3. GEOMETRIC DESIGN OF THE TRACK

DIFFERENT GAUGES

Gauge	Distance between rails
Broad gauge	1.676 m
Meter gauge	1.0 m
Narrow gauge	0.762 m
Light gauge (feather track)	0.610 m
Standard gauge (used in delhi metro)	1.435 m

SAFE SPEED ON CURVES BASED ON MARTINS FORMULA

(a) For Transition Curve

(i) For B.G & M.G. $V = 4.35\sqrt{R - 67}$ where, V is in kmph.

(ii) For N.G $V = 3.65\sqrt{R - 6}$ for V is km/hr.

(b) For Non-Transition Curve $V = 0.80 \times \text{speed calculated in (a)}$

(c) For High Speed Trains $V = 4.58\sqrt{R}$

SAFE SPEED BASED ON SUPER ELEVATION

(a) For Transition curves

(i) For B.G $v = 0.27\sqrt{(c_a + c_d)R}$

(ii) For M.G $v = 0.347\sqrt{(c_a + c_d)R}$

The above two formula based on the assumption that G = 1750 mm for B.G
G = 1057 mm for N.G

and $e = \dfrac{Gv^2}{127R}$ where, e = super elevation.

(iii) For N.G $v = 3.65\sqrt{R - 6}$

where, v = Speed in km/hr
R = Radius of curve in 'mm'
c_a = Actual cant in 'mm'
c_d = Cant deficiency in 'mm'.

SPEED FROM THE LENGTH OF TRANSITION CURVE

(a) For speed upto 100 km/hr.

$$V_{max.} = \frac{134\,L}{c_a} \text{ or } \frac{134\,L}{c_d} \quad \text{(min. of two is adopted)}$$

where, L= Length of transition curve based on rate of change of cant as 38 mm/sec. for speed upto 100 km/hr & 55 mm/sec for speed upto 100 km/hr & 55 mm/sec for high speeds.
c_a = Actual cant in 'mm'.
c_d = Cant deficiency in 'mm'.

(b) For high speed trains (speed > 100 km/hr)

Either, $V_{max} = \dfrac{198\,L}{c_a}$ or $\dfrac{198\,L}{c_d}$

Minimum of the two is adopted.

RADIUS & DEGREE OF CURVE

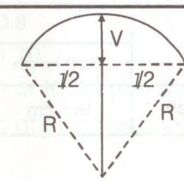
$D = \dfrac{1720}{R}$ If one chain length = 30 m.

$D = \dfrac{1150}{R}$ If one chain length = 20 m
where, R = Radius

$$D = \text{Degree of curve} = \begin{cases} 10° \rightarrow \text{B.G} \\ 16° \rightarrow \text{M.G} \\ 40° \rightarrow \text{N.G} \end{cases}$$

VERSINE OF CURVE (V)

$V = \dfrac{L^2}{8R}$



GRADE COMPENSATION

For B.G → 0.04% per degree of curve
M.G → 0.03% per degree of curve
M.G → 0.02% per degree of curve

SUPER ELEVATION (CANT) (e)

$$e = \frac{GV^2}{127R}$$

where, e = Super elevation in meter
V = Speed in km/hr., R = Radius in meter
G = Gauge distance between the centre of rails.

EQUILIBRIUM CANT (e′)

$$e' = \frac{GV_{av}^2}{127R}$$

where, V_{av} = Average speed or equilibrium speed.

EQUILIBRIUM SPEED OR AVERAGE SPEED (V_{av})

(a) When maximum Sanctioned Speed > 50 km/hr.

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

(b) When Sanctioned speed < 50 km/hr

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

(c) Weighted Average Method

$$V_{av} = \frac{n_1v_1 + n_2v_2 + \ldots}{n_1 + n_2 + \ldots}$$

where, n_1, n_2, n_3... etc. are number of trains running at speeds v_1, v_2, v_3 ... etc.

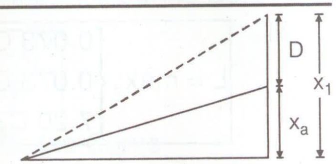
MAXIMUM VALUE OF CANT (e_{max})

	B.G. Track		M.G.	N.G.
	<120 kmph	>120 kmph		
e_{max} (actual)	16.5 cm	18.5 cm	10.0 cm	7.6 cm

CANT DEFICIENCY (D)

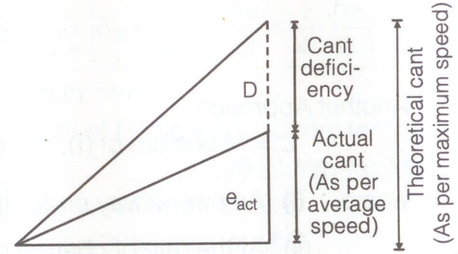
$$\text{Cant deficiency} = x_1 - x_A$$

where,
x_A = Actual cant provided as per average speed
x_1 = Cant required for a higher speed train.



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

where, e_{th} = Theoretical cant
e_{act} = Actual cant
D = Cant deficiency.

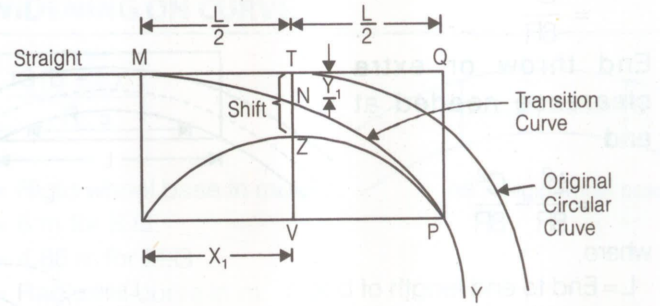


	B.G. Track		M.G.	N.G.
	<100 kmph	>100 kmph		
D_{max}	7.60 cm	10.0 cm	5.10 cm	3.80 cm

TRANSITION CURVE (CUBIC PARABOLA)

Equation of transition curve;

$$y = \frac{X^3}{6RL}$$



(a) Shift (S)

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

where, S = Shift in 'm'
L = Length of transition curve in 'm'
R = Radius of circular curve in 'm'.

(b) **Length of Transition Curve**: According to Indian Railway.

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

where,

L = Length of transition curve in 'm'.

V_{max} = Maximum permissible speed in km/hr.

C_a = Actual cant on curve in 'cm'.

C_d = Cant deficiency in 'cm'.

Another Approach

L = Maximum of (I), (II), (III) and (IV).

where, (i) As per railway code, $L = 4.4\sqrt{R}$ where L & R in 'm'.

(ii) At the rate of change of super elevation of 1 in 360.

(iii) Rate of change of cant deficiency, say 2.5 cm is not exceeded.

(iv) Based on rate of change of radial acceleration with radial acceleration of 0.3048 m/s^2.

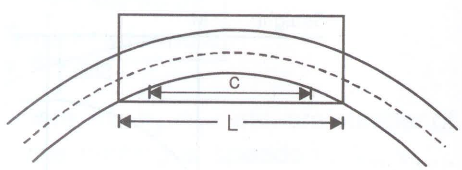
$$L = \frac{3.28V^3}{R}$$ where V is in m/s.

EXTRA LATERAL CLEARANCE ON CURVES

(a) **Over throw or extra clearance needed of centre**

$$= \frac{C^2}{8R}$$

(b) **End throw or extra clearance needed at end**



$$= \frac{L^2}{8R} - \frac{C^2}{8R}$$

where,

L = End to end length of bogie

C = Centre to centre distance of two bogie.

R = Radius of curve.

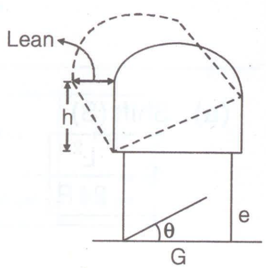
(c) **Lean (L)**

$$L = \frac{h \cdot e}{G}$$

where, h = Height of vehicle

e = Super elevation

G = Gauge.



(d) **Total Extra Lateral Clearance Needed Outside the Curve**

$$E_1 = \text{end throw} = \frac{L^2 - C^2}{8R}$$

(e) **Total Extra Lateral Clearance Inside the Curve**

$$E_2 = \text{Overthrow} + \text{Lean} + \text{Sway}$$

$$E_2 = \frac{c^2}{8R} + \frac{he}{G} + \frac{1}{4}\cdot\frac{he}{G}$$

where, R = Radius of curve in 'mm'.

L = End to end length of bugie = 21340 mm for B.G
= 19510 mm for M.G

h = Height of bougie = 4025 mm for B.G
= 3355 mm for M.G

c = Bogie centres distance = 1475 mm for B.G
= 13715 mm for M.G

e = Super elevation in mm

G = 1.676 m for B.G = 1.0 m for M.G

EXTRA CLEARANCE ON PLATFORMS

(a) **For platforms situated inside of curve**

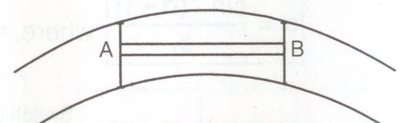
$= E_2 - 41$ mm.

(b) **For platforms situated outside the curve**

$= E_1 - 25$ mm.

GAUGE WIDENING ON CURVES

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



where,

B = Rigid wheel base in meters.
= 6 m for B.G.
= 4.88 m for M.G

R = Radius of curve in m.

L = Lap of flange in 'm'. $= 0.02\sqrt{h^2 + Dh}$

h = Depth of wheel flange below rails in cm.

D = Diameter of wheel in cm.

w_e = Gauge widening in cm.

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