2020

MADE EASY WORKBOOK

Detailed Explanations of Try Yourself *Questions*

Civil Engineering

Railway, Airport, Tunneling, Dock and Harbour Engineering

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2 Geometric Design of Track

Detailed Explanation of Try Yourself Questions

T1 : Solution

We know that, by Martin's formula for a *BG* track in a transition zone for speed > 100 kmph

$$V = 4.58\sqrt{R}$$

where V is maximum permissible speed in kmph and R is radius of curvature in meters

Now, $V = 110$ kmph (given)

$\therefore$ $110 = 4.58\sqrt{R}$

$\Rightarrow$ $R = 576.84$ m

Degree of curvature is given as

$$\frac{2\pi R}{360} = \frac{30}{D}$$

$\therefore$ $D = 2.98° \approx 3°$

For $D = 3°$

$$R = \frac{1718.9}{D°} = \frac{1718.9}{3°} = 573 \text{ m}$$

Theoretical superelevation is given by

$$e_{th} = \frac{GV^2}{127R} \text{ where G = Gauge distance}$$

$$= \frac{(1.676 \times 100) \times 110^2}{127 \times 573} = 27.868 \text{cm}$$

Now, maximum cant deficiency of speeds higher then 100 kmph

$D_{max} = 10$ cm

$\therefore$ actual superelevation, $e_{act} = e_{th} - D_{max}$

$= 27.868 - 10 = 17.868$ cm (> 16.5 cm as $V < 120$ kmph)

(Not OK)

$\therefore$ Now use Degree of curvature, $D = 2^\circ$

Radius of curvature is, $\frac{2\pi R}{360^\circ} = \frac{30}{D}$

$\therefore \quad R = 860 \text{ m}$

Now, theoretical superelevation is given as,

$$e_{th} = \frac{GV^2}{127R} = \frac{(1.676\times 100)\times 110^2}{127\times 860}$$

$$e_{th} = 18.567 \text{ cm } (> 16.5 \text{ cm})$$

$\therefore \quad e_{act} = 18.567 - 10 = 8.567 \text{ cm } (< 16.5 \text{ cm})$ (Hence OK)

Length of transition curve, $L = ?$

(i) $L = 4.4\sqrt{R} = 4.4\sqrt{860} = 129.03 \text{ m}$

(ii) $L = 3.6e_{act} = 3.6\times 8.567 = 30.84 \text{ m}$

(iii) $L = \frac{V^3}{CR} = \frac{\left(110\times\frac{5}{18}\right)^3}{0.3048\times 860} = 108.832 \text{ m}$

Thus, length of transition curve $= 129.03 \approx 130$ m (maximum of above 3).

Radius = 860 m, $e_{act} = 8.567$ cm, Degree of curvature = 2°, $V_{max} = 110$ kmph

T2 : Solution

As per Indian Railways the length of the transition curve is the greater out of the following three values

(i) $L = 7.20 \times e = 7.20 \times 12 = 86.4 \text{ m}$

(ii) $L = 0.073\, D \times V_{max} = 0.073\, D \times 7.6 \times 100 = 55.48 \text{ m}$

(iii) $L = 0.073\, e \times V_{max} = 0.073 \times 12 \times 100 = 87.6 \text{ m} \approx 88 \text{ m}$

Hence length of curve is to be taken as 88 m

Now, $L = 90$ m (say)

The equation of cubic parabola which is used as a transition curve is given by

$$y = \frac{x^3}{6\,RL}$$

But $R = \frac{1720}{\text{Degree of curve}} = \frac{1720}{4^\circ} = 430 \text{ m}$

Taking offsets at 15 m intervals, we get

$$y_{15} = \frac{(15)^3 \times 100}{6\times 430\times 90} = 1.45 \text{ cm}$$

$$y_{30} = \frac{(30)^3 \times 100}{6\times 430\times 90} = 11.63 \text{ cm}$$

$$y_{45} = \frac{(45)^3 \times 100}{6 \times 430 \times 90} = 39.24 \text{ cm}$$

$$y_{60} = \frac{(60)^3 \times 100}{6 \times 430 \times 90} = 93.02 \text{ cm}$$

$$y_{75} = \frac{(75)^3 \times 100}{6 \times 430 \times 90} = 181.69 \text{ cm}$$

$$y_{90} = \frac{(90)^3 \times 100}{6 \times 430 \times 90} = 313.95 \text{ cm}$$

Chainage (m)	15	30	45	60	75	90
Offset (cm)	1.45	11.63	39.24	93.02	181.69	313.95

Shift of the curve, $S = \frac{L^2}{24R} = \frac{(90)^2}{24 \times 430} = 0.785 \text{ m}$

T3 : Solution

(i) **Equilibrium speed:**

15 trains at a speed of 50 km/hr
12 trains at a speed of 60 km/hr
8 trains at a speed of 70 km/hr
3 trains at a speed of 80 km/hr

Equilibrium speed, V_{avg} = Weighted average of speed

$$V_{avg} = \frac{(15 \times 50) + (12 \times 60) + (8 \times 70) + (3 \times 80)}{15 + 12 + 8 + 3}$$

$$= 59.73 \text{ Kmph}$$

(ii) **Cant Provided:**

Given: degree of curve, $D = 3°$

$$\therefore \quad R = \frac{1720}{3} = 573.33 \text{ m} \qquad \left[\because \; D = \frac{1720}{R}\right]$$

actual cant provided, $e_{act} = \frac{GV_{avg}^2}{127R} \text{ m}$

For BG track, $G = 1.676$ m

$$\therefore \quad e_{act} = \frac{1.676 \times (59.73)^2}{127 \times 573.33}$$

$$= 0.082 \text{ m or } 8.21 \text{ cm} < 16.5 \text{ cm (max)}$$

Thus, the actual cant provided is 8.21 cm.

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3 Points and Crossings

Detailed Explanation *of* Try Yourself Questions

T1 : Solution

With the given data,

$$\alpha = 6° \ 42' \ 35''$$
$$\beta = 1° \ 34' \ 27''$$
$$G = 1.676 \text{ m}$$
$$d = 11.43 \text{ cm} = 0.1143 \text{ m}$$
$$x = 0.85 \text{ m}$$

(i) Radius, $R_0 = \dfrac{G - d - x\sin\alpha}{\cos\beta - \cos\alpha}$

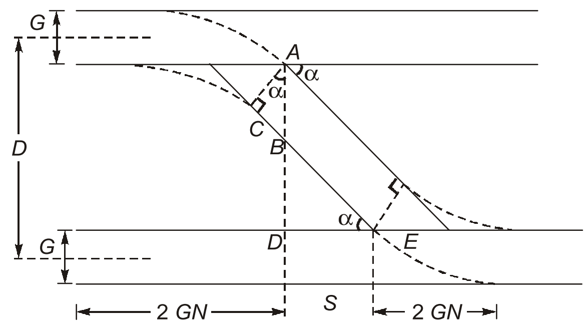
$$= \frac{1.676 - 0.1143 - 0.85 \times 0.1168}{0.9996 - 0.9932} = 229 \text{ m}$$

$\therefore$ $R = R_0 - \dfrac{G}{2} = 229 - 0.838 = 228.162 \text{ m}$

(ii) Crossing lead, $L = x\cos\alpha + (G - d - x\sin\alpha)\cot\dfrac{\alpha+\beta}{2}$

$$= 0.85 \times 0.9932 + 1.4625 \times 13.809$$
$$= 0.844 + 20.180$$
$$= 21.024 \text{ m}$$

T2 : Solution



Let N = Number of crossing

α = Angle of crossing

G = Gauge distance (1.676 m in case of BG)

D = Centre to centre distance between two tracks

$2GN$ = Length of turnouts

S = Straight horizontal portion between the turnouts

$N = \cot\alpha$

From Δ BDE, $S = DE = BD\cot\alpha$

$= (AD - AB)\cot\alpha$

$= [(D - G) - G\sec\alpha]\cot\alpha$ $\quad \left[\because \cos\alpha = \dfrac{AC}{AB} \text{ and } AC = G\right]$

$= \left[(D-G) - G\sqrt{1+\tan^2\alpha}\right]N$

$= \left[(D-G) - G\sqrt{1+\dfrac{1}{\cot^2\alpha}}\right]N$

$= \left[(D-G) - \dfrac{G}{N}\sqrt{1+N^2}\right]N$

$\Rightarrow$ $S = (D-G)N - G\sqrt{1+N^2}$

But overall length of cross over $= 4\,GN + S$

$= 4\,GN + (D-G)N - G\sqrt{1+N^2}$

Given that G = 1.676 m, N = 8.5, D = 5 m

$\therefore$ Overall length of cross over $= 4 \times 1.676 \times 8.5 + (5 - 1.676) \times 8.5 - 1.676\sqrt{1+(8.5)^2}$

= 70.89 m

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4 Track Stresses, Traction and Tractive Resistances

Detailed Explanation of Try Yourself Questions

T1 : Solution

Number of wagons in the train = 20

Weight of each wagon = 18 tonnes

$\therefore$ Total weight of wagons = $18 \times 20 = 360$ tonnes

Also, weight of locomotive = 120 tonnes

$\therefore$ Weight of train = $360 + 120 = 480$ tonnes

Now, number of driving axles in a 2-8-2 locomotive, $n = \frac{8}{2} = 4$

and load on each driving axle = 22.5 tonnes (given)

$\therefore$ Hauling capacity = $\mu n W$

where μ = coefficient of friction which has a value = $\frac{1}{6}$

n = number of driving axles in locomotive

W = load on each driving axle

$\therefore$ Hauling capacity = $\frac{1}{6} \times 4 \times 22.5 = 15$ tonnes

Tractive effort of locomotive = 15 tonnes

We know that total resistance = $RT_1 + RT_2 + RT_3 + W \tan\theta$

where RT_1 = Rolling resistance independent of speed

RT_2 = Resistance dependent on speed

RT_3 = Atmospheric resistance

Now, RT_1 = RT_1 for locomotive + RT_1 for wagons

= $3.5 \times 120 + 2.5 \times 360 = 420 + 900 = 1320$ kg or 1.32 tonnes

RT_2 = 2.65 tonnes (given)

RT_3 = $0.0000006\, WV^2$

where W = Total weight of train = 480 tonnes

V = Speed of train in kmph

$\therefore$ $RT_3 = 0.0000006 \times 480 \times (50)^2 = 0.72$ tonnes

Now, Hauling capacity = Total resistance

But Total resistance = $RT_1 + RT_2 + RT_3 + W \tan\theta$

$\Rightarrow$ $15 = 1.32 + 2.65 + 0.72 + 480 \tan\theta$

$$\Rightarrow \quad \tan\theta = \frac{10.31}{480}$$

$$\Rightarrow \quad \tan\theta = \frac{1}{46.56}$$

Thus the steepest gradient will be 1 in 47 (approx.)

T2 : Solution

Total weight of train = Weight of locomotive + Weight of wagons

= $120 + 20 \times 18 = 480$ tonnes

Rolling resistance of each wagon = $2.5 \times 18 = 45.0$ kg

Rolling resistance of all wagons = $45 \times 20 = 900$ kg

Rolling resistance of locomotive = $120 \times 0.35 = 42$ kg

Therefore total resistance of locomotive and wagon

= 942 kg = 0.942 tonnes

Atmospheric resistance = $0.0000006\, wV^2$

= $0.0000006 \times 480 \times 50^2 = 0.72$ tonne

Resistance depending upon speed = $0.00008\, wV$

= $0.00008 \times 480 \times 50 = 1.92$ tonnes

Train resistance = Rolling resistance + Resistant depending on speed + Atmospheric resistance + Resistance due to gradient

$$= 0.942 + 1.92 + 0.72 + \frac{1}{g} \times 480$$

where the gradient required is 1 in g.

Equating the resistance with tractive effort of locomotive

$$12 = 3.582 + \frac{480}{g}$$

$$\Rightarrow \quad g = \frac{480}{8.418} = 57 = 60(\text{say})$$

$\therefore$ Steepest gradient permissible is 1 in 60.

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