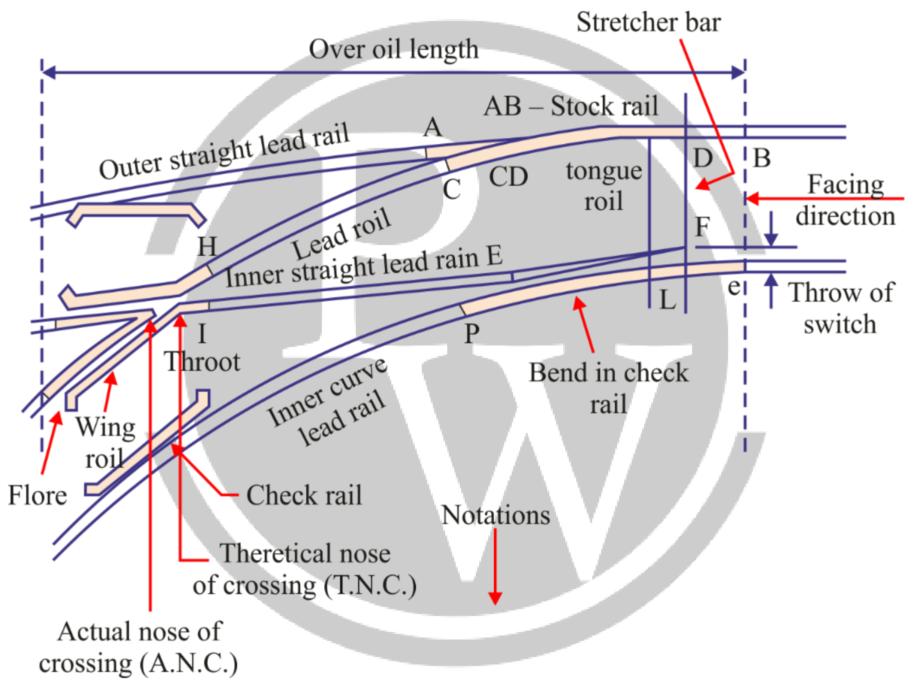
6 POINTS AND CROSSING

6.1. Introduction

Turnout: It's the combination of points and crossing which enables a back either a branch line or siding to take off from main track.



Turn out consists of

(i) 2 points or switches

(ii) 2 pair of stock rails

(iii) A pair of check rails.

(iv) An acute angle crossing

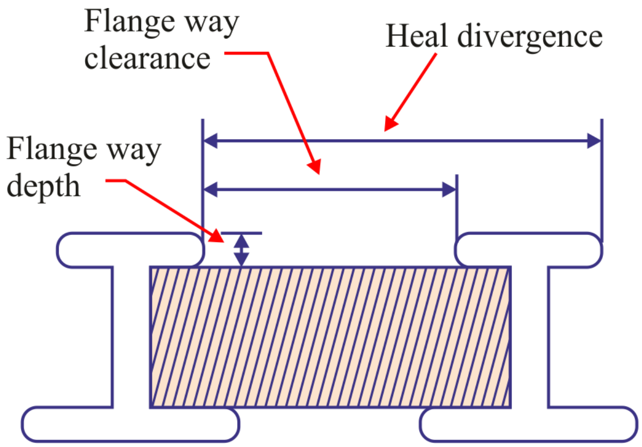
(v) 4 lead rails

(vi) A pair of stock rail

Important Points of Switch:

(i) Heel divergence: Distance b/w running faces of stock rail and tongue rail at the heel of switch.

(ii) Flange way clearance: Distance b/w adjacent faces of tongue rail and stock rail at the heel of switch.



(iii) Flange way depth: Vertical distance b/w top of rail to heel block.

(iv) Throw of switch: max distance by which toe of tongue rail moves sideways.

(v) Switch angle: Angle b/w running faces of stock rail and tongue rail when tongue rail touches the stock rail.

$$\alpha = \frac{\text{Heel divergence}}{\text{Length of tongue rail}}$$

When thickness of tongue rail at toe, t = 0

$$\sin\alpha = \frac{d}{s_2}$$

When thickness of tongue rail at toe = t

$$\sin\alpha = \frac{d-t}{s_1}$$

d = heel divergence

S_1 = Actual length of tongue rail

S_2 = Theoretical length of tongue rail.

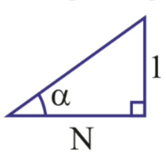
Crossing Angle:

$$\text{No. of crossing } (N) = \frac{\text{The speed at the leg of crossing}}{\text{The length of crossing T.N.C}}$$

T.N.C. is the theoretical nose of crossing

Method to calculate crossing angle 'N'

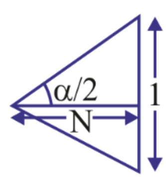
Cole's method (right angle triangle method)



$N = \cot\alpha$

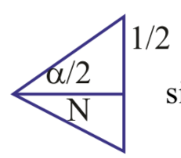
Indian railway's method

Centre line method



$$\tan\frac{\alpha}{2} = \frac{1/2}{N}$$

isosceles triangle method



$$\sin\left(\frac{\alpha}{2}\right) = \frac{1/2}{N}$$

Design of Turnout:

(i) Curve lead: Distance measured along stock rail b/w TNC and toe of switch

(ii) Switch lead: Distance between heel of the switch and toe of the switch

(iii) Lead: Distance between TNC and heel measured along stock rail

Curve Lead = Lead + Switch Lead

Method (a):

(i) $CL = G \cot\frac{\alpha}{2}$

$CL = \sqrt{2R_0G}$

$CL \approx 2\ GN$

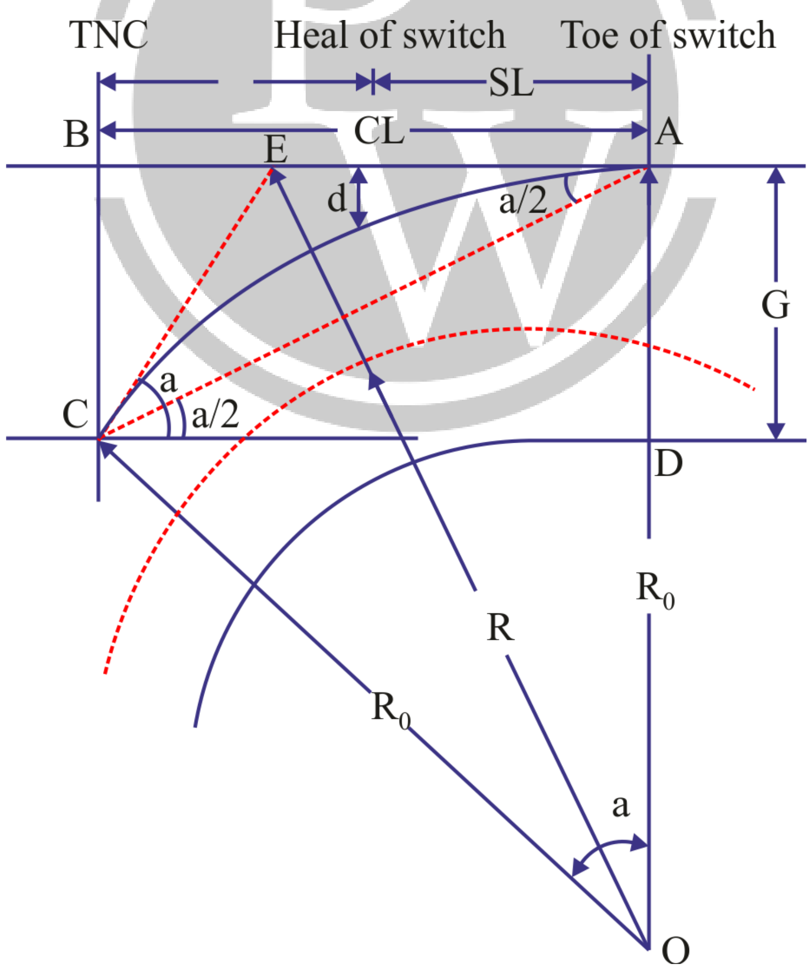
(ii) Central Radius R

$$r = R_0 - \frac{G}{2} R_0 = G + 2GN^2$$

$$R_0 = 1.5G + 2GN^2$$

Indian Railways

$$R_0 = CL \operatorname{cosec} \alpha$$

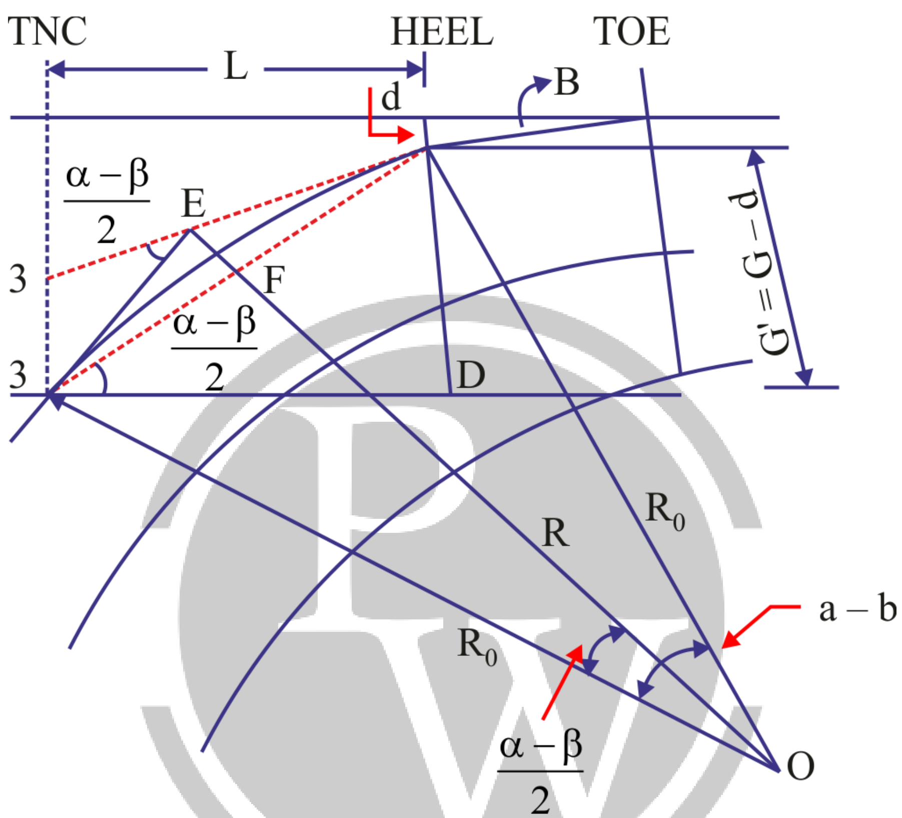


(i) $SL = \sqrt{2R_0 d}$

(ii) $L = CL - SL$

(v) $d = \frac{SL^2}{2R_0}$

Method (b):



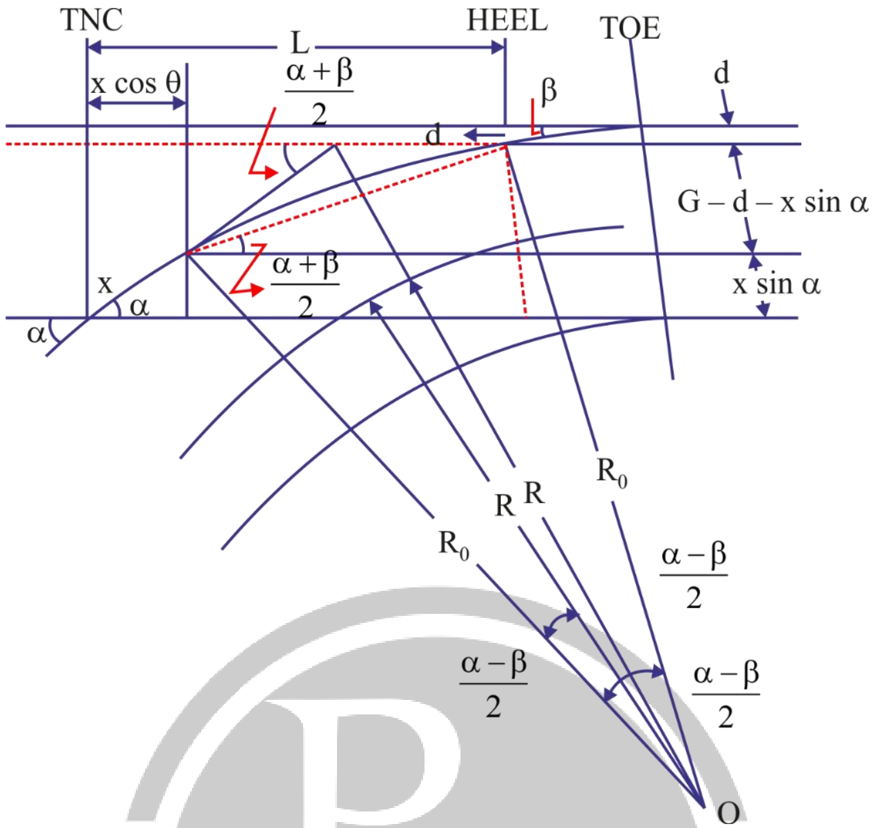
(i) $L = (G - d) \cot\left(\frac{\alpha + \beta}{2}\right)$

(ii) $R = R_0 - \frac{G}{2} r_0 = \frac{G - d}{\cos\beta - \cos\alpha}$

Method (c)

(i) $L = x \cos a + (G - d - x \sin\alpha) \cot\left(\frac{\alpha + \beta}{2}\right)$

(ii) $R_0 - \frac{G - d - x\sin\alpha}{\cos\beta - \cos\alpha}$ $R = R_0 - \frac{G}{2}$



Types of switches

- **Stab switch**: No separate tongue rail is provided
- **Split switch**: Tongue rail is combined with stock rail
  - Loose heel type
  - Fixed heel type

Note: Check rails are provided on opposite sides of the crossing for guiding the wheel while wing rails help in channelizing the wheels in their route.

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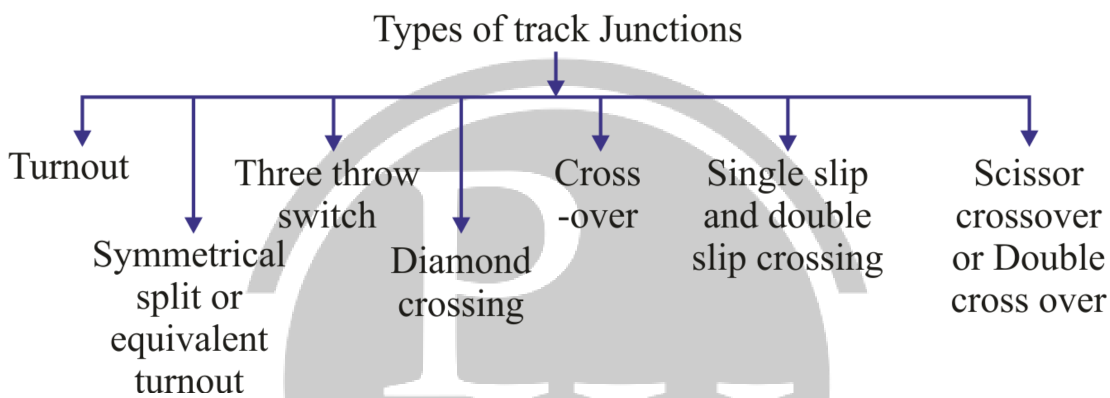
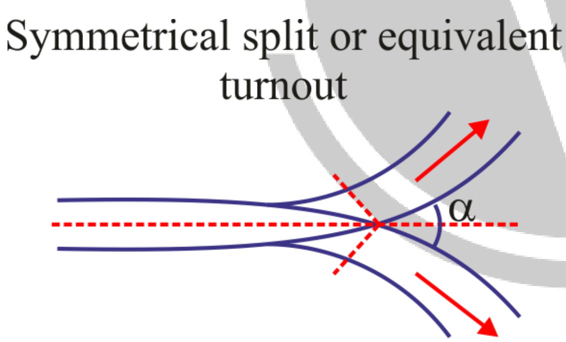
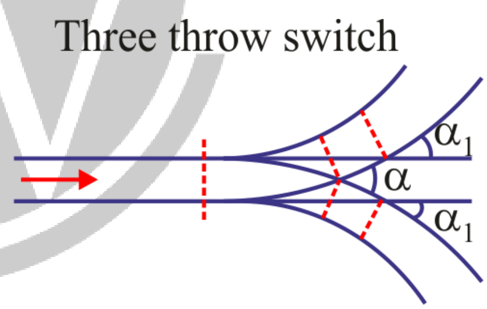
7 TRACK JUNCTIONS

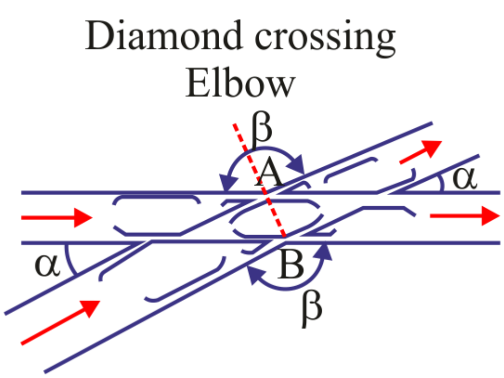
7.1. Track Junctions

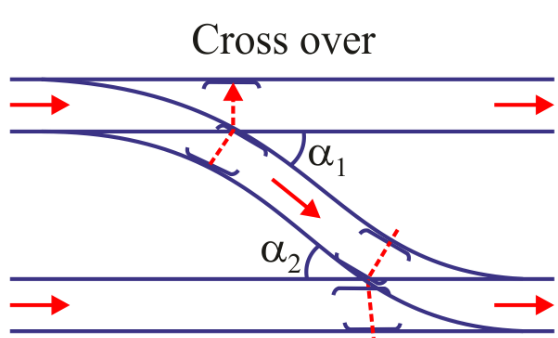
It's used to transfer trains from one track to another

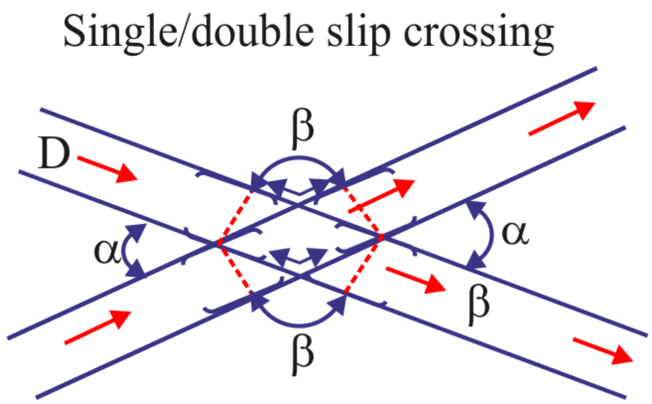


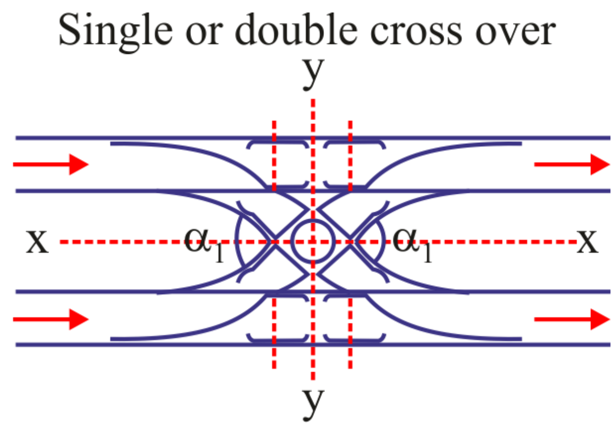












(i) Diamonds crossings are avoided on curves

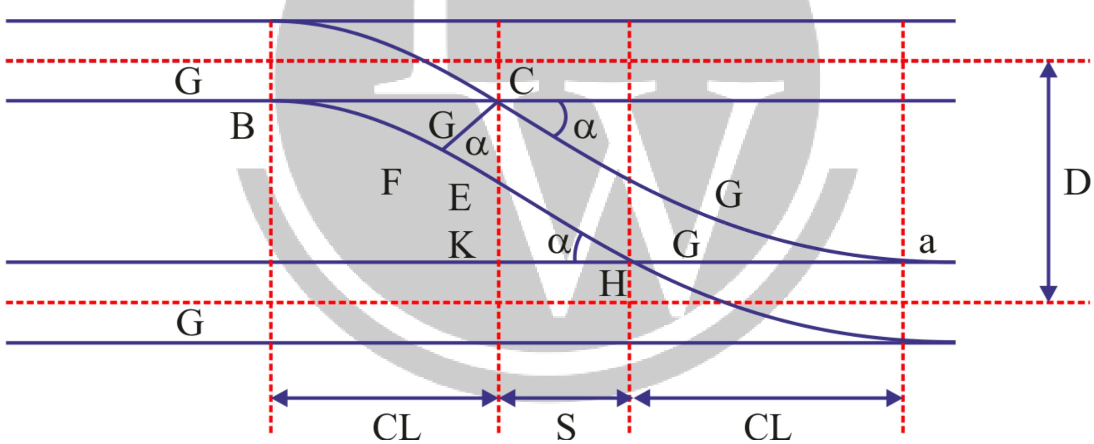
(ii) Cross-over are useful when trains are approaching from one direction only.

(iii) In single slip tracks can be changed from one direction only while in double tracks can be changed from either direction.

(iv) Scissor cross-over enables the train to change track from either direction.

7.2. Design of Cross-Over

Type 1: Two turn out provided on two tracks joint with straight position between two turnoffs.



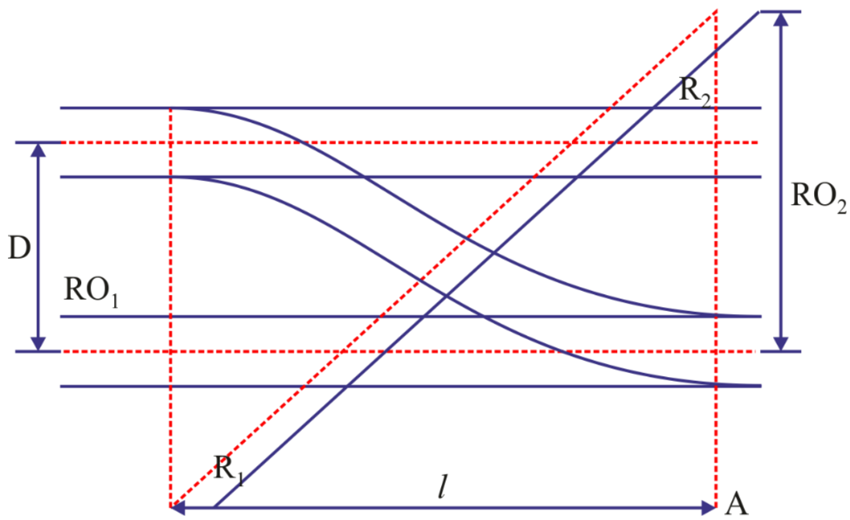
N = cot

Length of one turnout = CL = 2GN

Length of straight portion S = $(d - a)N - G\sqrt{1+N^2}$

Overall length of turnout = $4NG + (D - a)N - G\sqrt{1+N^2}$

Type 2: Cross over with curved path between two turnouts having different crossing angles.

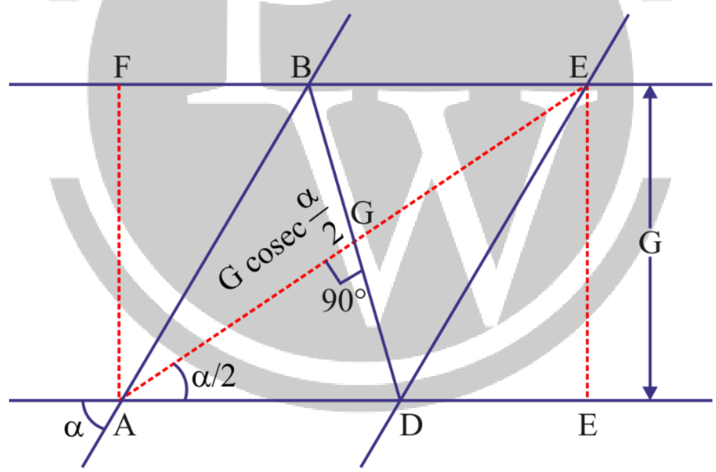


$RO_1 + 1.5G + 1.5\,GN_1^2$ $\qquad$ $RO_2 = 1.5G + 1.5\,GN_2^2$

$R_1 = RO_2 - \frac{G}{2}$ $\qquad$ $R_2 = RO_2 - \frac{G}{2}$

Overall length $L = \sqrt{(O_1O_2)^2 - (A_1A_2)^2}$

7.2.1. Design of Diamond Crossing



(i) AB = BC = CD = DA = G cosec

(ii) DE = BF = G cot α

(iii) AC = G cosec $\frac{\alpha}{2}$

(iv) BD = G sec $\frac{\alpha}{2}$

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8 RAILWAY STATION AND STATION YARD

8.1. Introduction

Classification of Railway station

- Operational classification
  - Block station
  - Non Block station
  - Special class station
- Functional classification
  - Non function station
  - Junction station
  - Terminal station

Operational Classification Functional Classification

Loop: When branch from main line again terminates at the same line.

Sidings: When a branch line from main line or a loop line terminates at a dead end with a buffer stop or sand hump

Station yards

- Passanger bougie yard
- Goods yards
- Marshalling yards
  - Flat yards
  - Gravitational yards
  - Hump yards
- locomotive yards

Note: Marshalling yard is considered as "the heart that pumps the flow of commence along the track and it may too, without the internal vigilance become the grave yard of wagons".

Other Equipments of Station Yard

(i) Engine shed or loco shed: Purpose is to clean, repair and maintain locomotives

(ii) Ash pits: To receive ashes from locomotive boilers.

(iii) Drop pits: To remove wheels of engine

(iv) Triangles and turn tables: Changing the direction of engine

(v) Traverser: To transfer wagons one at a time to and fro from parallel tracks without necessity of shunting.

(vi) Scotch blocks: To separate all the sidings and shunting lines through running lines.

(vii) Fouling marks: Points fixed between a pair of converging tracks to indicate a foul or possibility of collision of vehicles beyond these points.

(viii) Sand Hump or Snag dead end: A hump of sand with a rising gradient at the dead end of siding is provided.

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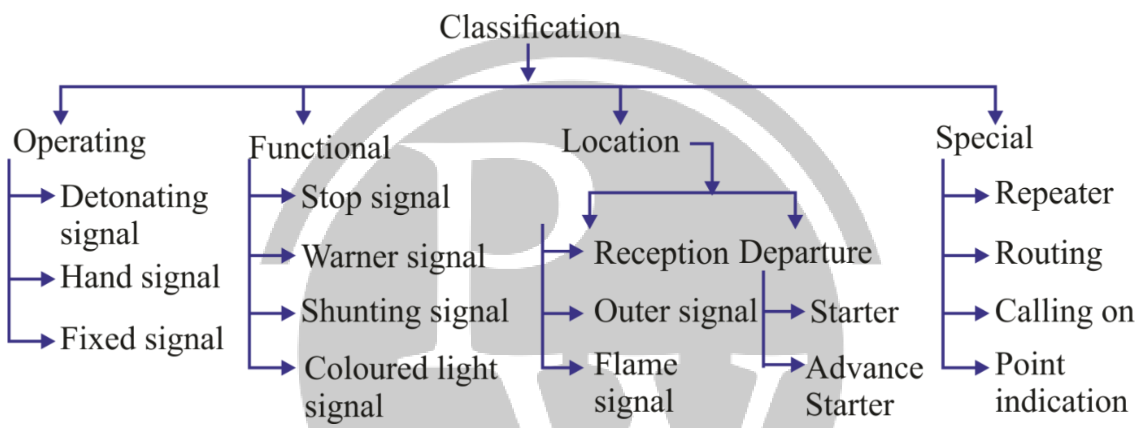
9 SIGNALLING AND CONTROL SYSTEMS

9.1. Introduction

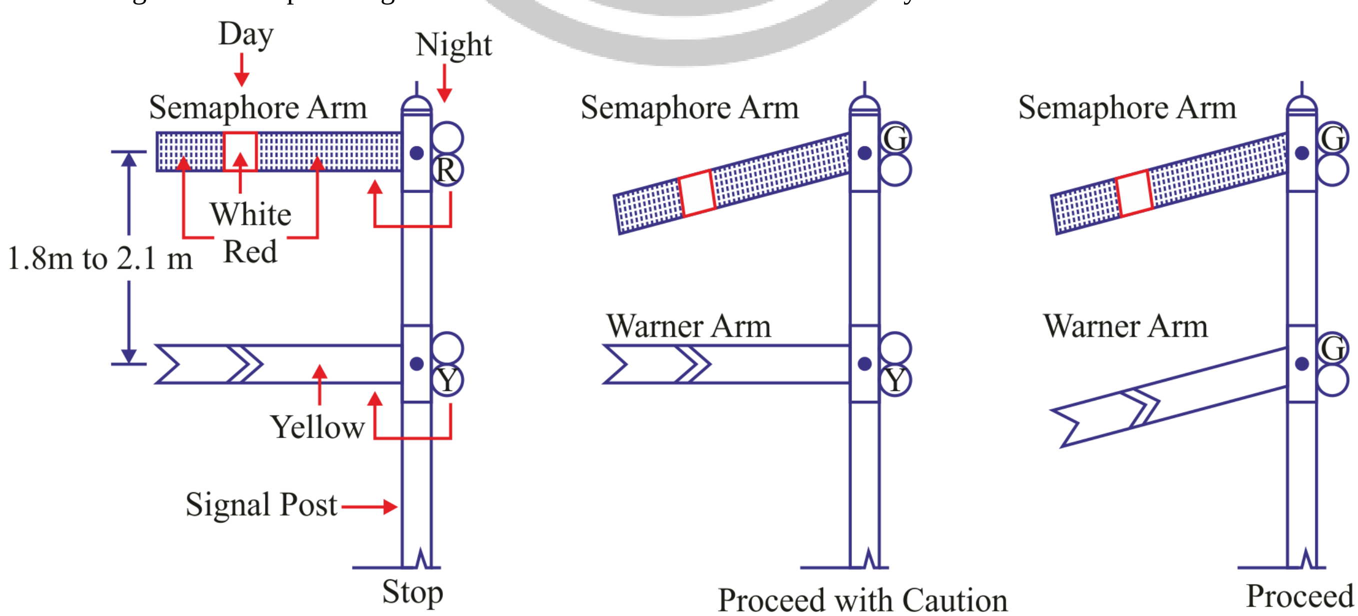
These are systems devices and means by which trains are operated efficiently.



(i) Detonating signals are used in foggy and cloudy weather. These are placed on rails which explode with when train passes over them.

(ii) Stop/Semaphore Signal: Under normal position its arm is horizontal and it indicates stop or danger indication.

(iii) Warner signal: A semaphore signal at entrance is combined with a warner system.



(iii) Shunting signals are used in station yards in shunting operation.

(iv) Calling on signals are very much useful with repair work, it permits to the train to proceed with caution.

(v) Repeater or co-acting signal's are used where driver's vision is obstructed. A duplicate arm of smaller size is placed at a suitable position on the same post.

(vi) Routing signals are provided where no of lines exist at a station taking off different locations from main line.

Note: Absolute block system or space interval system is extensively used in India.

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10 TRACTION AND TRACTIVE RESISTANCE

10.1. Introduction

Tractive Effort: Pull applied by engine on driving wheel

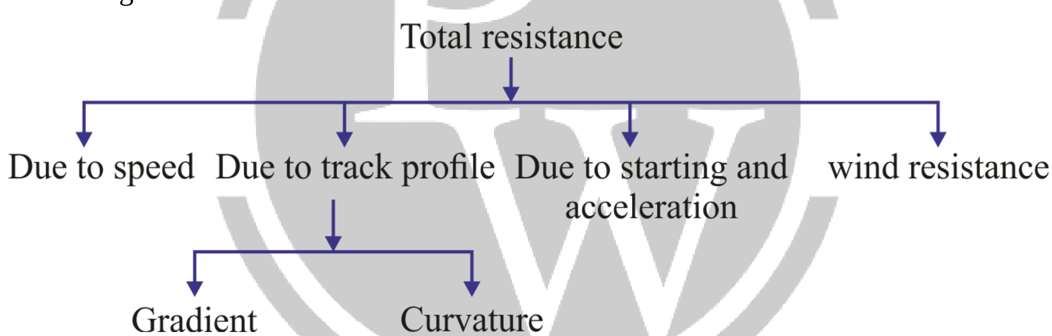
Hauling Capacity: Maximum value of frictional force due to driving wheels

Hauling Capacity (H.C.) = $\propto nw$

μ = Friction coefficient

n = No of driving wheels

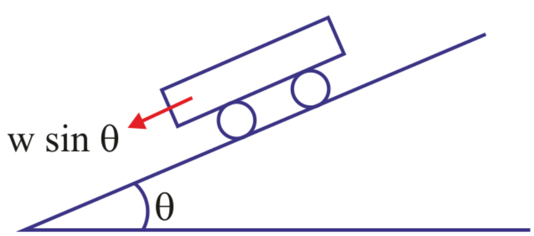
w = wt. of one pair of driving wheel



(i) Due to speed

$R_T = 0.0016\ w + 0.00008\ wv + 0.0000006\ wv^2$

w = wt. of train in tonnes V= Speed of trains in km.ph



(ii) Due to track profile

(a) Gradient $R_g = \omega \tan e$

(b) Curvature $R_c = 0.0004\ WD$ → For BG

0.0003WD → 4ForMG where D-degree of curve

0.0002 WD 4 For NG

(iii) Due to starting and acceleration

(a) Starting $R_S = 0.15\ W_1 + 0.005\ W_2$

W_1 = wt. of locomotive (tonnes)

W_2 = wt. of Wagons (tonnes)

(b) Acceleration $Ra = 0.28\ W\left(\frac{V_2 - V_1}{t}\right)$

$V_2, V_1 \rightarrow$ In kmph

$T \rightarrow$ 4 In secs

(iv) Wind Resistance

$R_W = 0.000017\ a\ V_W^2$

a = exposed area of train in m^2

V_W = Speed of wind in kmph

Note: For Moving Train, Tractive Resistance > Hauling Capacity > Total Resistance

Library:- https://smart.link/sdfez8ejd80if

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