AIR-1 Notes

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Railway

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RAILWAY

CONTENT

Railway

Ch-1 Rail, Railway and Rail Joint

→ A mode of transportation

→ IR is second largest in the world. (1st is Russia)

→ IR has 5 training institutes,

1) Indian Railway Institute of CE, Pune.

→ For R & D, IR has it's own unit RDSO, Research, Design and Standards Organisation at Lucknow. It's function is to provide input support to almost all disciplines to R&D wing of IR.

⇒ Classification of Railway Route

→ Done on the basis of importance, traffic carried and the maximum permissible speed of train

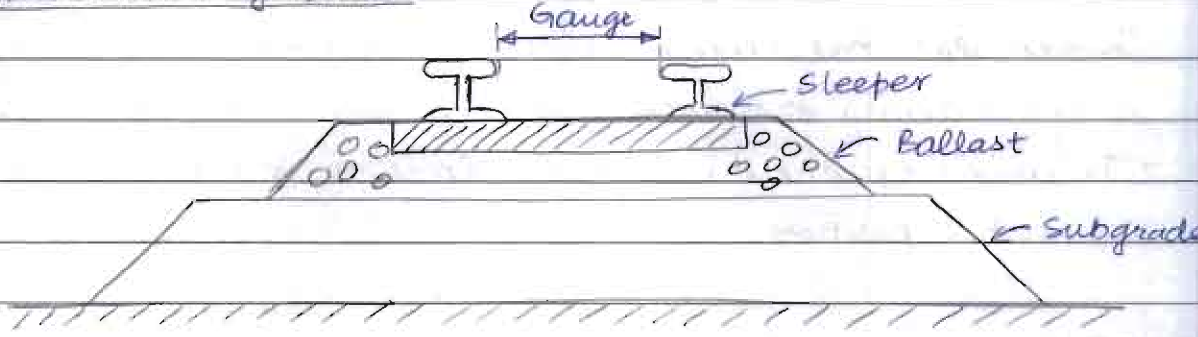
→ B.G. Route

1. Group A → Speed upto 160 kmph
2. Group B → Speed upo 130 kmph
3. Group C → Suburban railway of Delhi, Chennai, Mumbai, Kolkata.
4. Group D → Speed upto 110 kmph, traffic density < 20 GMT
5. Group D (special) → Speed upto 110 kmph and annual traffic density more than 20 GMT (Gross million Tonne)
6. Group E → All other sections and speed < 100 kmph
7. Group E (special) → Speed upto 100 kmph and section where traffic density is very high or likely to grow.

→ M.G. Route

1. Q } > 75 kmph
2. R } ≤ 75 kmph
3. S } < 75 kmph

→ Cross-section of Track



→ The track consists of parallel lines of rail. fitting and fastening, ballast etc. To provide hard, smooth and stable passage.

→ Gauge: It is the distance b/w the inner edge of the heads of rail.

→ It is measured 16 mm below the plan of rail running table.

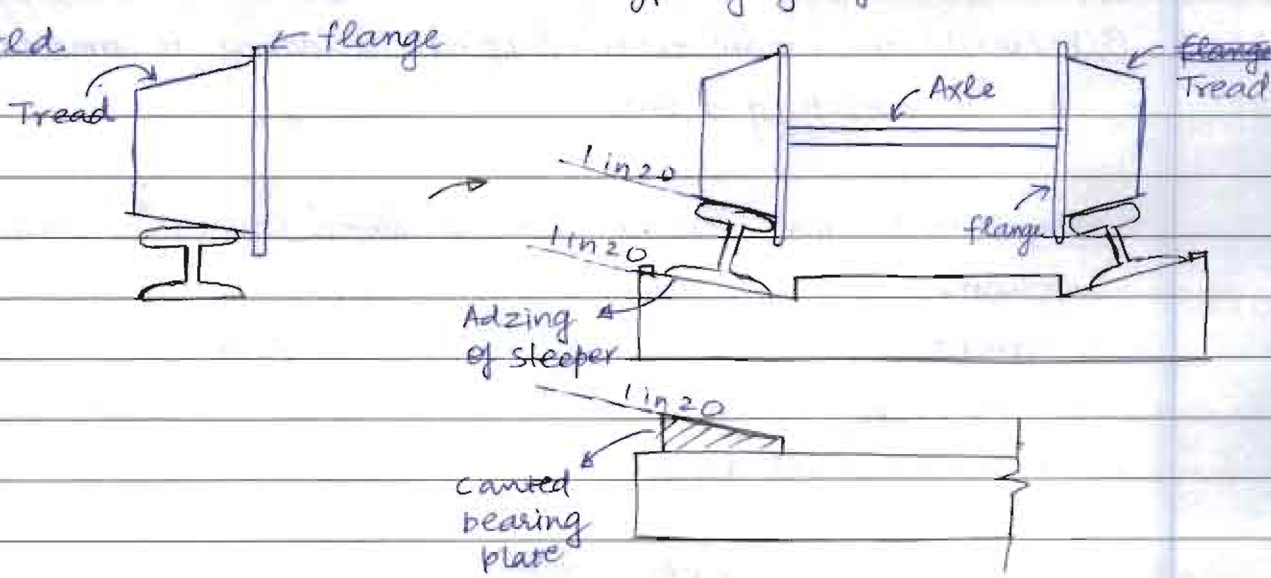
→ In India we have 3+1 type of gauge.

1. Broad gauge → 1.676 m
2. Metre gauge → 1.000 m
3. Narrow gauge → 762 mm, 610 mm (Darjeeling)
4. Standard gauge → 1.435 m (Used in Metro)

→ In India, approx 63% BG, 31% MG and 6% NG exist.

→ Whereas, in world 62% Standard gauge and 15% BG exist.

→ Other than these more than 20 type of gauges are there in the world.



→ Coning of wheel - The head of wheels of railway vehicle are not made flat but sloped at 1:20 and this sloping of surface along the circumference forms a part of cone.

→ The coning of wheel is mainly done to maintain the vehicle in central position

→ Behaviour of coned wheel -

① On straight track - Keeps the train in central position. Hence reducing wear and tear of wheel flange. If at any moment the wheel goes out of it's central position, the dia of contact point will become different and there fore, the wheels retreat till they are at central position once again with equal dia.

② On curved track - When train moves on curved track, the distance covered by outer wheel is more than the inner wheel. Centrifugal force shifts the outer wheel outwards, thus causing an increase in diameter. which helps it in moving longer distance compared to inner wheel. Hence more length of outer rail is partly adjusted due to coning.

→ Advantage of coning

① Produces self centering effect

② Reduces wear and tear of wheel flange and rail.

③ Prevents the wheel from slipping / skidding to some extent when negotiating a curve.

⇒ Adzing of Sleeper - Coning of wheel alone without tilting the rail has some disadvantages like:

(a) Lateral Bending stress on rail due to eccentric loading

(b) High concentration of stress at inner edge of rail and on tread of wheel as well.

→ Tilting of rail in 1:20 is done to control above problems.

→ It can be done by either directly making groove on sleeper or with the help of canted Bearing Plate.

→ Now, making groove on sleepers at 1:20 is known as Adzing of sleeper.

Ch-2 Geometric Design

⇒ Gradient – Any rise or fall in the track level is known as gradient.

→ Gradient are represented either by 1 in X form or p%

eg – 1 in 200 ⇒ 0.5%

→ Type of Gradient on Railway track

① Ruling Gradient

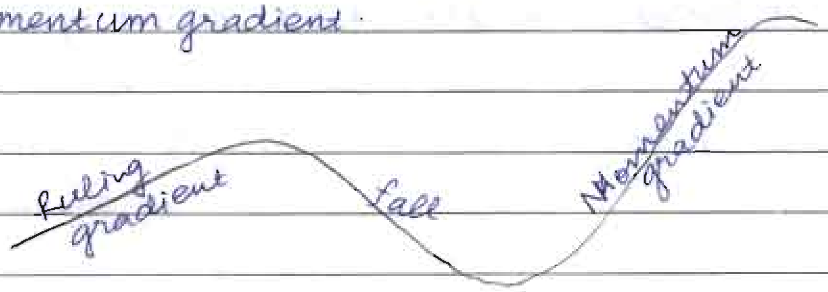
→ In most general case, the maximum gradient allowed is known as Ruling gradient.

→ It is the gradient where there may not be any appreciable loss of speed.

→ In general, for plain areas → 1 in 150 – 1 in 250 → Ruling gradient
for hilly areas → 1 in 100 – 1 in 150 →

② Momentum Gradient

If rising gradient is followed by falling gradient, the train while coming down in a falling gradient acquires sufficient momentum which enables the train to negotiate a steeper gradient than the ruling gradient. This rising gradient is called momentum gradient.



③ Pusher / Helper gradient

→ In hilly areas to reduce the length of railway line, gradient steeper than ruling gradient is provided.

→ In such situation, instead of limiting the train load, the train is run by an assistant or helper engine. Such gradients are called as pusher gradient. [Generally steeper than 1 in 75]

④ → Gradient in Station yard

→ In station yard, gradient is provided for drainage.

→ It should be sufficiently low so as to:

① To prevent the movement of standing vehicle.

② To prevent additional resistance at the start of vehicle.

→ Maximum → 1 in 400 and minimum → 1 in 1000.

⇒ Grade compensation

→ Due to curvature on the grade, resistance to motion of train increases.

→ In order to avoid resistance beyond allowable limit, the gradients are reduced on the curve.

→ This reduction in gradient is known as grade compensation.

** → For IR,

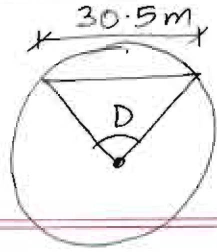
(a) For BG → 0.04 % per degree

(b) For MG → 0.03 % per degree

(c) For NG → 0.02 % per degree

Q → If curve of 4 degree accompanied by ruling gradient of 1 in 150 on BG track, the permissible gradient would be

$\boxed{1 \text{ in } 197.37}$ → permissible / allowable / steepest grade.



⇒ Radius / Degree of curve

→ A curve is defined either by it's radius or by it's degree. The degree (D) of curve is the angle subtended at it's centre by 30.5m (100 feet) chord.

$$\boxed{D = \frac{1750}{R}}$$

→ Maximum Degree of curve or minimum radius:

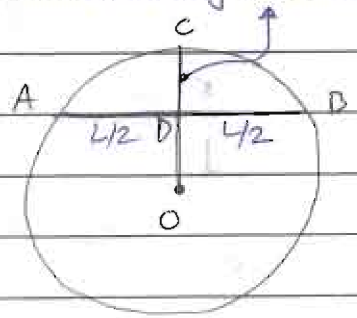
BG → 10° → $R_{min} = 175\,m$

MG → 16° → $R_{min} = 109\,m$

NG → 40° → $R_{min} = 44\,m$

⇒ Versine of curve

→ It is used to check the accuracy of curvature. For a chord AB, CD is known as versine of curve.



→ Using property of circle i.e. Intersecting chord theorem.

→ $\frac{L}{2} \times \frac{L}{2} = CD \times (2R - CD)$

→ Assuming $2R - CD \simeq 2R$

So, $\boxed{CD = \frac{L^2}{8R}}$

Q. For 20 m chain length and 600 m radius of curve, Degree of curve will be → $\frac{1146}{R} = \frac{1146}{600} = 1.91^\circ$

⇒ Super elevation

→ When train negotiates a horizontal curve it is subjected to centrifugal force which pushes the train away from the curve, hence results in increase of pressure on outer rail.

→ To encounter the effect of centrifugal force, the level of outer rail is raised above the inner rail by certain amount known as super elevation

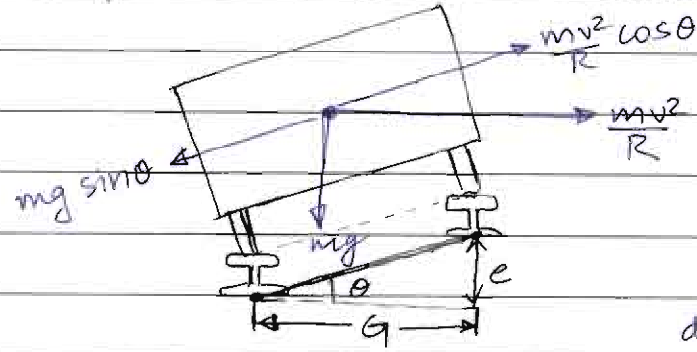
→ Objective of s/e

① To encounter the effect of centrifugal force.

② To provide equal distribution of wheel load on 2 rails

③ To provide smooth and comfortable ride with safety.

→ Friction force is not considered while deriving s/e.



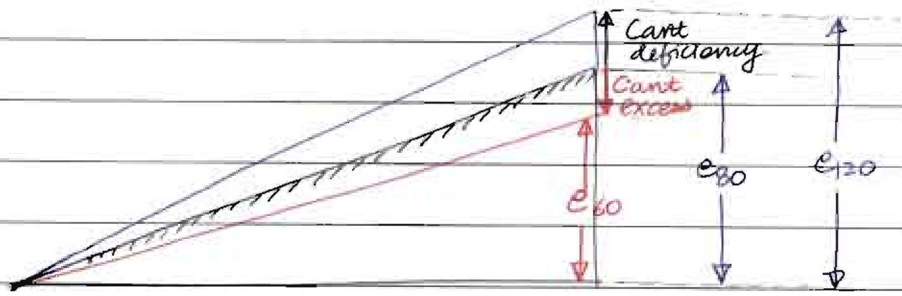
$G = \begin{cases} 1750 \text{ mm for BG} \\ 1058 \text{ mm for MG} \end{cases}$

↓ dynamic Gauge

$$mg\sin\theta = \frac{mv^2}{R}\cos\theta$$

$$\tan\theta = \frac{v^2}{gR} = \frac{e}{G} \Rightarrow \boxed{e = \frac{G v^2}{gR} = \frac{G V^2}{127R}}$$

(v in m/s, V in kmph)



e_{60}, e_{80}, e_{120} → equilibrium cant provided for 60 kmph, 80 kmph, 120 kmph

e_{80} → Cant provided → Called Actual Cant. (Ca)

→ G: Dynamic gauge is the c/c horizontal distance b/w the ~~gauge~~ rails

→ whereas wheel gauge is defined as the distance b/w inner face of rails

→ Track gauge of BG is 1676 mm

→ Maximum superelevation

→ Maximum value of superelevation in 1/10 to 1/12 of the gauge

Gauge	Group	Under Normal Conditions (mm)	With permission of CE (mm)
BG	A	** 165	185
	B, C	~~140~~ 165	—
	D, E	140	—
MG	Q R S	90	100
NG		65	75

⇒ Equilibrium speed and Equilibrium cant

→ Mixed traffic of fast and slow trains moves on the track. Cant provided for slow train will not suit fast train and vice versa. So actual cant provided for an average speed [equilibrium speed] so that all trains with different velocities can be allowed.

→ When load on both the rails is equal then, the cant provided is known as equilibrium cant.

⇒ Equilibrium speed

(a) > 50 kmph

(i) Speed from Martin formula

(ii) $V_{eq} = 0.75 \times V_{max}$

(b) < 50 kmph

(i) Martin formula or super elevation formula

(ii) $V_{eq} = V_{max}$.

Not much useful.

{Not used by IR currently}

** (c) Weighted average method

$$V_{eq} = \frac{v_1 n_1 + v_2 n_2 + \cdots}{n_1 + n_2 + \cdots} = \frac{\Sigma v_i n_i}{\Sigma n_i} = \frac{\Sigma v_i w_i n_i}{\Sigma w_i n_i}$$

weight

where $n_1, n_2, \ldots$ are no. of trains at a speed of $v_1, v_2, \ldots$

Q. Calculate the equilibrium speed of BG curve of 3° if the speed of several trains running on the line are

No of trains	Speed of train (kmph)
10	60
8	50
3	70

$V_{eq} = 57.62$ kmph

⇒ Cant Deficiency

→ The actual cant is provided on the basis of equilibrium or average speed. For the trains running at higher speed, the actual cant requirement is more than the provided cant for equilibrium speed. This shortage of cant is called cant deficiency

$$\boxed{C_d = C_{th} - C_a}$$

⇒ Limitation of Cant deficiency

Cant deficiency is limited because:

① Higher cant deficiency gives much discomfort

② Extra pressure on outer rail.

⇒ Allowable Cant deficiency

Gauge	Group	Normal C_d (mm)	Remark
BG	A & B	** 75	For BG group of A and B route ~~100 mm Cd is permitted with the~~ approval of CE
	C, D & E	75	
MG		50	
NG		40	

⇒ Cant Excess

→ Cant excess occurs when train travels around a curve at a speed less than the equilibrium speed.

$$\boxed{C_{ex} = C_a - C_{th}}$$

⇒ Maximum Cant Excess → For BG ⇒ 75 mm
→ For MG ⇒ 65 mm

NOTE: Book speed of the goods train should be taken into account for working out cant excess.

⇒ Speed of train

→ Safe speed on Railway track should be minimum of the following

(a) → Safe speed on curve as per Martin's formula (Not in use Nowadays by IR)

(b) Speed calculated as per cant Formula allowing cant deficiency

(c) Maximum speed as per transition length

(d) Maximum specified speed as per Railway Board

⇒ Calculation of speed on curve

~~I/ When speed < 100 kmph~~

(a) Martin's formula

(i) When speed < 100 kmph

① On transition curve → $V_{max} = 4.4\sqrt{R-70}$ kmph (BG, MG)

→ $V_{max} = 3.65\sqrt{R-6}$ kmph (NG)
(subjected to max. of 50 kmph)

R → Radius (in metres)

② On Non-transition curve

80% of the speed given by ① is allowed for respective gauge

(ii) When speed > 100 kmph

$$V_{max} = 4.58\sqrt{R}$$

NOTE: All the Martin's formulae are not in use by IR

(b) Used by IR

For BG, $V_{max} = 0.27\sqrt{R(C_a+C_d)}$

For MG, $V_{max} = 0.347\sqrt{R(C_a+C_d)}$

For NG, $V_{max} = 3.65\sqrt{R-6}$

Here, $C_a \rightarrow$ actual Cant in mm

$C_d \rightarrow$ Cant deficiency in mm

$R \rightarrow$ Radius of curve in m

Q- S/e provided for 70 kmph locomotive running on 900 m radius curve. $= \dfrac{GV^2}{127R} = 75.022$ mm

Q- What is the maximum speed of train which can run on a curved BG track with radius 650 m and s/e of 5.5 cm.

$$e = \frac{GV^2}{127R} \Rightarrow V = \sqrt{\frac{127 \times 650 \times (55+75)}{1750}} = 78.3 \text{ kmph}$$

Q- Minimum velocity of rolling stock permitted to run on BG track with radius 500 m and equilibrium cant 12 cm.

$$V = \sqrt{\frac{127 \times 500 \times (120-75)}{1750}} = 40.41 \text{ kmph}$$

Q- What actual cant will be provided in 3° curve of BG railway track for a maximum speed of Rolling stock 100 kmph.

$$R = \frac{1750}{3} = 583.33 \text{ m} \Rightarrow 100 = \sqrt{\frac{127 \times 583.33 \times (e+75)}{1750}}$$

$\Rightarrow e = 16.12$ cm < 16.5 cm

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→ Determining minimum Radius of curve for given permissible speed (V_m) and book speed (V_g) [Here cant and Radius both are unknown]

① Assume maximum permissible value of C_d and C_{ex} has reached

$$C_a = \frac{G V_m^2}{127 R} - C_{d,max} \rightarrow \text{based on } C_{d,max}$$

$$C_a = \frac{G V_g^2}{127 R} + C_{ex,max} \rightarrow \text{based on } C_{ex,max}$$

Equating both, we get

$$\boxed{R_{min,1} = \frac{13.76 (V_m^2 - V_g^2)}{C_{d,max} + C_{ex,max}}}$$

② considering maximum permissible limit of C_a and C_d are reached

$$C_{a,max} = \frac{G V_m^2}{127 R} - C_{d,max}$$

$$\boxed{R_{min,2} = \frac{13.76 V_m^2}{C_{a,max} + C_{d,max}}}$$

→ Provide $R_{provided} = \max(R_{min_1}, R_{min_2})$

Q. Determine the minimum radius on BG where max^m permissible speed is 120 kmph, $V_g = 65$ kmph

$$165 = \frac{13.76 (120)^2}{R_{min}} - 75 \Rightarrow R_{min} = 825.6 \text{ m}$$

$$\frac{13.76 (120)^2}{R_{min}} - 75 = \frac{13.76 (65)^2}{R_{min}} + 75 \Rightarrow R_{min} = 933.4 \text{ m}$$

So, provide $\boxed{R = 933.4 \text{ m}}$

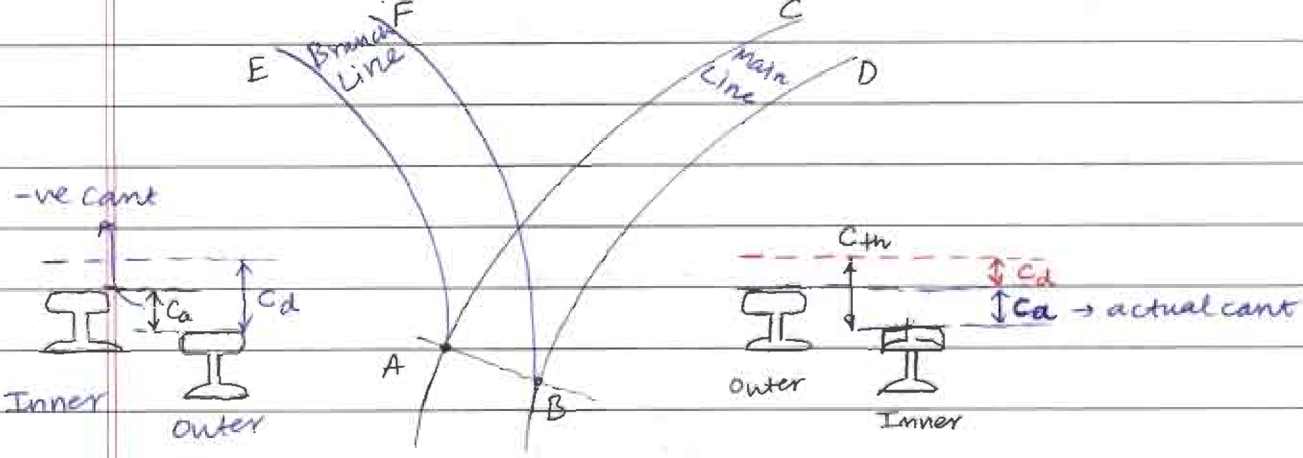
Q. Find the minimum permissible radius on a BG high speed route to permit a maximum speed of 140 kmph

→ $165 = \frac{13.76 V_m^2}{R_{min}} - 75 \Rightarrow R_{min} = 1123.73\ m$

⇒ Negative ~~Relative~~ superelevation

→ If the level of outer rail in curve is above the level of inner rail, then the s/e is called positive s/e and if the level of outer rail is below the level of inner rail, the s/e is known as negative s/e.

→ When a mainline on curve has a turnout of opposite curvature, leading to a branch line, then the level of outer rail in branch line is kept lower than level of inner rail, this leads to negative super elevation for branch line.



→ Steps to calculate speed on mainline

① → Calculate theoretical cant on branch line by assuming some velocity, $e_{th} = \frac{GV^2}{127R}$

② → By deducting cant deficiency in branch line, calculate the actual cant, $e_a = e_{th} - e_d < 0$

③ → This negative s/e will become actual s/e for main line.

④ → Permissible speed on main line is obtained based on

$$e_{th} = e_a + e_d$$