ACE ENGINEERING PUBLICATIONS

Since 2011

ACE

GATE | PSUs

CIVIL ENGINEERING

CIVIL ENGINEERING

TRANSPORTATION ENGINEERING

Volume-1 : 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	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 $= \frac{W}{2n} = \frac{3.5\times1000}{2\times60}$

$= 29.2$ mm

02. Ans: (d)

Sol: Height of crown $= \frac{W}{2n} = \frac{3.5\times1000}{2\times40}$

$= 43.75$ mm

04. Ans: (a)

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

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

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

The compensated gradient $= 6\% - 1.5$

$= 4.5\%$

05. Ans: (a)

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

$\frac{W}{2n} = 7.5$

$2n = \frac{9\times100}{7.5}$

$n = 60 \Rightarrow 1$ in 60

Chapter- 5
Highway Geometric Design - Sight Distances

01. Ans: (c)

Sol: B.D = 16 m,

$f = 0.4$

$\frac{V^2}{254f} = 16 \Rightarrow \frac{V^2}{254\times0.4} = 16$

$V = 40.3$ 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

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

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

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

SSD for single two way traffic = 2 × SSD

= 2 ×82.1 = 164.2 m

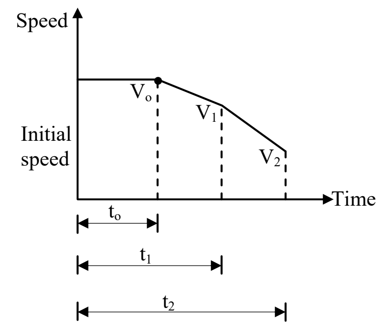
06. Ans: (c)

Sol: ISD = 2 × 80 = 160 m

07. Ans: (83 kmph)

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 to be uniform

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

= 22.98 m/s = 82.76 kmph

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

= 83 kmph

08. Ans: (13.6 m)

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

A = 3, β = 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

$$= \frac{3(4.25)}{0.04} - \frac{3}{(0.04)^2}(1 - e^{-0.04\times4.25}) + 0$$

x = 25.62 m

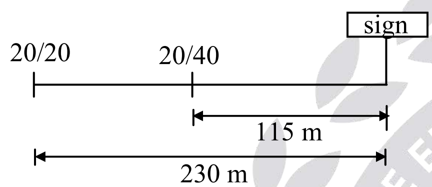
Intersection + length of car

7.5 + 6.1 = 13.6 m

$\therefore$ He can clear the intersection

09. Ans: T = 7.13 sec, V = 138 kmph

Sol:



$$\frac{20}{20} \rightarrow 230 \text{ m}$$

$$\frac{20}{40} \rightarrow x$$

x = 115 m

In question they give it will take 3 sec to red sign

So

Speed of $\frac{20}{40}$ vision driver $= \frac{115}{3}$ m/sec

$= 138$ kmph

For speed of $\frac{20}{40}$ vision driver is 58kmph

i.e $58 \times \frac{5}{18} = 16.11$ m/sec

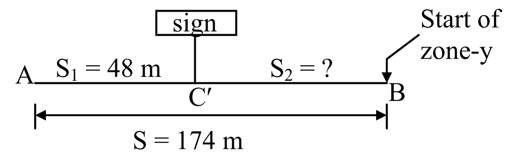
$$\text{Velocity} = \frac{D}{T}$$

$$T = \frac{115}{16.11}$$

T = 7.13 sec

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

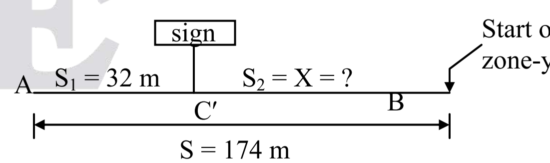
S_1 = Distance traveled by the vehicle during perception – reaction time for 6/6 vision driver

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.

11. Refer previous GATE solutions Book (Cha-2, Two marks 9th Question -pg: 821)

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

$S = ut + \frac{1}{2} at^2$

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

$a = 1.2\ m/sec^2$

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

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

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

OSD = $d_1 + d_2 + d_3$

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

$= 236.21 + (22.22 \times 10.05)$

$= 459.521$ m

≈ 460 m

07. Ans: (d)

Sol: Desirable length of OZ = 5 OSD

$= 5 (d_1 + d_2 + d_3)$

$= 5 \times 460$

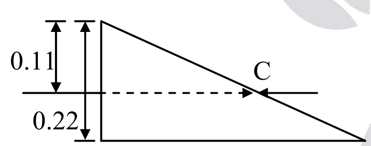
$\simeq 2300$ m

Chapter- 7
Highway Geometric Design - Horizontal Curves

Common data for Questions 01 & 02

01. Ans: (a)

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



$E = e\,w = 0.031 \times 7 = 0.22$ 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: $e_{cal} = \dfrac{V^2}{225R} = \dfrac{65^2}{225 \times 125} = 0.15$

$e_{cal} > 0.07$

$\therefore$ V = 65 kmph is not suitable

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

$= 0.196 > 0.15$

V_a should be calculated

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

$V_a = 59.1$ kmph

Common data for Questions 04 to 06

04. Ans: (b)

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

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

$\Rightarrow e = 0.00748 = 0.74\%$

05. Ans: (b)

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

06. Ans: (c)

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

$\Rightarrow e = 15.75\%$

07. Ans: (a)

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

08. Ans: (b)

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

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

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

09. Ans: (a)

Sol: $b = 2.4$ m

$h = 4.2$ m

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

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

$\therefore$ Lateral skidding occur first

Chapter- 8
Horizontal Curves (Extra Widening)

Common data for Questions 01 & 02

01. Ans: (d)

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

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

02. Ans: (d)

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

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

$\therefore$ Total width = 7 + 0.787

= 7.78 m

03. Ans: (c)

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

$= \dfrac{2\times 8^2}{2\times 300} + \dfrac{100}{9.5\sqrt{300}} = 0.821\,\text{m}$

04. Ans: (c)

Sol: Given

$W_m = 0.096$

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

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

$= \dfrac{2\times 6.6^2}{2\times 226.87} + \dfrac{80}{9.5\sqrt{226.87}}$

= 0.75 m

Chapter- 9
Set Back Distance and Curve Resistance

01. Ans: (a)

Sol: Set back or the clearance is the distance required from the centre line of horizontal curve to an obstruction on the inner side of the curve to provide adequate sight distance at a horizontal curve.

02. Ans: (c)

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

Common data for Questions 03 & 04

03. Ans: (c)

Sol: L = 180 m S = 80 m

L > S

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

Width of pavement is not indicated

$m = R - R\cos(\alpha/2)$

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

$m = 360 - 360\cos(6.36)$

$= 2.2$ m

04. Ans: (c)

Sol: L = 180 m S = 250 m

L < S

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

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

$$m = 360 - 360\cos(14.32) + \frac{250-180}{2}\sin(14.32) = 19.85\text{ m}$$

Common data for Questions 05 & 06

05. Ans: (c)

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

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

$= 124.35$ m ≈ 125 m

06. Ans: (d)

Sol: S = 125 m

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

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

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

$= 11.52$ 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: Let 'T' is the original Tractive force

loss of tractive force = T(1– cosθ)

= T(1–cos45°)

Ratio of loss of Tractive force to original is

= 0.243

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

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

∴ The length of T.C = 50.4 m

(from the 3 values maximum value)

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

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

$$= 23.7 \text{ m}$$

Considering 'N' value

$$e = \frac{V^2}{225\,R} = \frac{80^2}{225 \times 900} = 0.0316$$

(for mixed traffic)

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

$$= \frac{0.0316 \times 150}{2} \times 7 = 16.59\,\text{m}$$

Considering terrain

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

$\therefore$ 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

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

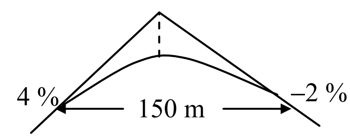
$$= \frac{0.09 \times 120^2}{\left(\sqrt{2 \times 1.5} + \sqrt{2 \times 0.15}\right)^2} = 249 \text{ m}$$

02. Ans: (d)

Sol: N = 4 – (–2) = 6%

$6\% \rightarrow 150$ nm

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



03. Ans: (c)

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

$1\ \% \rightarrow 100$ 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

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

$$\simeq 442 \text{ m}$$

05. Ans: (b)

Sol: $6\ \% \rightarrow 442$ m

$$4\ \% \rightarrow \frac{4}{6} \times 442 = 294.66\,\text{m}$$

$$= 294.66$$

06. Ans: (b)

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

Assume $L > OSD$

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

$$= 421.09 \text{ m}$$

$421.09 < 470$

Take $L < OSD$

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

$$= 406.66 \text{ m}$$

07. Ans: (a)

Sol: Refer previous GATE solutions Book (Cha-2.8, Two marks 5th Question -pg: 830)

08. Ans: (c)

Sol: Take $L \geq OSD$

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

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

$$= 468.75 \text{ m} < 500 \text{ m}$$

Take $L < OSD$

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

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

$$= 466.67 \text{ m} < 500 \text{ m}$$

$\therefore$ Length of summit cure,

$$L \approx 467 \text{ m}$$

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

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

$$= 114$$

$L > SSD$

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

$$= 373.86 \text{ m} \simeq 374 \text{ m}$$

02. Ans: (b)

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

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

03. Ans: (a)

Sol: For 9% $\rightarrow$ 373.86

For 4 % $\rightarrow$?

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

$$\simeq 166$$

Chapter- 13
Highway Materials and Testing

01. Ans: (a)

Sol: $k_1 d_1 = k_2 d_2$

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

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

03. Ans: (a)

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

$= 141600 \text{ N/cm}^2$

$= 141.6 \text{ kN/cm}^2$

04.

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

= 2600 gm

% wt of material ;

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

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

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

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

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

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

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

$= 2.41$

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

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

$= 4.15\%$

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

(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. Ans: G_f =2.48, G_m = 2.30

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

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

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 = 2.30

06. Ans: (c)

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

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

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

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

= 3.92 %

Adopt higher one.

$\therefore$ CBR(%) = 4.4

Chapter- 14
Pavement Design

01. Ans: 34.22 msa

Sol: Assume lane distribution factor, F = 1

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

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

= 34.22 msa

02. Ans: (c)

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

Assume F = 0.75

$$N = \frac{365\left[(1+0.1)^{15}-1\right]\times 1610.51\times 3\times 0.75}{0.1}$$

= 42.02 msa

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

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

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. Ans: F = 3.74, N = 25.86 msa

Sol:

S.No	Wheel load	% Total Traffic (Ni)	EF [Fi]
1	2268	25	1
2	2722	12	2.07
3	3175	9	3.84
4	3629	6	6.55
5	4082	4	10.49
6	4536	2	16
7	4490	1	23.43
		$\Sigma N_i = 59\%$	

$$\Sigma EF = \left(\frac{\text{Actual load}}{\text{Standard load}}\right)^4$$

$$(1) \rightarrow EF_1 = \left(\frac{2268}{2268}\right)^4 = 1$$

$$(2) \rightarrow EF_2 = \left(\frac{2722}{2268}\right)^4 = 2.07 \ldots\ldots$$

$$VDF = \frac{\Sigma N_i f_i}{\Sigma N_i} = \frac{25\times1+12\times2.07+9\times3.84+6\times6.55+4\times10.49+2\times16+1\times23.23}{59}$$

VDF = 3.74

Given LDF = 0.4

Total Traffic = 1860 cv/day

$\therefore$ Total commercial traffic (A) = $1860\times\frac{59}{100} = 1094.4$ cv/day

$$N = \frac{365\left((1+0.075)^{20}-1\right)(1094.4\times0.4\times3.74)}{0.075}$$

$N = 25.94 \times 10^6$ csa = 25.87 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

$\therefore$ The equivalent axle load = 2662.5 kN

$$\text{VDF} = \frac{(1000\times1)+(100\times16)+(1000\times0.0625)}{1000+100+1000}$$

$$= 1.26$$

Chapter- 15
Rigid Pavements

01. Ans: (a)

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

$$= 35.71\text{ m}$$

(δ' = 50% of gap expansion joint)

Common data for Questions 02 & 03

02. Ans: (a)

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

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

$$= 22.35\text{ kg/cm}^2$$

03. Ans: (d)

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

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

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

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

$$= 8.75\text{ kg/cm}^2$$

Common data for Questions 04 & 05

04. Ans: (a)

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

$=137.22\ cm^2/m$

$$\text{Spacing} = \frac{100\times A}{A_s} = \frac{100\times\left(\frac{\pi}{4}\times 10^2\right)}{137.22}$$

$= 57.23$ cm $\simeq$ 550mm c/c

05. Ans: (b)

Sol: $L = \dfrac{d\sigma_s}{2\sigma_b} = \dfrac{1\times 1700}{2\times 24.6} = 34.55\,cm \simeq 35$ cm

Common data for Questions 06 & 07

06. Ans: (c)

Sol: $L = \dfrac{2\sigma_c}{\gamma_c f} = \dfrac{2\times 0.8\times 10^4}{2400\times 1.5} = 4.4\,m\,c/c$

07. Ans: (c)

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

$$= \frac{200\times 1200\times\frac{\pi}{4}\times\left(10\times 10^{-1}\right)^2}{3.75\times 20\times 2400\times 1.5}\times \text{no. of bars}$$

$= 8.72$ c/c

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

08. Ans: (a)

Sol: $\sigma_f = \dfrac{\gamma_c\,f\,L}{2\times 10^4} = \dfrac{2400\times 4\times 1.2}{2\times 10^4}$

$= 0.576\,kg/cm^2$

Chapter- 16
Traffic Engineering

01 Ans: (a)

Sol: Time mean speed

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

$(V_t) = 49.8$ kmph

$V_s \Rightarrow$ space mean speed

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

$V = 9.76$

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

02. Ans: (a)

Sol:

Speed Range (m/s)	Frequency PCU/hr (q)	Mid-pt speed (v)	qv	q/v
2.5	1	2.5	2.5	0.4
7.5	4	7.5	30	0.533
11.5	0	11.5	0	0
15.5	7	15.5	108.5	0.45
	Σq=12		Σqv= 142.0	$\Sigma\frac{q}{v}$ 1.38

$$V_t = \frac{\sum q\,v}{\sum q} = \frac{141}{12} = 11.75\,m/s$$

$$V_s = \frac{\sum q}{\sum(q/v)} = \frac{12}{1.38} = 8.69\,m/s$$

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 $= \dfrac{1}{1.2/60} = 50\,\text{kmph}$

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

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

Average travel speed

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

$= 41.8$ kmph

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

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

$= 40.91$ kmph

04. Ans: 4000 veh/hr

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

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

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

Peak hour volume (q)

$= 700 + 812 + 1000 + 635$

$= 3147$

$$\therefore \text{ Design flow rate} = \frac{3147}{\dfrac{3147}{4000}} \approx 4000 \text{ veh / hr}$$

05.

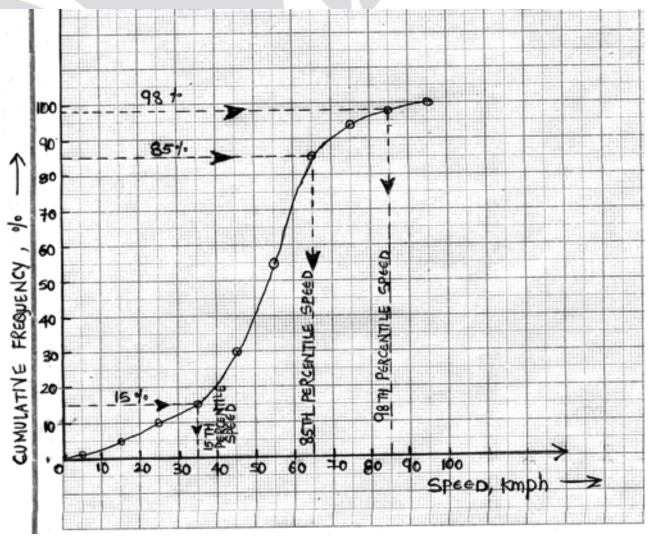
Sol: Total frequency = 100

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

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

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

$= 86.7$ m

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

$$C = \frac{1000\,V}{S} = \frac{1000 \times 65}{91.7}$$
$$\simeq 709\ \text{veh/hr/lane}$$

07. Ans: (b)

Sol: $t = 0.7$ Assume

$$SSD = 0.278\,Vt = 7.78\ m$$
$$S = SSD + L = 12.78\ m$$
$$C = \frac{1000\,V}{S} = 3129$$
$$\simeq 3130\ \text{veh/hr}$$

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

$$k_j = \frac{1000}{s} = \frac{1000}{7}$$
$$k = k_j/2$$
$$q = U_{sf}\left[k - \frac{k^2}{k_j}\right] = U_{sf}\left[k - \frac{k}{2}\right]$$
$$= U_{sf}\left[\frac{k_j}{2} - \frac{k_j}{4}\right]$$
$$= U_{sf}\left[\frac{k_j}{4}\right]$$
$$q = 70 \times \frac{1000}{7} \times \frac{1}{4}$$
$$= 2500\ \text{veh/hr}$$

11. Ans: (d)

Sol: V_{sf} = 80 kmph

k_j = 100 veh /km

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

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

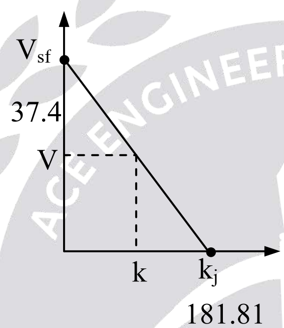
q_{max} is $V_{s\ max}$) $= \dfrac{80}{2} = 40\,\text{kmph}$

12. Ans: 33 veh/km & 149 veh/km

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

$q = v.k$

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

$4861.23 = (181.81-k)k$

$4861.23 = 181.81\,k - k^2$

k = 149 veh/km and k = 32.6 veh/km

$\simeq$ 33 veh/km

13. Ans: 35.7 kmph

Sol: $V_{sf} = 50$ kmph

$t_j = 70$ veh/km

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

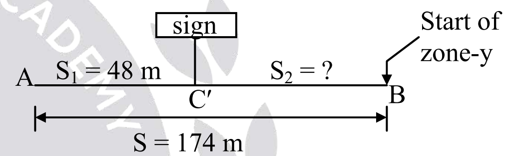
K = 20 veh/km

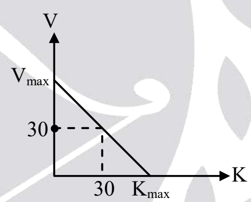
$$\frac{K_j}{V_{sf}} = \frac{K_j - K}{V - 0}$$

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

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

w = 14 m; e = 8.4 m

L = 35 m

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

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

$$Q_p = \frac{280\times14\left(1+\dfrac{8.4}{14}\right)\left(1-\dfrac{0.5}{3}\right)}{1+14/35}$$

= 3733.33 PCU/hr

16. Ans: 2064.10 veh/hr

Sol: w = 6m ; p = 0.5

L = 20 m ; e = 5.5 m

$$= \frac{280\times6\left[1+\dfrac{5.5}{6}\right]\left[1-\dfrac{0.5}{3}\right]}{1+\dfrac{6}{20}}$$

Q_p = 2064.10 veh / hr

17. Ans: 0.8%

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

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

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

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

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

= 76.7 sec ≈ 77 sec

19. Ans: (d)

Sol: $y = 0.5 = y_a + y_b$

L = 10 sec

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

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

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

S → Saturation flow

g_i → effective green time

C_o → Cycle time/Optimum signal cycle length

$\frac{g_i}{C_o} \rightarrow$ 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)

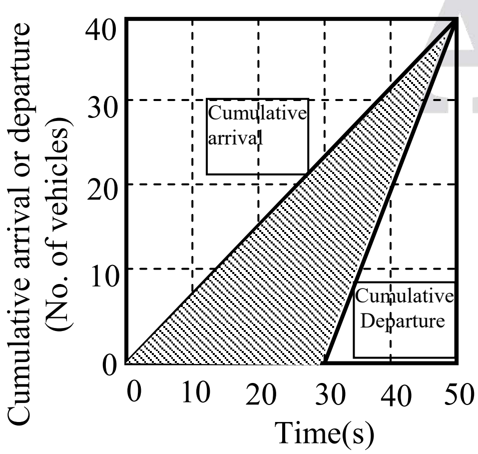
Sol: Average delay at red signal is $=\frac{\text{red time}}{2}$

$$= \frac{30}{2}$$

$= 15$ 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

$\therefore$ 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

$h \rightarrow$ Time headway

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

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

$$= 700 \text{ veh/hr/lane}$$

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 = $V_b = \dfrac{5}{25}\text{km/min}$

Let speed of stream is V km/min

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

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

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 ($V_b = 0$)

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

Equating (1) & (2)

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

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

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

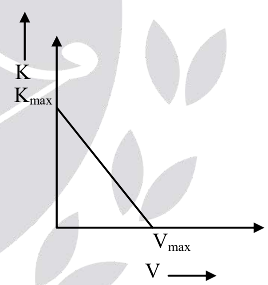
$$\Rightarrow V = \frac{5}{25 \times 0.2}$$

$\Rightarrow$ 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, $q = \left[\dfrac{K_{max} \times V_{max}}{4}\right]$

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

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 = 3m/sec^2

Car length = 4.0 m

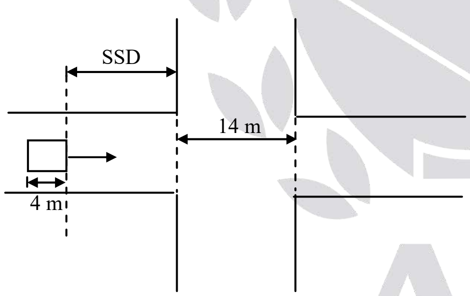
Intersection width = 14

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

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

$$= (16.67\times1.5)+\frac{(16.67)^2}{2\times9.81\times0.35}$$

= 65.47 m

Total distance to be covered

= 65.47 + 14 +4 = 83.47 m

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

$$= \frac{83.47}{16.67}$$

= 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: 0.1353

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

$P(h \geq 8) = e^{-0.25\times8}$

$P(h \geq 8) = 0.1353$

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

$= 0.04 \times 4 = 0.16\%$

03. Ans: (b)

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

Grade compensation at 0.04% per degree of Curve = $0.04 \times 3 = 0.12\%$

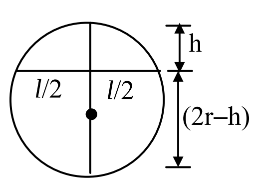
Compensated gradient = $0.4 - 0.12$

$= 0.28\%$

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

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 $= 2 \times 0.04\ \%$

$= 0.08\%$

Stipulated ruling gradient = 0.5%

Steepest gradient = 0.5% – 0.08%

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

08. Ans: (c)

Sol:

Curve resistance $= 0.04\% \times D°$

$= 0.04 \times 4 = 0.16\%$

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

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

Compensated gradient

$= 0.67 - 0.16$

$= 0.51\%$

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

10. Ans: 91.26 kmph

Sol: Given, $D° = 2°$

$$R = \frac{1720}{D°} = \frac{1720}{2}$$

R = 860 mm

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

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

$$V = \frac{15\times50 + 10\times60 + 5\times70 + 2\times80}{15+10+5+2}$$

V = 58.125 kmph

$$e = \frac{GV^2}{127R} = \frac{1.676\times58.125^2}{127\times860}$$

= 0.0518 m

= 5.18 cm

Theoretical cant = Equilibrium cant + cant deficiency

= 5.18 + 7.60

= 12.78 cm

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

$$\frac{12.78}{100} = \frac{1.676\times V^2}{127\times860}$$

V = 91.26 kmph

According to railway boards Speed formula

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

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

$$V = 122.5\ \text{kmph}$$

Hence maximum permissible speed

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

11. 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: (a)

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

02. Ans: (a)

Sol: Length of runway understandard condition

= 2100 m

We have to increase 7% for every 300 m elevation above ground so length of

runway $= 2100 + \frac{7}{100} \times 2100$

= 2247 m

03. Ans: (c)

Sol: Runway elevation = 1000 m (above msl)

Airport reference temperature (ART) = 16°C

Airport standard temperature(AST)

= standard temperature at ms*l* −6.5°C for

1 km height above ms*l*

AST = 15 −6.5 = 8.5°C

Rise in temperature as per

ICAO = 16 −8.5 = 7.5°C

04. 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 standard temperature. $(3.5057^{o} - 11.841^{o}) = 23.729°$

1% → 1^{o} change

x→ $(35.57^{o} - 11.84\%)$

x = 23.729%

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

= 3388.89 m

Correction for effective gradient

20% ↑ → 1% effective gradient

x → 0.75%

x = 15%

Total runway length = 1.15 × 3388.89

= 3897.22 m

≃ 4000 m = 4 km

05. 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

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

06. Ans: (d)

Sol: Given $T_m = 40^oC$

$T_a = 25^oC$

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

$$= \frac{2\times 25 + 40}{3}$$

$= 30^oC$

07. Ans: 2102.17 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 %

$280 \rightarrow x$

$x = 6.53\%$

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

$= 1747.15$ m

Correction for temperature (ICAO)

ART = 33.5°C m

Temperature gradient

$1000 \text{ m} \rightarrow 6.5°$

$280 \text{ m} \rightarrow x$

$x = 1.82°$

Temp @ airport @ 280 m elevation

$= 15 - 1.82$

$= 13.18°$

1% increase in length for 1° above standard temperature $= 33.5^o - 13.18^o$

$= 20.32^o$

$1^o \uparrow \rightarrow 1\% \uparrow$

$20.32^o \uparrow \rightarrow x$

$x = 20.32\%$

$$\text{Correction} = \frac{20.32}{100}\times 1747.15 + 1747.15$$

$= 2102.17$ m

08. Ans: 0.36 %

Sol:

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

09. Ans: 400 m

Sol:

(i) Horonjeff's equation:

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

$$= \frac{0.388\times 17.7^2}{0.5(23)-\left(6+\frac{6.62}{2}\right)} = 55.50 \text{ m}$$

(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

$\therefore$ Turning radius = Maximum of three conditions

= 393.85 m

$R \approx 400$ m