CIVIL ENGINEERING

GATE | PSUs

TRANSPORTATION ENGINEERING

Volume - I : Study Material with Classroom Practice Questions

Transportation Engineering

Solutions for Volume : I Classroom Practice Questions

Chapter- 1
Highway Development and Planning

01. Ans: (d)

Sol:

Road	**Length (km)**	**Number of with population**			**Utility**	**Utility/km**
		< 2000	**2000 – 5000**	**> 5000**		
P	20	8	6	1	8×0.5+6×1+1×2 = 12	12/20 = 0.6
Q	28	19	8	4	19×0.5+8×1+4×2= 25.5	25.5/28 =0.91
R	12	7	5	2	7×0.5+5×1+2×2= 12.5	12.5/12=1.04
Weightage factor		0.5	1	2		

∴ RQP

02. Ans: (a)

Sol:

Road Lane	**Length (cm)**	**Number of villages with population ranges**				Industrial Product	**Utility**	**Utility/km**
		1000-2000	2000-5000	5000-10000	>10000			
P	300	100	80	30	6	200	100×1+80×2+30×3+6×4+200 =574	574/300 =1.91
Q	400	200	90	00	8	270	200×1+90×2+8×4+270	682/400 =1.70
R	500	240	110	70	10	315	240×1+110×2+70×3+10×4+315 =1025	1025/500 =2.05
S	550	248	112	73	12	335	248×1+112×2+73×3+12×4+335 =1074	1074/550 =1.95
Weightage factor		1	2	3	4			

∴ RSPQ

Chapter- 4
Highway Geometric Design - Gradients

Common data for Questions 01 & 02

01. Ans: (b)

Sol: Height of crown $= \frac{W}{2n} = \frac{3.5 \times 1000}{2 \times 60}$

$= 29.2$ mm

02. Ans: (d)

Sol: Height of crown $= \frac{W}{2n} = \frac{3.5 \times 1000}{2 \times 40}$

$= 43.75$ mm

03. Ans: (b)

04. Ans: (a)

Sol: $G.C = \frac{30 + R}{R}$

$G.C = \frac{30 + 50}{50} = 1.6$

Max $GC = \frac{75}{50} = 1.5$ $\quad \therefore GC = 1.5$

The compensated gradient = 6% – 1.5

= 4.5%

05. Ans: (a)

Sol: Height of crown $= \frac{W}{2n} = 7.5\,cm$

$\frac{W}{2n} = 7.5 \quad 2n = \frac{9 \times 100}{7.5}$

$n = 60 \Rightarrow$ 1 in 60

06. Ans: (d)

07. Ans: (a)

Chapter- 5
Highway Geometric Design - Sight Distances

01. Ans: (c)

Sol: B.D = 16 m,

f = 0.4

$\frac{V^2}{254f} = 16 \Rightarrow \frac{V^2}{254 \times 0.4} = 16$

V = 40.3 kmph ≈ 40 kmph

02. Ans: (c)

Sol: V = 30 kmph,

f = 0.4

$BD_{down} = 2\ BD_{up}$

$\frac{V^2}{254(f - 0.01n)} = \frac{2 \times V^2}{254(f + 0.01n)}$

f + 0.01 n = 2 f – 0.02n

0.03 n = 0.4

n = 13.33%

03. Ans: (b)

Sol: V = 72 kmph, n = 2%,

f = 0.15,

t=1.5 sec

$$SSD = 0.278\,Vt + \frac{V^2}{254(f+0.01n)} = 150\text{ m}$$

04. Ans: (b)

Sol: V = 60 kmph

t = 2.5 sec ,f = 0.36

$$\frac{0.278\,Vt}{V^2/254(f+0.01n)} = \frac{6}{5}$$

$$0.278\times 60\times 2.5 = \frac{6}{5}\left[\frac{60^2}{254(0.36+0.01n)}\right]$$

$$n = 4.78 \simeq 4.8$$

05. Ans: (c)

Sol: V = 60 kmph, t = 2.5 sec, f = 0.35

$$SSD = 0.278\,Vt + \frac{V^2}{254f}$$

$$= 0.278\times 60\times 2.5 + \frac{60^2}{254\times 0.35} = 82.1\text{ m}$$

SSD for single two way traffic = 2 × SSD

= 2 ×82.1 = 164.2 m

06. Ans: (c)

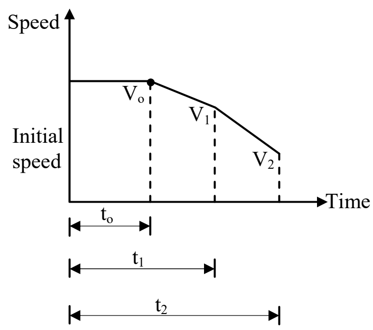
Sol: ISD = 2 × 80 = 160 m

07.

Sol:

There are 3 phases in the problem

1. Driver lifts foot from accelerator and moves it to brake pedal – the velocity is uniform.
2. Deceleration increases from zero to maximum
3. Braking system locks the wheels and deceleration assumed to be constant until vehicle strikes the stationary vehicle



A = fg = 0.75× 9.81 = 7.35 m/s^2

During 1st phase, assume driver reaction time 0.5 sec

$$v_o = v_1 + \frac{a}{2}(t_1 - t_o)$$

During 3rd phase, deceleration assumed assumed to be uniform

$$v_1 = \sqrt{v_2^2 + 2aS} = \sqrt{11.18^2 + 2\times 7.35\times 27.45}$$

= 23 m/s = 82.76 kmph

$$v_o = 82.76 + \frac{7.35}{2}(0.8-0.5)$$

= 83.86 kmph

08.

Sol: $\frac{dv}{dt} = 3 - 0.04v$

$A = 3$, $\beta = 0.04$, $t = 5 - 0.75 = 4.25$

Width of intersection = 7.5 m

Equation for distance as a function of time

$$x = \frac{\alpha t}{\beta} - \frac{\alpha}{\beta^2}(1 - e^{-\beta t}) + \frac{v_o}{\beta}(1 - e^{-\beta t})$$

v_o = initial speed = 0

$$= \frac{3(4.25)}{0.04} - \frac{3}{(0.04)^2}(1 - e^{-0.04\times 4.25}) + 0$$

x = 25.62 m

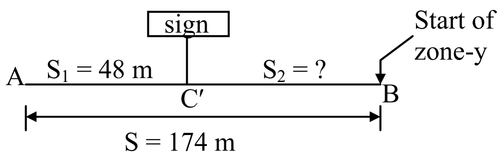
Intersection + length of car

7.5 + 6.1 = 13.6 m

$\therefore$ He can clear the intersection

10. Ans: 142

Sol: For normal driver with 6/6 vision the position of sign post is shown below.



$S_2 = 174 - 48 = 126$ m

S_2 = The distance from sign post to the start of zone-y

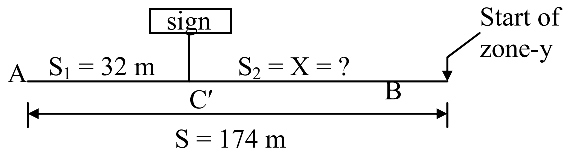
S_1 = Distance traveled by the vehicle during perception – reaction time for 6/6 vision driver

S = total distance required to reduce the speed to 30 kmph from design speed.

For a driver with 6/9 vision (with defective sight), the distance of sign post should be nearer as compared to driver with normal sight.

$\therefore$ Modified $S_1 = \frac{6}{9} \times 48 = 32\,m$

The position of sign post is as shown below



The distance from modified position of sign post to the start of zone-y (i.e. C′B) = 174 – 32 = 142 m.

Chapter- 6
Highway Geometric Design - Overtaking Sight Distance

Common data for Questions 01, 02 & 03

01. Ans: (c)

Sol:

V = 80 kmph a = 2.5 kmph/sec

V_b = 50 kmph S = 16 m

t = 2 sec

$$T = \sqrt{\frac{14.4s}{A}} = \sqrt{92.16}\,sec$$

= 9.6 sec

OSD = $d_1 + d_2$

= $0.278\, V_b\, t + (0.278\, V_b\, T + 2s)$

= 193.24 m

02. Ans: (d)

Sol: OSD = $d_1 + d_2 + d_3$

$= 0.278V_bt+(0.278V_bT+2s)+0.278\ VT$

$= 406.74$ m

03. Ans: (c)

Sol: Since division is there

OSD = $d_1 + d_2 = 193.24$ m

Common data for Questions 04 & 05

04. Ans: (c)

Sol: V = u + at

u = 100 kmph

= 27.7 m/s

= 27.7 + 0.8 × 5

V = 31.72 m/s

$V^2 - u^2 = 2 \times as$

$(31.7)^2 - (27.7)^2 = 2 \times 0.8 \times S$

S = 148.5 m

Distance traveled in next 2 sec

= 323 – 148.5

S = 174.5 m

Now, u = 31.7 m/s

$S = ut + ½ at^2$

$$174.5 = (31.7 \times 5) + \left(\frac{1}{2}\times a\times 5^2\right)$$

$a = 1.2$ m/sec^2

05. Ans: (d)

Sol: Distance traveled in overtaking process (d_2)

$d_2 = (V_b\ T + 2\ s)$ $S_1 = 25$ m

$= (V_b\ T + S_1 + S_2)$ $S_2 = 20$ m

$$T = \sqrt{\frac{4s}{a}} = 10.6 \text{ sec}$$

$d_2 = (0.278 \times 100 \times 10) + (25 + 20)$

= 323 mm

Common data for Questions 06 & 07

06. Ans: (c)

Sol: OSD = $d_1 + d_2$

V = 22.22 m/s $V_b = 16.67$ m/s

$a = 0.7$ m/s^2

$S = (0.7\ V_b + l) = 17.67$ m

$$T = \sqrt{\frac{4s}{a}} = 10.05 \text{sec} \qquad t = 2 \text{ sec}$$

OSD = $d_1 + d_2 + d_3$

$= V_b\ t + (V_b\ T + 2s) + VT$

= 236.21 + (22.22 ×10.05)

= 459.521 m

≈ 457.2 m

07. Ans: (d)

Sol: Desirable length of OZ = 5 OSD

$= 5\ (d_1 + d_2 + d_3)$

= 5 ×459.521

= 2298 m

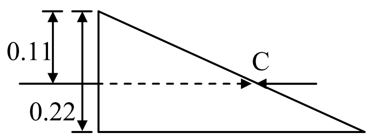
≃ 2300 m

Chapter- 7
Highway Geometric Design - Horizontal Curves

Common data for Questions 01 & 02

01. Ans: (a)

Sol: $e = \frac{V^2}{225R} = \frac{65^2}{225 \times 600} = 0.031$



E = e w = 0.031 × 7 = 0.22 m

w.r.t centre line = 0.11 m

02. Ans: (b)

Sol: w.r.t inner edge ; E = 0.22 m

03. Ans: (c)

Sol: $e_{cal} = \frac{V^2}{225R} = \frac{65^2}{225 \times 125} = 0.15$

$e_{cal} > 0.07$

∴ V = 65 kmph is not suitable

$0.07 + f = \frac{V^2}{127R} \rightarrow f = \frac{65^2}{127 \times 125} - 0.07$

$= 0.196 > 0.15$

V_a should be calculated

$0.07 + 0.15 = \frac{V_a^2}{127 \times 125}$

$V_a = 59.1$ kmph

Common data for Questions 04 to 06

04. Ans: (b)

Sol: $e + f = \frac{V^2}{127R}$

$e + 0.15 = \frac{100^2}{127 \times 500}$

$\Rightarrow e = 0.00748 = 0.74\%$

05. Ans: (b)

Sol: $f = \frac{V^2}{127R} = \frac{100^2}{127 \times 500} = 0.157 \simeq 0.16$

06. Ans: (c)

Sol: $f = 0$; $e + 0 = \frac{100^2}{127 \times 500}$

$\Rightarrow e = 15.75\%$

07. Ans: (a)

Sol: $e = \frac{V^2}{225R} = \frac{60^2}{225 \times 500} = 0.032 = 3.2\%$

08. Ans: (b)

Sol: $R_{Ruling} = \frac{V^2}{127(f+e)}$

$= \frac{100^2}{127(0.07 + 0.13)}$

$= 393.7 \text{ m} \approx 395 \text{ m}$

09. Ans: (a)

Sol: b = 2.4 m

h = 4.2 m

$$\frac{b}{2h} = \frac{2.4}{2\times 4.2} = 0.286 > f$$

$$\frac{b}{2h} > f$$

∴ Lateral skidding occur first

Chapter- 8
Horizontal Curves (Extra Widening)

Common data for Questions 01 & 02

01. Ans: (d)

Sol: $e + f = \frac{V^2}{127R}$

$$R_{Ruling} = \frac{76^2}{127\left(\frac{1}{15}+0.15\right)} = 209.9\,m$$

02. Ans: (d)

Sol: $W_e = \frac{n\ell^2}{2R} + \frac{V}{9.5\sqrt{R}}$

$$= \frac{2\times 7^2}{2\times 209} + \frac{76}{9.5\sqrt{209}} = 0.787\text{ m}$$

∴ Total width = 7 + 0.787 = 7.78 m

03. Ans: (c)

Sol: $W_e = \frac{n\ell^2}{2R} + \frac{V}{9.5\sqrt{R}}$

$$= \frac{2\times 8^2}{2\times 300} + \frac{100}{9.5\sqrt{300}} = 0.821/m$$

04. Ans: (c)

Sol: Given W_m = 0.096

$$\frac{\ell^2}{2R} = 0.096 \Rightarrow R = 226.87\,m$$

$$W_e = W_m + W_{ps} = \frac{n\ell^2}{2R} + \frac{V}{9.5\sqrt{R}}$$

$$= \frac{2\times 6.6^2}{2\times 226.87} + \frac{80}{9.5\sqrt{226.87}} = 0.75\text{ m}$$

Chapter- 9
Set Back Distance and Curve Resistance

01. Ans: (a)

02. Ans: (c)

Sol: $m = \frac{S^2}{8R} \Rightarrow R = \frac{80^2}{8\times 10} = 80\,m$

Common data for Questions 03 & 04

03. Ans: (c)

Sol: L = 180 m S = 80 m

L > S

$$m = \frac{S^2}{8R} = \frac{80^2}{8\times 360} = 2.22\,m$$

Width of pavement is not indicated

m = R – R cos (α/2)

$$\frac{\alpha}{2} = \frac{180S}{2\pi R} = \frac{180 \times 80}{2\pi \times 360} = 6.36$$

m = 360 – 360 cos (6.36)

= 2.2 m

04. Ans: (c)

Sol: L = 180 m S = 250 m

L < S

$$m = R - R\cos\left(\frac{\alpha}{2}\right) + \frac{S-L}{2}\sin\left(\frac{\alpha}{2}\right)$$

$$\frac{\alpha}{2} = \frac{180L}{2\pi R} = \frac{180 \times 180}{2\pi \times 360} = 14.32$$

m = 360 – 360cos(14.32)

$$+\frac{250-180}{2}\sin(14.32) = 19.88 \text{ m}$$

Common data for Questions 05 & 06

05. Ans: (c)

Sol: $SSD = 0.278\,V\,t + \frac{V^2}{254f}$

$$= (0.278 \times 80 \times 2.4) + \frac{80^2}{254 \times 0.355}$$

= 124.35 m ≈ 125 m

06. Ans: (d)

Sol: S = 125 m

$$d = \frac{W}{4} = \frac{7}{4} = 1.75\,m$$

$$\frac{\alpha}{2} = \frac{180S}{2\pi(R-d)} = \frac{180 \times 125}{2\pi(200-1.75)} = 18.06$$

$$m = R - (R-d)\cos\left(\frac{\alpha}{2}\right)$$

= 11.52 m

m^1 = m – d

= 11.52 – 1.75 = 9.77 m

(or)

In approximately

$$m = \frac{S^2}{8R} = 9.76\,m$$

Problems on Curve Resistance

01.

Sol: Ratio of loss of tractive force = T(1– cosθ)

= T(1–cos45°)

= 0.293T

02.

Sol: Curve resistance = T(1 – cosθ)

= T(1 – cos30°)

= 0.134 T

03.

Sol: Curve resistance = T(1–cosθ)

= T(1–cos90°)

= 0

Chapter- 10
Highway Geometric Design -Transition Curves

Common data for Questions 01 & 02

01. Ans: (d)

Sol: $L = \frac{0.0215 V^3}{C R}$

$= \frac{0.0215 \times 60^3}{0.6 \times 200} = 38.7\,m$

Considering N value

$L = eN (W + W_e) = 0.07 \times 100 (7 + 0.2)$

$= 50.4$ m

$L = \frac{2.7 V^2}{R} = \frac{2.7 \times 60^2}{200} = 48.6\,m$

$\therefore$ The length of T.C = 50.4 m

(from the 3 values)

02. Ans: (d)

Sol: $S = \frac{L^2}{24 R} = \frac{(50.4)^2}{24 \times 200} = 0.53\,m$

Common data for Questions 03 & 04

03. Ans: (c)

Sol: $C = \frac{80}{75 + V} = \frac{80}{75 + 80} = 0.516\,m/sec^3$

04. Ans: (a)

Sol: Considering 'C' value

$L = \frac{0.0215 V^3}{C R} = \frac{0.0215 \times 80^3}{0.516 \times 900}$

$= 23.7$ m

Considering 'N' value

$e = \frac{V^2}{225 R} = \frac{80^2}{225 \times 900} = 0.04$

(for mixed traffic)

$L = \frac{e N}{2}(W + W_e)$

$= \frac{0.04 \times 150}{2} \times 7 = 21\,m$

Considering terrain

$L = \frac{2.7 V^2}{R} = \frac{2.7 \times 80^2}{900} = 19.2\,m$

$\therefore$ Length of T.C = 23.7 m

Chapter- 11
Highway Geometric Design -Vertical Curves

01. Ans: (b)

Sol: Length of summit parabolic curve,

Assume L > S

$L = \frac{NS^2}{\left(\sqrt{2H} + \sqrt{2h}\right)^2}$

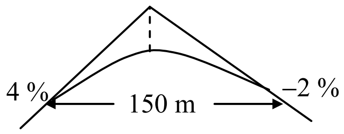
$= \frac{0.09 \times 120^2}{\left(\sqrt{2 \times 1.5} + \sqrt{2 \times 0.15}\right)^2} = 249$ m

02. Ans: (d)

Sol: N = 4 – (–2) = 6%

6% → 150 nm

$4\% \rightarrow \frac{4}{6}\times 150 = 100\,\text{m}$



03. Ans: (c)

Sol: $N = \frac{1}{50} - \left(-\frac{1}{100}\right) = 0.03 = 3\%$

1 % → 100 m

$3\ \% \rightarrow \frac{3}{1}\times 100 = 300\,\text{m}$

Common data for Q 04 & 05

04. Ans: (c)

Sol: $N = \frac{1}{25} - \left(-\frac{1}{50}\right) = 0.06 = 6\%$

S = 180 m

Take L > SSD

$L = \frac{NS^2}{4.40} = \frac{0.06\times 180^2}{4.4} = 441.8\,\text{m}$

≃442 m

05. Ans: (b)

Sol: 6 % → 442 m

$4\ \% \rightarrow \frac{4}{6}\times 442 = 294.7\,\text{m}$

06. Ans: (b)

Sol: $N = \frac{1}{100} - \left(\frac{-1}{120}\right) = 0.0183$

Take L > OSD

$L = \frac{NS^2}{9.6} = \frac{0.0183\times 470^2}{9.6}$

= 421.09 m

Take L < OSD

$L = 2S - \frac{9.6}{N} = 2\times 470 - \frac{9.6}{0.0183}$

= 415.4 m

07. Ans: (a)

08. Ans: (c)

Sol: Take L ≥ OSD

$L = \frac{NS^2}{9.6}$

$= \frac{0.018\times 500^2}{9.6}$

= 468.75 m < 500 m

Take L < OSD

$L = 2S - \frac{9.6}{N}$

$= 2\times 500 - \frac{9.6}{0.018}$

= 466.67 m < 500 m

∴ Length of summit cure,

L ≈ 470 m

Chapter- 12
Highway Geometric Design -Valley Curves

Common data for Questions 01 to 03

01. Ans: (c)

Sol: $-n_1 = \frac{1}{25}$ V = 100 kmph

$n_2 = \frac{1}{20}$ C = 0.6 m/s^3

SSD = 180 m

$N = (-n_1 - n_2) = n_1 + n_2$

$= \frac{1}{25} + \frac{1}{20} = 0.09$

(a) L = 0.38 $(NV^3)^{1/2}$

$= 0.38(0.09 \times 100^3)^{\frac{1}{2}}$

= 114

L > SSD

(b) $L = \frac{NS^2}{1.5 + (0.035S)} = \frac{0.09 \times 180^2}{1.5 + 0.035(180)}$

= 373.86 m ≃ 374 m

02. Ans: (b)

Sol: $I = \frac{1.6NV^2}{L}$

$= \frac{1.6 \times 0.09 \times 100^2}{374} = 3.85$

03. Ans: (a)

Sol: For 9% → 373.86

For 4 % → ?

$= \frac{4 \times 374.0}{9} = 166.22$ m

Chapter- 13
Highway Materials and Testing

01. Ans: (a)

Sol: $k_1 d_1 = k_2 d_2$

$(200) \times (30) = (k_2)(75)$

$k_2 = k_{\text{of soil}} = 80\,N/cm^3$

02. Ans: (a)

03. Ans: (a)

Sol: $E = \frac{1.18\,Pa}{\delta} = \frac{1.18 \times 800 \times \left(75/2\right)}{2.5 \times 10^{-1}}$

= 141600 N/cm^2

= 141.6 kN/cm^2

04.

Sol: Total weight = 825+1200 + 325 +150 + 100

= 2600 gm

% wt of material ;

$A_1 \rightarrow \frac{825}{2600} \times 100 = 31.7\%$

$A_2 \rightarrow \frac{1200}{2600} \times 100 = 46.15\%$

$A_3 \rightarrow \frac{325}{2600} \times 100 = 12.5\%$

$A_4 \rightarrow \frac{150}{2600} \times 100 = 5.7\%$

Bitumen $\rightarrow \frac{100}{2600} \times 100 = 3.8\%$

$$G_t = \frac{100}{\left(\frac{w_1}{G_1} + \frac{w_2}{G_2} + \frac{w_3}{G_3} + \frac{w_4}{G_4} + \frac{w_5}{G_5}\right)}$$

$$= \frac{100}{\left[\frac{31.7}{2.63} + \frac{46.15}{2.51} + \frac{12.5}{2.46} + \frac{5.7}{2.43} + \frac{3.8}{1.05}\right]}$$

$= 2.41$

$G_m = \frac{1100}{475} = 2.31$

(a) $V_a = \frac{G_t - G_m}{G_t} \times 100 = \frac{2.41 - 2.31}{2.41} \times 100$

$= 4.15\%$

(b) $V_b = \frac{w_b}{G_b} \times G_m = \frac{3.80}{1.05} \times 2.31 = 8.36$

(c) VMA= $V_v + V_b = 4.15\% + 8.36$

$= 12.51\ \%$

$\text{VFB} = \frac{V_b}{\text{VMA}} \times 100$

$= \frac{8.36}{12.51} \times 100 = 67\ \%$

05.

Sol: $G_t = \frac{100}{\frac{w_1}{G_1} + \frac{w_2}{G_2} + \frac{w_3}{G_3}}$

$= \frac{100}{\frac{60}{2.72} + \frac{35}{2.66} + \frac{5}{1.0}} = 2.48$

$V_a = 7\%$

$V_a = \frac{G_t - G_m}{G_t} \times 100$

$\Rightarrow 7 = \frac{2.48 - G_m}{2.48} \times 100$

$G_m = 2.31$

06. Ans: (c)

Sol: CBR (%)= $\frac{P_{2.5}}{P_{st\,2.5}} \times 100$

$= \frac{60.5}{1370} \times 100 = 4.4\%$

CBR (%) = $\frac{P_5}{P_{st\,5}} \times 100$

$= \frac{80.5}{2055} \times 100$

$= 3.92\ \%$

Adopt higher one.

$\therefore$ CBR(%) = 4.4

Chapter- 14
Pavement Design

01. Ans: 25.66 msa

Sol: Assume lane distribution factor, F = 0.75

$$A = 1000\left(1+\frac{7.5}{100}\right)^5 = 1435.6\,\text{CVPD}$$

$$N = \frac{365\left[(1+0.075)^{15}-1\right]\times 1435.6\times 2.5\times 0.75}{0.075}$$

= 25.66 msa

02. Ans: (b)

Sol: $$N = \frac{365\left[(1+r)^n-1\right]\times A\times D\times F}{r}$$

$A = P(1+r)^n$

$= 1000\,(1+0.1)^5 = 1610.51$

Assume F = 0.75

$$N = \frac{365\left[(1+0.1)^{15}-1\right]\times 1610.51\times 2.5\times 0.75}{0.1}$$

= 35 msa

03. Ans: (b)

Sol: $N = N_1 + N_2$

$$= \frac{365\left[(1+r)^n-1\right]\times A\times D\times F}{r}$$

$$N = \frac{365\left[(1+0.075)^{10}-1\right]\left[2000\times 5+200\times 6\right]}{0.075}$$

= 57.8 msa

04.

Sol:

Wheel load	EF	Number of vehicles	Total vehicles with standard axle loads
2268	1	465	1×465 = 465
2722	2.07	224	2.07×224 = 464
3175	3.84	168	3.84×168 = 645
3629	6.5	112	6.5×112 = 728
4082	10.49	75	10.49 ×75 = 787
4536	16	38	16 ×38 = 608
4990	23.43	19	23.43 ×19 = 446
		1101	Σ = 4143

Compared to standard load how many times the others create the damage.

Consider the standard axle load = 2268

$\frac{25}{100}\times 1860$ = 465 cv/day

$$EF = \left[\frac{2722}{2268}\right]^4 = 2.07$$

Total number of vehicles, A = 4143 cv/day

n = 20 years
r = 75% (as per IRC)
D = 0.4 (as per IRC)
F = 4.5 (>1500 cv/day, plain terrain)

$$N\ (msa) = \frac{365\left[(1+r)^n - 1\right]ADF}{r} = 118\ msa$$

05. Ans: 1.26

Sol:

Equivalent axle load and vehicle damage factor (VDF)

Axle load	**Number of load repetition**	**Equivalent factor**	**Equivalent axle load**
80	1000	$(80/80)^4 = 1$	1000
160	100	$(160/80)^4 = 16$	1600
40	1000	$(40/80)^4 = 0.0625$	62.5
			2662.5

∴ The equivalent axle load = 2662.5 kN

$$VDF = \frac{(1000\times 1)+(100\times 16)+(1000\times 0.0625)}{1000+100+1000}$$

= 1.26

Chapter- 15
Rigid Pavements

01. Ans: (a)

Sol: $L = \dfrac{\delta'}{\alpha(t_2 - t_1)} = \dfrac{2.5/2}{10\times10^{-6}(45-10)} = 3571.42\text{m}$

$= 35.71$ m

(δ' = 50% of gap expansion joint)

Common data for Questions 02 & 03

02. Ans: (a)

Sol: $\sigma_{w(e)} = \dfrac{C_x E\alpha t}{2}$

$= \dfrac{0.92\times3\times10^5\times10\times10^{-6}\times16.2}{2}$

$= 22.36$ kg/cm^2

03. Ans: (d)

Sol:

$$l = \left[\frac{Eh^3}{12k(1-\mu^2)}\right]^{1/4}$$

$$= \left[\frac{3\times10^5\times20^3}{12\times8(1-0.15^2)}\right]^{1/4} = 71.1\text{cm}$$

$$\sigma_{w(c)} = \frac{E\alpha t}{3(1-\mu)}\sqrt{\frac{a}{l}}$$

$$= \frac{3\times10^5\times10\times10^{-6}\times16.2}{3(1-0.15)}\times\sqrt{\frac{15}{71.1}}$$

$= 8.75$ kg/cm^2

Common data for Questions 04 & 05

04. Ans: (a)

Sol: $A_s = \dfrac{B\,h\,f\,r_c}{\sigma_s\times100} = \dfrac{1/2\times7.2\times18\times1.5\times2400}{1700\times100}$

$= 1.37$ cm^2/m

$$\text{Spacing} = \frac{100\times A}{A_s} = \frac{100\times\left(\pi/4\times10^2\right)}{1.37}$$

$= 57.32$ cm $\simeq$ 550mm c/c

05. Ans: (b)

Sol: $L = \dfrac{d\sigma_s}{2\sigma_b} = \dfrac{1\times1700}{2\times24.6} = 34.55\,\text{cm}$

Common data for Questions 06 & 07

06. Ans: (c)

Sol: $L = \dfrac{2\sigma_c}{\gamma_c f} = \dfrac{2\times0.8\times10^4}{2400\times1.5} = 4.4\,\text{m c/c}$

07. Ans: (c)

Sol: $L = \dfrac{200\,\sigma_s A_s}{B\,h\,\gamma_c\,f}$

$$= \frac{200\times1200\times\frac{\pi}{4}\times\left(10\times10^{-1}\right)^2}{3.75\times20\times2400\times1.5}\times\text{no. of bars}$$

$= 8.72$ c/c

$$\text{No. of bars} = \frac{\text{width}}{0.3} = \frac{3.75}{0.3} = 12.5 \simeq 13\ \text{No's}$$

08. Ans: (a)

Sol: $\sigma_f = \frac{\gamma_c f L}{2\times10^4} = \frac{2400\times4\times1.2}{2\times10^4}$

$= 0.576\,kg/cm^2$

Chapter- 16
Traffic Engineering

01 Ans: (a)

Sol: Time mean speed

$= \frac{50+40+60+54+45}{5}$

(V_t) = 49.8 kmph

$V_s \Rightarrow$ space mean speed

$\frac{1}{V} = \frac{1}{50}+\frac{1}{40}+\frac{1}{60}+\frac{1}{54}+\frac{1}{45}$

V = 9.76

$V_s = V \times n = 9.76 \times 5 = 48.80$ kmph

02. Ans: (a)

Sol:

Speed Range (m/s)	Frequency PCU/hr (q)	Mid-pt speed (V)	qv	q/v
2.5	1	3.5	3.5	0.29
7.5	4	7.5	30	0.533
11.5	0	11.5	0	0
15.5	7	15.5	108.5	0.45
	12		142.0	1.273

$V_t = \frac{\sum q v}{\sum q} = \frac{142}{12} = 11.83\,m/s$

$V_s = \frac{\sum q}{\sum (q/v)} = \frac{12}{1.27} = 9.44\,m/s$

Always the time mean speed is more than space mean speed i.e, $V_t > V_s$\

03. Ans: 41.8 & 40.91

Sol:

Speed of vehicle-A $= \frac{1}{1.2/60} = 50\,kmph$

Speed of vehicle-B $= \frac{1}{1.5/60} = 40\,kmph$

Speed of vehicle-C $= \frac{1}{1.7/60} = 35.3\,kmph$

Average travel speed

$(V_t) = \frac{50+40+35.3}{3}$

= 41.8 kmph

Space mean speed $(V_s) = \frac{n}{\sum\left(\frac{1}{v_i}\right)}$

$= \frac{3}{\frac{1}{50}+\frac{1}{40}+\frac{1}{35.3}}$

= 40.91 kmph

04. Ans: 4037

Sol: Design flow rate $= \frac{q}{pHF}$

$PHF = \frac{q}{4(q_{15})}$

Volume during peak 15 min (q_{15}) = 1000

Peak hour volume (q)

= 700 + 812 + 1000 + 635

= 3147

$$PHF = \frac{3147}{4 \times 1000} = 0.78$$

$$\therefore \quad \text{Design flow rate} = \frac{3147}{0.78} \approx 4037\ \text{veh/hr}$$

05.

Sol:

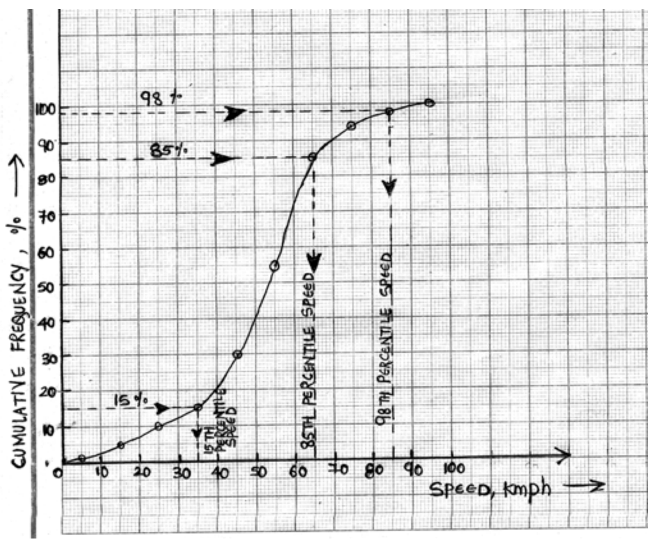
Total frequency = 100

$$\% \text{ frequency} = \frac{10}{1000} \times 100 = 1$$

(i) 85^{th} percentile speed is considered as a safe speed from graph V_{85} = 65 kmph

(ii) 98^{th} percentile speed is considered as a design speed from graph V_{98} = 85 kmph

(iii) 15^{th} percentile speed is considered as a minimum speed on the highway from graph V_{15}=35 kmph



06. Ans: (c)

Sol: $SSD = 0.278\,Vt + \frac{V^2}{254 f}$

$$= 0.278 \times 65 \times 2.5 + \frac{65^2}{254 \times 0.4}$$

= 86.7 m

$S = SSD + L = 86.7 + 5 = 91.7\,\text{m}$

$$C = \frac{1000\,V}{S} = \frac{1000 \times 65}{91.7} = 708.83\ \text{veh/hr/lane}$$

07. Ans: (b)

Sol: $t = 0.7$ Assume

$SSD = 0.278\,Vt = 12.77$ m

$S = SSD + L$

$$C = \frac{1000\,V}{S} = 3130\ \text{veh/hr}$$

08. Ans: (b)

Sol: S = SSD + L =20+6 = 26 m

$$C = \frac{1000\,V}{S} = \frac{1000 \times 40}{26} = 1538\ \text{veh/hr/lane}$$

09. Ans: (c)

Sol:

Given standard deviation (SD) = 8.8kmph

mean speed $\bar{x}$ = 33kmph

$$\text{Coefficient of variation} = \frac{SD}{\bar{x}} = \frac{8.8}{33}$$

= 0.2666

10. Ans: (b)

Sol:

$q = uk$

$U = U_{sf}\left[1-\frac{k}{k_j}\right]$

$\therefore\ q = U_{sf}\left[1-\frac{k}{k_j}\right]k = U_{sf}\left[k-\frac{k^2}{k_j}\right]$

For max traffic flow ; $\frac{d_q}{d_k} = 0$

$\frac{d_q}{d_k} = U_{sf}\left[1-\frac{2k}{k_j}\right] = 0$

$1-\frac{2k}{k_j} = 0$

$k_j = 2k$

$U_{sf} = 70$ km/hr

$k_j = \frac{1000}{s} = \frac{1000}{7}$

$k = k_j/2$

$q = U_{sf}\left[k-\frac{k^2}{k_j}\right] = U_{sf}\left[k-\frac{k}{2}\right]$

$= U_{sf}\left[k_j/2 - k_j/4\right]$

$= U_{sf}\left[k_j/4\right]$

$q = 70\times\frac{1000}{7}\times\frac{1}{4}$

$= 2500$ veh/hr

11. Ans: (d)

Sol:

$V_{sf} = 80$ kmph

$k_j = 100$ veh /km

$Q_{max} = \frac{V_{sf}\times k_j}{4} = \frac{80\times 100}{4} = 2000\,\text{veh/hr}$

$V_s = \frac{V_{sf}}{2}$ (the speed corresponding to

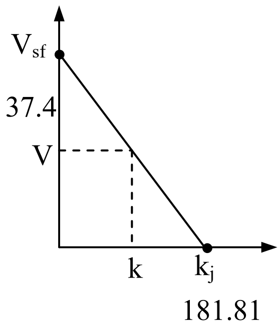
Q_{max} is $V_{s\ max}$) $= \frac{80}{2} = 40\,\text{kmph}$

12. Ans: 32.6

Sol: $q_m = 1700$ veh/hr

$k_m = \frac{1000}{S} = \frac{1000}{5.5} = 181.81$

$q_m = \left(\frac{V_m}{2}\right)\left(\frac{k_m}{2}\right)$



$1700 = \left(\frac{V_m}{2}\right)\left(\frac{181.81}{2}\right)$

$V_m = 37.40$ kmph

For q = 1000 veh/hr

$\tan\theta = \frac{V_m}{k_m}$

$V = \frac{37.4}{181.81}\times(181.81-K)$

For normal condition

$q = V.K$

$1000 = \frac{37.4}{181.81}\times(181.81-K)\times K$

$4860.96 = (181.81-K)K$

$4860.96 = 181.81\,K-K^2$

K = 149 veh/hr and K = 32.6 veh/km

13. Ans: 35.7 kmph

Sol: $V_{sf} = 50$ kmph

$t_j = 70$ veh/km

$$q_{max} = \frac{V_{sf} + K_j}{4} = \frac{50 \times 70}{4} = 875 \text{ veh/hr}$$

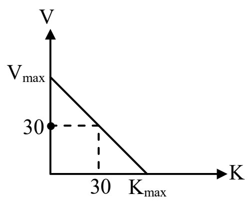
K = 20 veh/km

$$\frac{K_j}{V_{sf}} = \frac{K_j - K}{V - 0}$$

$$\frac{70}{50} = \frac{70-20}{V} \Rightarrow V = 35.7 \text{ kmph}$$

14. Ans: 1268 veh/hr

Sol:



$$\frac{V_{max}}{K_{max}} = \frac{30\text{kmph}}{(130-30)}$$

$K_{max} = 130$ veh/km

$$V_{max} = \frac{30}{130-30} \times 130$$

$= 39$ kmph

$$K_{max} = \left(\frac{V_{max}}{2}\right)\left(\frac{K_{max}}{2}\right)$$

$$= \frac{39}{2} \times \frac{130}{2}$$

$\simeq 1268$ veh/hr

15. Ans: (b)

Sol: $$Q_p = \frac{280\, w\left(1 + \frac{e}{w}\right)\left(1 - \frac{p}{3}\right)}{1 + w/L}$$

w = 14 m; e = 8.4 m

L = 35 m

$$p = \frac{\text{Crossing traffic}}{\text{Total traffic}}$$

$$= \frac{1000}{2000} = 0.5$$

$$Q_p = \frac{280 \times 14\left(1 + \frac{8.4}{14}\right)\left(1 - \frac{0.5}{3}\right)}{1 + 14/35}$$

= 3733.33 PCU/hr

16. Ans: 2064.10 veh/hr

Sol: w = 6m ; p = 0.5

L = 20 m ; e = 5.5 m

$$= \frac{280 \times 6\left[1 + \frac{5.5}{6}\right]\left[1 - \frac{0.5}{3}\right]}{1 + \frac{6}{20}}$$

$Q_p = 2064.10$ veh / hr

17. Ans: 0.8%

Sol: $$\text{Weaving ratio} = \frac{\text{weaving traffic}}{\text{total traffic}}$$

$$= \frac{V_{13} + V_{24} + V_{43}}{V_{13} + V_{23} + V_{24} + V_{14} + V_{43} + V_{21}}$$

$$= \frac{450 + 1090 + 600 + 310}{450 + 200 + 1090 + 412 + 600 + 310}$$

Weaving ratio = 0.80%

18. Ans: (b)

Sol:

$$\left.\begin{aligned} y_N &= \frac{1000}{2500} \\ y_S &= \frac{700}{2500} \end{aligned}\right\} y_{NS} = 0.4$$

$$\left.\begin{aligned} y_E &= \frac{900}{3000} \\ y_w &= \frac{550}{3000} \end{aligned}\right\} y_{Ew} = 0.3$$

$y = y_{NS} + y_{Ew}$

$= 0.4 + 0.3 = 0.7$

L = 12 sec

$$C_o = \frac{1.5L+5}{1-y} = \frac{1.5\times12+5}{1-0.7}$$

$= 76.7$ sec ≈ 77 sec

19. Ans: (d)

Sol: $y = 0.5 = y_a + y_b$

L = 10 sec

$$C_o = \frac{1.5L+5}{1-y} = \frac{1.5\times10+5}{1-0.5} = 40 \text{ sec}$$

20. Ans: 14.23 /veh , 1540 veh/hr

Sol: $C = S \times \dfrac{g}{C_o}$

$S \rightarrow$ Saturation flow

$g_i \rightarrow$ effective green time

$C_o \rightarrow$ Cycle time/Optimum signal cycle length

$\dfrac{g_i}{C_o} \rightarrow$ Green Ratio

$C = 2800 \times 0.55$

$= 1540$ veh/hr

$$d_i = \frac{\frac{C_o}{2}\left(1-\frac{g_i}{C_o}\right)^2}{1-\frac{V_i}{s}}$$

$$= \frac{\frac{90}{2}(1-0.55)^2}{1-\frac{1000}{2800}} = 14.2 \text{ /veh}$$

21. Ans: (a)

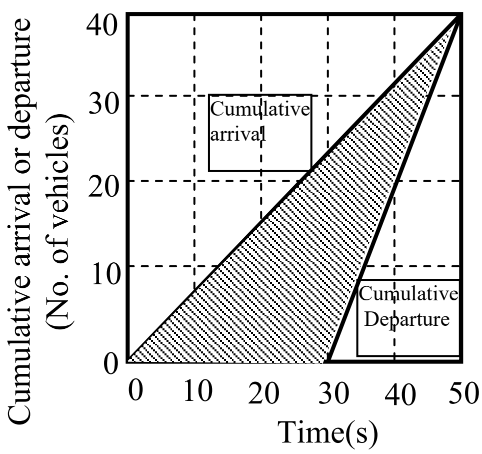
Sol: Average delay at red signal is $\dfrac{\text{red time}}{2}$

$= \dfrac{30}{2}$

$= 15$ sec

(or)

Alternative Solution:



From fig:

The average delay = The area between cumulative arrival and cumulative departure /Total no of vehicles (or) The hatched area in above figure/total number of vehicles

∴ The average delay

$$= \frac{\frac{1}{2}(50)(40) - \frac{1}{2}(20)(40)}{40}$$

$$= \frac{1}{2}(50) - \frac{1}{2}(20) = 25 - 10 = 15\,\text{sec}$$

22. Ans: (a)

Sol:

Critical lane volume on major road is increased to 440 veh/hr/lane those for green time should be increased for major road and it remains same for minor road.

23. Ans: (a)

Sol:

Green Time = 27 sec

Yellow Time = 4 sec

Total lost time, t_L = Start up lost time +Clearance lost time

= 2 + 1 = 3 sec

Effective green time ; $g = G + y - t_L$

= 27 + 4 –3 = 28 sec

Saturation flow rate; $S = \frac{3600}{h} = \frac{3600}{2.4}$

= 1500 veh/hr

h → Time headway

Capacity of lane, $C = S \times \left(\frac{g_i}{C_o}\right)$

$= 1500 \times \left(\frac{28}{60}\right)$

= 700 veh/hr/lane

24. Ans: (d)

Sol:

: Distance travelled by bicycle = 5 km

Time of travel, t = 40 – 15 = 25 min

Stop time = 15 min

Speed of bicycle = $V_b = \frac{5}{25}\,\text{km/min}$

Let speed of stream is V km/min

Assume traffic density is the constant on the road (K = Constant).

but $K = \frac{q}{V}$

During journey relative speed of stream=V– V_b

$= \left(V - \frac{5}{25}\right)$

$$K = \frac{\left(\frac{60}{25}\right)\text{Vechicles/min}}{\left(V - \frac{5}{25}\right)} \quad \ldots\ldots.(1)$$

During stop (V_b = 0)

$$K = \frac{\left(\frac{45}{15}\right)\text{Vehicles/min}}{V} = \frac{45}{15V} \quad \ldots\ldots.(2)$$

Equating (1) & (2)

$$K = \frac{\left(\frac{60}{25}\right)}{\left(V - \frac{5}{25}\right)} = \frac{\left(\frac{45}{15}\right)}{V} = \frac{45}{15V}$$

$$0.8 = \left(1 - \frac{5}{25V}\right)$$

$$0.2 = \frac{5}{25V}$$

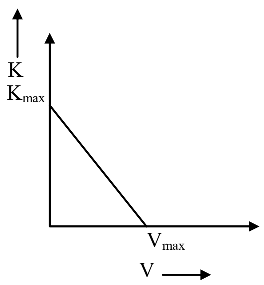
$$\Rightarrow V = \frac{5}{25 \times 0.2}$$

$\Rightarrow$ V = 1 km/min

V = 60 km/hr

25. Ans: 2133.33 veh/hr

Sol: V = 80 – 0.75 K



V_{max} occur, when K = 0

V_{max} = 80 kmph

K_{max} occur when V = 0

$$K_{max} = \frac{80}{0.75} = 106.67 \text{ veh/km}$$

Capacity of road, $q = \left[\frac{K_{max} \times V_{max}}{4}\right]$

$$q = \frac{106.67 \times 80}{4}$$

q = 2133.33 veh/hr

26. Ans: (c)

Sol: In R: 2,5 combination is possible 1,3 and 4,6 are not possible

27. Ans:

Sol: Given:

Speed of the vehicle = 60 kmph

Amber duration = 4 sec

Comfortable deceleration = $3 m/sec^2$

Car length = 4.0 m

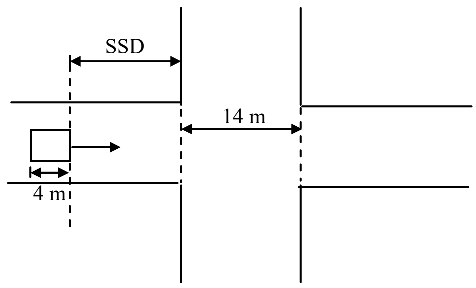
Intersection width = 14

Longitudinal friction factor = 0.35

Perception reaction time = 1.5 sec

When the vehicle reaches section A, he sees the amber right. Hear, two situation are possible.

There are two possibilities



(i) Driver decides to cross intersection:

Total distance to be covered

= SSD + 14 + 4.0

$$SSD = (vt) + \frac{v^2}{2gf}$$

$$= (16.67 \times 1.5) + \frac{(16.67)^2}{2 \times 9.81 \times 0.35}$$

= 65.47 m

Total distance to be covered

$= 65.47 + 14 + 4 = 83.47$ m

Time required $= \frac{\text{distance}}{\text{speed of vehicle}}$

$= \frac{83.47}{16.67}$

$= 5.0$ sec > 4 sec

(ii) He decides to stop the vehicle time taken to stop the vehicle after sighting the amber light.

= Reaction time + time taken to stop the vehicle after application of brakes

$$= 1.5 + \left(\frac{60 \times \frac{5}{18} - 0}{3} \right)$$

$= 1.5 + 5.55$

$= 7.05$ sec > 4 sec

Therefore, in both the situation, the required duration is greater than the provided amber duration hence the driver's claim is correct.

28. Ans:

Sol:

Probability that the gap is greater than 8 sec

$P(h \geq t) = e^{-\lambda t}$

λ = rate of arrival per second

$= \frac{900}{3600} = 0.25$

t = 8 sec

$P(h \geq 8) = e^{-0.25 \times 8}$

$P(h \geq 8) = 0.1353$

Chapter- 17
Geometric Design of Railway Track

01. Ans: (b)

Sol:

Grade compensations on curves:

For BG : 0.04% per degree of curve

For MG: 0.03% per degree of curve

For NG : 0.02% per degree of curve

Therefore, in the present case, for 4° curve, the grade compensation is

$= 0.04 \times 4 = 0.16\%$

02. Ans: (d)

03. Ans: (b)

Sol:

Ruling gradient in % $= \frac{1}{250} \times 100 = 0.4\%$

Grade compensation at 0.04% per degree of

Curve $= 0.04 \times 3 = 0.12\%$

Compensated gradient $= 0.4 - 0.12$

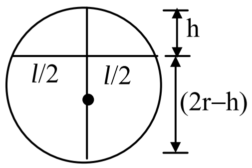
$= 0.28\%$

$= \frac{0.28}{100} = \frac{1}{357}$

04. Ans: (a) **05. Ans: (c)**

06. Ans: (c)

Sol:



From circle property,

$$\frac{\ell}{2}.\frac{\ell}{2} = h(2r - h)$$

$$\frac{\ell^2}{4} = 2rh - h^2$$

h^2 is neglected (being very small)

$$\therefore\ h = \frac{\ell^2}{8r}$$

07. Ans: (a)

Sol:

Grade compensation = 2 × 0.04 %

= 0.08%

Stipulated ruling gradient = 0.5%

Steepest gradient = 0.5% – 0.08%

$$= 0.42\% = \frac{1}{238}$$

08. Ans: (c)

Sol:

Curve resistance = 0.04% × D°

= 0.04 × 4 = 0.16%

$$\text{Ruling gradient} = \frac{1}{150}$$

$$= \frac{1}{150}\times 100 = 0.67\%$$

Compensated gradient

= 0.67 – 0.16

= 0.51%

$$= \frac{0.51}{100} = \frac{1}{196}$$

09. Ans: (a)

10. Ans: (b)

Sol: Grade compensation = 2 × 0.04 %

= 0.08%

Stipulated ruling gradient = 0.5%

Steepest gradient = 0.5% – 0.08%

$$= 0.42\% = \frac{1}{238}$$

11. Ans: 91.26 kmph

Sol: Given, D° = 2°

$$R = \frac{1720}{D^\circ} = \frac{1720}{2}$$

R = 860 mm

The "weighted average" of different trains at different speeds is calculated from the equation

$$\text{Weighted average} = \frac{n_1V_1 + n_2V_2 + n_3V_3 + n_4V_4}{n_1 + n_2 + n_3 + n_4}$$

$$V = \frac{15\times 50 + 10\times 60 + 5\times 70 + 2\times 80}{15 + 10 + 5 + 2}$$

V = 58.125 kmph

$$e = \frac{GV^2}{127R} = \frac{1.676 \times 58.125^2}{127 \times 860}$$

$= 0.0518$ m

$= 5.18$ cm

Theoretical cant = Equilibrium cant + cant deficiency

$= 5.18 + 7.60$

$= 12.78$ cm

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

$$\frac{12.78}{100} = \frac{1.676 \times V^2}{127 \times 860}$$

V = 91.26 kmph

According to railway boards Speed formula

$V = 4.35\sqrt{R - 67}$

$V = 4.35\sqrt{860 - 67}$

$V = 122.5$ kmph

Hence maximum permissible speed

(i.e lower of the two value) is 91.26 kmph

12. Ans: 86.4 m

Sol:

e = 12cm

V_{max} = 85 kmph

D = 7.6 cm (BG)

Length of transition curves maximum of following:

(a) Based on arbitrary gradient of 1 in 720

L = 7.20 × e

L = 7.20 × 12 = 86.4cm

(b) Based on rate of change of cant deficiency

L = 0.073 DV_{max}

L = 0.073 × 7.6 × 85

L = 47.158cm

(c) Based on rate of change of super elevation

L = 0.073e V_{max}

L = 0.073 × 12 × 85

L = 74.46cm

∴ Take maximum L = 86.4cm

Chapter- 18
Airport Runway and Taxiway design

01. Ans: (d)

Sol:

The runway length after being corrected for elevation and temperature should further be increased at the rate of 20% for every 1 % of the effective gradient for 0.5%, 10% should be increased.

So runway length after correction of temperature and elevation

$$= 2845 + 10\left(\frac{2845}{100}\right) = 3129.5 \simeq 3130 \text{ m}$$

02. Ans: (c)

Sol: Runway elevation = 1000 m (above msl)

Airport reference temperature (ART) = 16°C

Airport standard temperature(AST)

= standard temperature at msl −6.5°C for 1 km height above msl

AST = 15 −6.5 = 8.5°C

Rise in temperature as per

ICAO = 16 −8.5 = 7.5°C

03. Ans: (a)

Sol:

Airport reference temperature,

$$\text{ART} = \frac{2T_a + T_m}{3} = \frac{2(40)+49}{3} = 43°\text{C}$$

04. Ans: (a)

Sol:

Wind coverage is the time in a year of time during which cross wind component is as minimum as possible.

05. Ans: (d)

Sol:

Airport reference temperature

$$\text{ART} = \frac{2T_a + T_m}{3}$$

$$= \frac{2\times 25 + 40}{3} = 30°\text{C}$$

06. A runway is located 450 m above the mean sea level. If the aeroplane reference field is 1800 m, what is the approximate corrected runway length for elevaton?

(a) 1849 m ***(b) 1889 m***

(c) 1987 m ***(d) 2013 m***

06. Ans: (c)

Sol: As per ICAO recommendations the basic runway length increased at a rate of 7% for 300 rise in elevation above msl.

For 300 m $\rightarrow$ 7%

Then 450 m$\rightarrow$ $\frac{7\times 450}{300} = 10.5\%$

Corrected length of runway

$$= 1800 + \frac{10.5}{100}\times 1800 = 1987 \text{ m}$$

07. Ans: 4 km

Sol: Runway length = 2460 m

Correction for elevation (ICAO)

300 m – 7%

486 – x

x = 11.34 %

corrected length after elevation correction

$$= \frac{11.34}{100}\times 2460 + 2460$$

= 2738.964 m

correction for temperature

$$ART = T_1 + \frac{T_2 - T_1}{3}$$

$$= 30.2 + \frac{(46.3 - 30.2)}{3}$$

ART = 35.57°

Temperature gradient 1000 – 6.5

486 – x

x = 3.159°

Temperature @ airport @ 486 m elevation

= 15 – 3.159 = 11.841°

1% increase in length for 1° above std temperature. (3.5057 –11.841) = 23.729°

1% ↑ – ↑ change

x–(35.57 – 11.84%)

x = 23.73

$$\text{Correction} = \frac{23.729}{100} \times 2738.964 + 2738.964$$

= 3388.89 m

Correction for effective gradient

20 – 1

x – 0.75, x = 15%

Total runway length = 1.15 × 3388.89

= 3897.22 m

≃ 4000 m = 4 km

08. Ans: 400 m

Sol:

(i) Horonjeff's equation:

$$R = \frac{0.388\,w^2}{0.5T - S}$$

$$= \frac{0.388 \times 17.7^2}{0.5(23) - \left(6 + \frac{6.62}{2}\right)} = 55.51 \text{ m}$$

(ii) Turning radius

$$R = \frac{V^2}{125f}$$

$$= \frac{80^2}{125 \times 0.13} = 393.85 \text{ m}$$

(iii) The minimum radius of sub sonic aircraft is 135 m

∴ Turning radius = Maximum of three conditions

= 393.85 m

R ≈ 400 m

09. The length of a runway under standard conditions is 2100m. The airport is to be provided at an elevation of 410 m above the mean sea level. The airport reference temperature is 32. Final length of runway?

09. Ans: 2753.455

Sol: Runway length = 2100 m

Correction for elevation

300 – 7 %

410 – X

x = 9.57%

Corrected length after elevation correction

$$\text{correction} = \frac{9.57}{100} \times 2100 + 2100$$

= 2300.97 m

Correction for temp correction

ART = 32

Temp gradient

1000 – 6.5

410 – x

x = 2.665°

Temp @ airport @ 410 m elevation

15 – 2.665

12.335

1% ↑ – 1° change

x = (32 – 12.335)

$$\text{correction} = \frac{19.665}{100} \times 2300.97 + 2300.97$$

= 2753.455

10. Ans: 2253.5 m

Sol: Length of runway = 1640 m

Elevation = 280 m

Reference temperature = 33.5°C

Effective gradient = 0.2%

Correction for Elevation (ICAO)

For 300 m – 7 %

280 – x

x = 6.53%

$$\text{correction} = 1640 + \frac{6.53}{100} \times 1640$$

= 1747.15 m

Correction for temperature (ICAO)

ART = 33.5°C m

Temperature gradient

1000 m – 6.5°

280 m – x

x = 1.82°

Temp @ airport @ 280 m elevation

= 15 – 1.82

= 13.18°

1% increase in length for 1° above standard temperature (33.5 – 13.18)

= 20.32° (33.5 –13.18) –x

x = 20.32

$$\text{Correction} = \frac{20.32}{100} \times 1797.15 + 1797.15$$

= 2102.17 m

Chainage	Gradient	Elevation
0	–	280 m
300	+1%	(280 +0.01×300) = 283
900	–0.5%	$283-\frac{0.5}{100}\times 600 = 280$
1500	+0.5	$280+\frac{0.5}{100}\times 690 = 283$
1800	+1	283 + 0.01×300 = 286
2100	–0.5	$286-\frac{0.5}{100}\times 300 = 284.5$
2700	0.4	$284.5-\frac{0.4}{100}\times 600 = 282.1$
3000	–0.1	$282.1-\frac{0.1}{100}\times 300 = 281.8$

$$\text{Effective gradient} = \left(\frac{286-280}{1640}\right)\times 100$$

$$= 0.36\%$$

$20\% \rightarrow 1\%$

$x \rightarrow 0.36\%$

$x = 7.2\%\uparrow$

Total length of runway = 1.072× 2102.17

= 2253.5 m