Railway Engineering

Total Number of Railway Zones-18

17th zone - Kolkata metro (Oldest metro in India)

18th zone- Southern (Vishakhapatnam) coast railway zone

Load transfer step-

Moving load of locomotive Rails → Sleepers → Ballast → Soil.

Note:

- Hammer test and fatting weight test is compulsory for testing of rails.
- Manganese steel is used for rail construction.
- Ordinary rail are made by high carbon steel.
- Rails on point and crossing is made by medium carbon steel.
- Metro and mono rails are made of manganese steel.
- Rails are made up of high carbon steel that resist wear and tear.

Composition of Rails

Composition	For ordinary rails (%)	For rails on point and crossing (%)
Carbon	0.55 - 0.68	0.50 - 0.60
Maganese (maximum)	0.65 - 0.90	0.95 - 1.25
Silicon	0.05 - 0.30	0.05 - 0.20
Sulphur	0.05	0.06
Phosphorus	0.06	0.06

Types of Rail Section

Double Headed Rails	First rail section designed by Indian railway. • It can be inverted and re-used.
Bull Headed Rails	It is most suitable at point and crossing and where lateral loads acts.
Flat Footed Rails (Vignole's rail)	• Now a days used in Indian railway and most popular. • Most suitable due to stability, economy and strength.

Important Railway Terminology

Coning of wheels	Wheel are coned at a slope of 1 IN 20 to prevent from rubbing the inside face of the rail head and to prevent lateral movement of the axle with its wheel.
Cant or superelevation	Rising of outer rail over the inner rail to counteract the effect of centrifugal force on curve.
Creep of Rails	It is the longitudinal movement of rails in a track. • Creep is measured with creep indicator
Flangeway clearance	It is the distance between the adjacent faces of the stock rail or running rails and the check or guard rails.

Hauling capacity	It is the total load which can be hauled by it. It indicate the power of the locomotive.
Heel divergence	It is the distance between the running face of stock rail and gauge face of tongue rail and gauge face of tounge rail.
Hallade Chart	It is a method related to the track geometry for designing, surveying and setting out of curve on railway tracks.
Point	It is the set of switches.
Switch	It is a combination of stock rail and tongue rail.
Turnout/ crossing	The combination of point and crossing by which a train is diverted from one track to another is called turnout.
Stock Rails	Stock rails are fitted against the tongue rails.
Tongue/ Switch Rails	It is the tapered movable rail, connected at its thick end to the running rail.
Switch angle	Angle between the gauge face of stock rail and tongue rail.
Throw of switch	Maximum distance by which the toe of tongue rail can moves sideway is called throw of switch.
Hogged rails	Those rails which get battered due to impact action of wheel over the end of the rails are called hogged rails.

Marshalling yard	Yard in which wagons are sorted and new trains are formed.
Goods yard	A yard in which goods wagons are shunted and sorted for loading and unloading is called a goods yard.
Buffer stop	The dead end of railway line is provided with a barrier erected across the track to prevent the vehicles running off the track.
Track modulus	It is an index of measure resistance due to deformation. It depends on gauge distance type of rails, sleeper density and type of ballast.

Types of turnout	Total no. of sleepers
1 IN 12 turnouts	70
1 IN 8.5 turnouts	62

Type of gauge	Heel Divergence(d)
B.G.	13.3- 13.7 cm
M.G.	11.7- 12.1 cm
N.G.	9.8 cm

$$\text{Switch angle, } \theta = \frac{\text{Heel divergence}}{\text{Length of tongue rail}}$$

Note:

- Height is the largest dimension in rail section.
- Flat footed rails are designated by Weight of rails/unit length and it is two types.

S.N.	Types	Suitability
1.	52 kg/m or 52 MR	Locomotive speed < 130 km/h
2.	60 kg/m or 60 MR	Locomotive speed < 160 km/h

Gauge distance for rail gauge

Rail Gauge	Gauge distance (mm)
Broad Gauge	1676
Standard Gauge	1435
Meter Gauge	1000
Narrow Gauge	762
Light Gauge	610

Calculation of max. axle load-

$$\frac{\text{Wt. of rail in tonnes}}{\text{Wt. of axle load in tonnes}} = \frac{W_R}{W_L} = \frac{1}{510}$$

Maximum axle load in India-

Gauge	Maximum axle load
Broad gauge	28.56 tonnes
Meter gauge	17.34 tonnes

- **Sleeper Density** = (N + X).

  where N = Length of one rail in meter.

  X = Constant value 3 to 6.

Track	Length of one rail
B. G. Track	13m
M. G. Track	12m

- Number of rails

$$= \frac{\text{Length of railway track}}{\text{Length of one rail}}$$

Material Required per km. of Railway Track

(i) No. of Rails/km

$$= \frac{1000}{\text{Length of rail in (m)}} \times 2$$

(ii) Weight of rails in Tonnes/km

= No. of rails × Length of rails × $\frac{\text{wt. of rail per m.}}{1000}$

(iii) No. of Sleeper/km

$= \frac{1}{2}$ No. of rail/km × sleeper density

(iv) No. of fish Plate = 2 × No. of rails/km

- 2 Fish plate per joint
- 4 Fish bolt per joint

(v) No. of Bearing Plates = 2 × No. of sleeper/km

Classification of rail joint according to

position of joint	1. Square or even rail joint. 2. Staggered or broken rail joint.
position of sleeper	1. Supported rail joint. 2. Suspended rail joint. 3. Bridge joint. 4. Compromise joint.

Maximum Tolerance Including Side Wear for M.G based on radius

Meter Gauge	Tolerance
On straight	3-6 mm
On curve (radius ≥ 290 m)	3-15 mm
On curve (radius < 290 m)	≤ 20 mm

Based on curve angle-

B.G track- For straight length and curves upto 6° For curves 6° - 10°	**Tolerance-** 3 mm tight to 6 mm slack 13 mm slack
M.G track- For straight length and curves upto 6° For curves 6° - 10°	**Tolerance-** 3 nun tight to 15 mm slack 13 mm slack

Breathing Length (B.L.)-

It is that min. length of welded rail at each end of LWR/CWR which is not subjected to expansion/contraction on account of temperature variation.

$$(\text{B.L.})_{\text{Total}} = (2n - 1) \times S$$

Where,

n = Number of sleepers required

S = Sleeper spacing

Formation width as per Indian standard

Particulars	Recommended dimension in (m)			
	B.G.	M.G.	N.G.	Slope
Embankment- Width of bank: (a) Single line (b) Double bank	 6.10 10.67	 4.88 8.53	 3.70 7.32	2 : 1
Cutting- Width of cutting excluding side drains (a) Single line (b) Double line	 5.49 10.06	 4.27 7.93	 3.35 7.01	1.5 : 1

Safe speed on curve by Marthin's Formula

- For Transition Curve-

For, B.G. & M.G., $\boxed{V = 4.35\sqrt{R-67}}$

N.G., $\boxed{V = 3.65\sqrt{R-6}}$, V is in kmph, R in m

- **For Non-transition curve-**

(i) For B.G. & M.G.-

V = 0.80 × Calculated Speed on transition curve

$= \boxed{3.48\sqrt{R-67}}$

(ii) For narrow gauge, $\boxed{V = 2.92\sqrt{R-6}}$

- **For High speed Trains-** $\boxed{V = 4.58\sqrt{R}}$ for B.G.

Safe Speed on curve Based on Superelevation

- **For Transition Curves-**

(a) B.G. $\boxed{V = 0.27\sqrt{(C_a + C_d)R}}$

(b) For M.G. $\boxed{V = 0.347\sqrt{(C_a + C_d)R}}$

(c) For N.G. $\boxed{V = 3.65\sqrt{R-6}}$

C_a = Actual cant (mm), C_d = Cant deficiency (mm)

R = Radius of curve (mm)

Cant Deficiency-

Cant deficiency becomes an inevitable consideration on a main line and branch line moving in same direction.

Cant deficiency = $X_1 - X_a$

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

Where,

X_a = Actual cant as per average speed

X_1 = Cant required for a high speed train.

e_{th} = Theoretical cant, e_{act} = Actual cant

Permissible limit of cant deficiency

Gauge	Speed < 100 km/h	Speed > 100 km/h
B.G.	7.6 cm	10.0 cm
M.G.	5.1 cm	—
N.G.	3.8 cm	—

Max. Permissible value of superelevation ($e_{max.}$)

Gauge	Speed < 120 km/h	Speed > 120 km/h
B.G.	16.5 cm	18.5 cm
M.G.	10.00 cm	—
N.G.	7.6 cm	—

Speed based on Length of Transition Curve

- Speed up to 100 km/hr

$$\boxed{V_{max} = \text{Minimum of}\left(\frac{134L}{C_a} \text{ OR } \frac{134L}{C_d}\right)}$$

- **For high speed train, speed > 100 km/h**

$$\boxed{V_{max} = \text{Minimum of}\left(\frac{198L}{C_a} \text{ OR } \frac{198L}{C_d}\right)}$$

Relation between Radius and Degree of curve-

- $\boxed{D = \frac{1720}{R}}$ For 30m chain
- $\boxed{D = \frac{1150}{R}}$ For 20m chain

Track	Max. Degree of Curve (D)	Min. Radius
B.G.	10°	175 m
M. G.	16°	169 m
N. G.	40°	44 m

Note: Versine of curve $= \frac{L^2}{8R}$

Grade Compensation

Broad Gauge	0.04%, OR $\left(\frac{70}{R}\right)$
Meter Gauge	0.03%, OR $\left(\frac{52.5}{R}\right)$
Narrow Gauge	0.02%, OR $\left(\frac{35}{R}\right)$

- **Super Elevation/Cant,** $e = \frac{GV^2}{127R}$
- **Equilibrium cant,** $e' = \frac{GV_{av}^2}{127R}$

G = Gauge distance (mm)

V = Kmph, R = Radius of curve (m)

V_{av} = Average speed

Equilibrium or Average Speed ($V_{avg.}$)-

(a) For speed > 50 kmph

$$V_{av} = \text{minimum of} \begin{cases} \frac{3}{4} \times V_{max} \\ \text{Safe speed by martins formula} \end{cases}$$

(b) For speed < 50 kmph

$$V_{avg.} = \text{minimum of} \begin{cases} V_{max} \\ \text{Safe speed by martins formula} \end{cases}$$

(c) Weighted average method-

$$V_{av} = \frac{n_1 v_1 + n_2 v_2 + \ldots}{n_1 + n_2 + \ldots} = \frac{\Sigma n.v}{\Sigma n}$$

Where, $n_1, n_2 \ldots$ are the number of trains running at speeds $v_1, v_2 \ldots$

Transition Curve -

Transition curve is a easement curve which is a curve of varying radius throughout of its length.

- It is usually provided in a shape of cubic parabola at each ends of circular curve.

Comparison of Different types of sleeper-

Property	Wooden sleeper	C.I. sleeper	Steel sleeper	Conc. Sleeper
Cost/sleeper	Low	Medium	High	Depend upon Design
Life (years)	10-15 for untreated 20-25 for treated	35-40	35-50	40-60
Maintenance cost	Higher than other sleeper	Minimum	Moderate	Moderate
Elasticity	Good	Not very good	Not very good	Not good
Scrap value	very less	Highest	next to C.I	-

Size of Sleeper

Gauge	Size (cm)	Bearing Area per Sleeper (in sq.ft.)
B.G.	275×25×12.5	5.00
M.G.	180×20×11.5	3.33
N.G.	150×18×11.5	2.25

Number of sleeper at crossing-

(i) 1 IN 8.5 - 51 Sleeper,

(ii) 1 IN 12 - 70 sleeper

Composite Sleeper Index CSI-

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

S = Strength Index

H = Hardness Index

Minimum CSI prescribed on Indian Railways

Types of Sleeper	Min.CSI
Track Sleeper	783
Crossing Sleeper	1352
Bridge Sleeper	1455

Standard Size of Ballast for Sleepers

Type of Sleeper	Size of Ballast
Wooden and CI pot	50 mm
Sleeper CST 9 and	40 mm
Through Sleeper Points and Crossing	25 mm

Adzing of Sleeper-

Process of cutting the wooden sleeper at a slope of 1 IN 20 at the rail seat before laying.

- Optimum depth of ballast cushion-

$$D = \frac{S - W}{2}$$

S = Sleeper spacing, W = Width of sleeper

Types of gauge	Depth of ballast cushion
Trunk line or BG	25 cm
Meter gauge	15-20 cm
Narrow gauge	15 cm

Classification of spikes

Dog pikes Depth-120.6 mm	Used to holding flat footed rails on wooden sleepers.
Screw/Catch spikes	It is costly and has double holding power than dog spikes
Elastic Spikes	Holding power is good and prevents the creep of rail.
Round spikes	Fixing chair of bull headed to wooden sleepers and for fixing slide chairs of point and crossing

Important terminology

Ballast cushion	Ballast provided at the bottom of sleeper.
Crib ballast	Ballast b/w two sleepers.
Shoulder ballast	Ballast provided at the ends of sleeper.
Packing	It is the process of ramming the ballast underneath the sleeper. • Min. packing space b/w two sleeper- 30-35 cm
Boxing	It is the process of filling the ballast around the sleepers.

Tools and its use in railway track

Tools	Use
Shovel and ballast rake	Handing the ballast on the sleeper
Rail tongs	For lifting the rails
Claw bars	Remove the dog spikes out of sleepers or for lifting track
Crow bars	To correct track alignment, and lift the track for surfacing.
Cotters	To connect CI sleepers to tie bars
Densometer	Measure the depression of sleeper or packing voids under the sleeper ends.

Viseur's mire	Measurement of unevenness of rail top and rectification of alignment
Jim crow	To bend the rails
Sleeper tongs	To lift sleepers
Treadle bar, point lock & detector	For interlocking

Note:

- Tractive resistance > Hauling capacity > total resistance.

Transition curve

- **Equation of cubic parabola-** $y = \frac{x^3}{6RL}$
- **Deflection Angle-** $\theta = \tan^{-1}\left(\frac{1}{3}\tan\phi\right)$
- **Spiral Angle-** $\phi = \tan^{-1}\left(\frac{x^2}{2RL}\right)$
- **Shifts-** $S = \frac{L^2}{24R}$
- **Curve lead** $= 2GN$

N = crossing number = cotα

- **Length of transition curve as per railway code-**

$$L = \max.\text{of}\begin{cases} 0.073C_a.V_{max} \\ 0.073C_d.V_{max} \\ 7.20C_a \end{cases}$$

or Maximum of

(i) $L = 4.4\sqrt{R}$, (ii) $L = \frac{3.28v^2}{R}$

v in m/sec., {L, R (in m)}

Gauge	Length of Bogie, L (mm)	Height of Bogie, h (mm)	C/C Distance of Bogie, C (mm)
B.G.	21340	4025	14785
M.G.	19510	3355	13715

Gauge widening on curves,

$$W_c = \frac{13(B+L)^2}{R}\text{cm}$$

Lap of flange, L (m) $= 0.02\sqrt{h^2 + D.h}$

Where,

B = Rigid wheel base (m)

R = Radius of curve in m.

h = Depth of wheel flange below rails (cm)

D = Wheel dia. (cm)

- **Crossing Lead-**

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

- **Radius,** $R = R_o - \frac{G}{2}$

Where, $R_0 = \frac{G - d - x\sin\alpha}{\cos\beta - \cos\alpha}$

Methods of Determine Crossing Number-

(i) Cole's or right angle triangle method-

$N = \cot\alpha$

(ii) Centre line method- $\alpha = 2\cot^{-1}(2N)$

(iii) Isosceles Triangle method,

$\alpha = 2\text{cosec}^{-1}(2N)$

Curve Lead-

$$\text{Curve lead} = GN + G\sqrt{1+N} \simeq 2G.N$$

Crossing Lead-

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

= Curve lead – Switch lead = CL – SL

Switch lead-

This is the distance from the tangent point to the theoretical nose of crossing measured along the main track.

Switch Lead, $SL = \sqrt{2R_c.d}$

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

d = Heel divergence, R_c = Radius of curve

Facing direction	One standing at the toe of switch and looks towards crossing.
Trailing direction	One standing at the crossing and looks toward the switch.
Facing point of turnout	Train passes over switch first and then crossing.
Trailing point of turnout	Train passes over crossing first and then switch.

Types of signal based on

Operating Characteristics
1. Detonating signal (fog or audible)
2. Hand signal
3. Fixed signal

Function Characteristics
1. Stop or semaphore
2. Warner signal
3. Shunting singal
4. Coloured light signal

Location Characteristics
1. Reception signal
   (a) Outer signal
   (b) Home signal
2. Departure signal
   (a) Starter signal
   (b) Advance starter signal

Special Characteristics
1. Repeater or coacting
2. Routing or coacting
3. Colling on signal
4. Point indicators
5. Modified lower quadrant semaphore signal