Geometric Design of Railway Track

The geometric design of railway tracks plays a crucial role in ensuring the efficient and safe movement of trains. It encompasses various factors, including alignment, gradients, curves, super elevation, and transitions. Railway engineers employ advanced techniques and mathematical principles to optimize track geometry, aiming to strike a balance between speed, comfort, and safety.

Different gauges

Gauge	Distance between rails
Broad gauge	1.676 m
Meter gauge	1.0
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√5-67 where, V is in kmph.

(ii) For N,G V = 3.65√R-6 For V is km/hr.

(b) For non-Transition curve

V=0.80 × speed calculated in (a)

(c) For high speed Trains V=4.58√R

Safe speed Based on Superelevation

(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 $e = \frac{Gv^2}{127R}$ 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.

$V_{\max} = \frac{134}{c_a} or \frac{134L}{c_d}$ (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>100km/hr)

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

Minimum of the two is adopted.

Radius & Degree of curve

$D = \frac{1720}{R}$ if one chain length = 30 m.

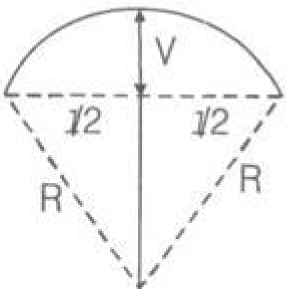
$D = \frac{1150}{R}$ if one chain length = 20 m

Where, R = Radius

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

Virsine of Curve (V)

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



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)

$e = \frac{GV_{av}^2}{127R}$ Where, V_{av} = Average speed or equilibrium speed.

Equilibrium speed or Average Speed (Vav)

(a) when maximum sanctioned speed>50km/hr.

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

(b) When sanctioned speed <50 km/hr

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

(c) Weighted Average Method

$$V_{av} = \frac{n_1 v_1 n_2 v_2 + \ldots}{n_1 + n_2 + \ldots}$$

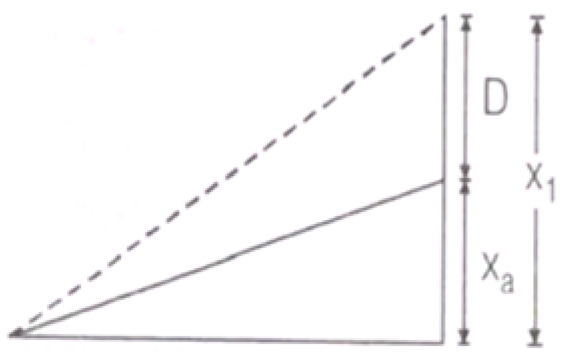
Where, $n_1, n_2, n_3 \ldots$ etc. are the number of trains running at speeds $v_1, v_2, v_3 \ldots$ etc.

Maximum value of Cant emax

	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)

Cant deficiency = $x_1 - x_A$

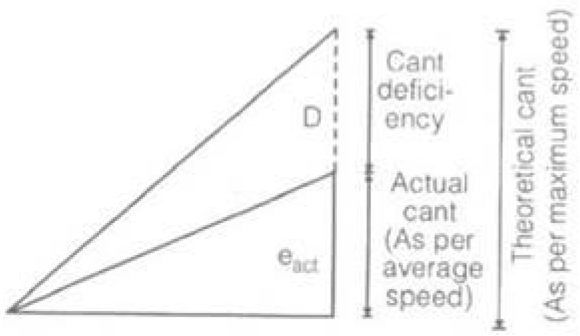


Where,

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

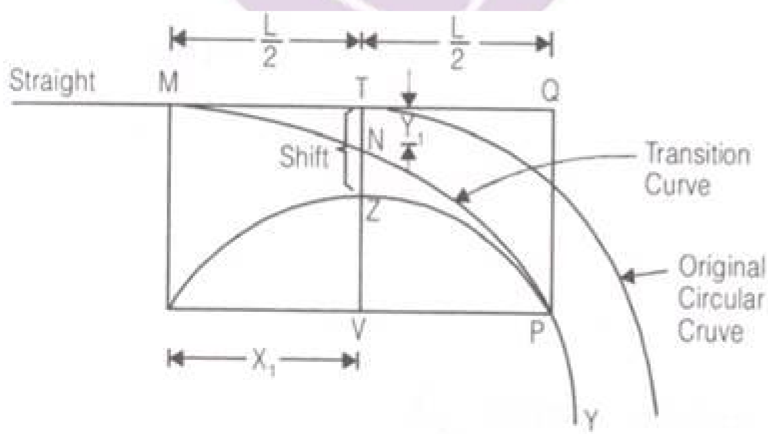
D = Cant deficiency.

	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 carve in 'm'

R = Radius of circular curve in 'm'

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

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

Where,

L = Length of transition curve in 'm'

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

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√R where L&R 'm'

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

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

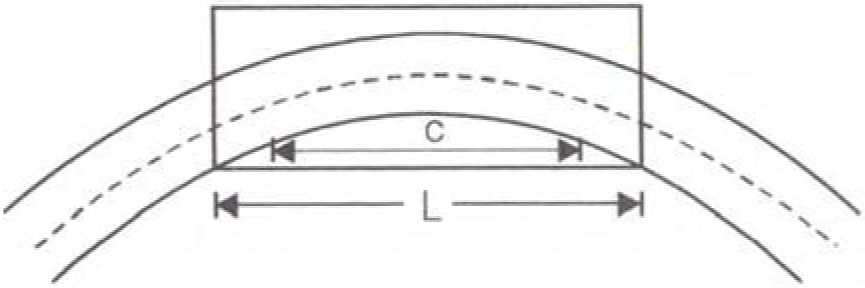
(iv) Based on the rate of change of radial acceleration with radial acceleration of 0.3048 m/s^2.

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

Extra Lateral Clearance on curves

(a) overthrow or extra clearance needed of centre = $\frac{C^2}{8R}$

(b) End throw or extra clearance needed at end



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

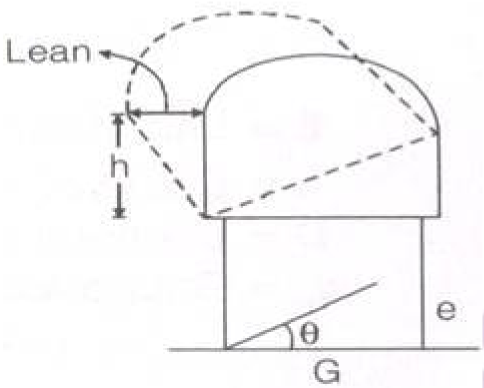
Where,

L = End to end length of bogie

C = Centre to center distance of two bogie.

R = Radius of curve.

(c) **Lean (L)**



$L = \frac{h.e}{G}$ Where, h = Height of vehicle

E = Super elevation

G = Gauge.

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

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

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

E_1 = Overthrow + Lean + Sway

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

Where, = 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 bogie = 4025 mm for B.G

3350 mm for M.G

C = Bogie centres distance = 1475 mm for B.G

3355 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

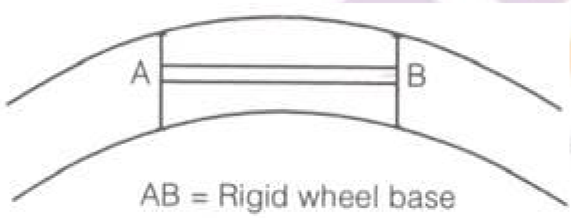
= E_2-41 mm.

(b) For platforms situated outside the curve

= E1-25 mm.

Gauge Widening on Curves

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



Where,

B = Right wheel base in meters.

= 6m for B.G

= 4.88 m for M.G

R = Radius of curve in m.

L = Leap 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.

The geometric design of railway tracks is a complex and vital aspect of modern rail infrastructure. By carefully considering alignment, gradients, curves, and transitions, engineers aim to create efficient, safe, and comfortable rail networks. Advanced technologies have revolutionized the design process, allowing for precise modeling and optimization. As rail networks continue to expand and evolve, the importance of geometric design in ensuring efficient and safe train operations will remain at the forefront of railway engineering.

Thanks!

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