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Super Elevation:

1] Determine the safe radius of circular curve for the following condition where the symbol contains their usual meaning

$V = 60$ mph, $e = 0.4$ ft/10 ft, $f = 0.15$ and $g = 32.2$ ft/s^2.

[PGCL-2014]

2] Radius = 300 ft, frictional factor is 0.02, Limited speed 30 Km/hr. What is the angle of curve or banking of road?

[NPCBL-2017, RPGCL-2017]

3] Radius of a horizontal circular curve is 100 m. The design speed is 50 Kmph and design co-efficient of lateral friction is 0.15, Calculate super elevation required if full lateral friction is assumed to develop.

[BB AD-2018]

4] Design the rate of super elevation for a horizontal highway curve of radius 500 m and speed 100 Kmph.

Transportation

V → Km/hr
v → m/s
v → ft/s
u → mile/hr

Super Elevation:

2| R = ?

V = 60 mph

$= 60 \times \frac{1.61}{3.6} \times 3.28$ ft/s

∴ v = 88 ft/s

e = 0.4 ft / 10 ft

= 0.04

f = 0.15

g = 32.2 ft/s²

Solution:

$$e + f = \frac{v^2}{gR}$$

$$\Rightarrow 0.04 + 0.15 = \frac{88^2}{32.2 \times R}$$

∴ R = 1265.77 ft (Am.)

1 mile = 1.61 Km

1 Km/hr = 1/3.6 m/s

1 m = 3.28 ft

g = 9.81 m/s²

g = 32.2 ft/s²

g = 981 cm/s²

$e_{max} = 0.067 = \frac{1}{15}$

$f_{max} = 0.15$

3| R = 300 ft $= 300 \times \frac{1}{3.28} = 91.46$ m

f = 0.02

V = 30 Km/hr $= \frac{30}{3.6} = 8.33$ m/s

∴ v = 8.33 m/s

θ = ?

Solution:

$$e + f = \frac{v^2}{gR}$$

$$\Rightarrow \tan\theta + f = \frac{v^2}{gR}$$

$$\Rightarrow \tan\theta + 0.02 = \frac{8.33^2}{9.81 \times 91.46}$$

$$\Rightarrow \tan\theta = 0.0573$$

∴ θ = 3.28° (Am.)

4| Solution:

$$e + f = \frac{v^2}{gR}$$

$$\Rightarrow e + 0.15 = \frac{13.89^2}{9.81 \times 100}$$

∴ e = 0.047 (Am.)

R = 100 m

V = 50 Kmph

∴ v = 13.89 m/s

f = 0.15

e = ?

$e_{max} = 0.067$
$f_{max} = 0.15$

8] Design, $e = ?$

$R = 500\ m$, $V = 100$ Kmph

$\therefore v = 27.78$ m/s

Solution:

$$e = \frac{(0.75\,v)^2}{gR}$$ [f দেওয়া না থাকলে এই সূত্র হবে।]

$$\Rightarrow e = \frac{(0.75 \times 27.78)^2}{9.81 \times 500}$$

$\Rightarrow e =$ ~~0.08~~ $0.0885 > e_{max}$ (not ok)

Now, Let, $e = e_{max} = 0.067$

$$e + f = \frac{v^2}{gR}$$

$$\Rightarrow 0.067 + f = \frac{27.78^2}{9.81 \times 500}$$

$\therefore f = 0.09 < f_{max}$ (ok)

So, Design is safe with a superelevation, $e = 0.067$. (Am.)

$e_{max} = 0.067$ ✓
$f_{max} = 0.15$ ✓

9] Determine the Super elevation for 20′ wide road whose radius of curve 300′, $f = 0.14$, $v = 90$ mi/hr. [DNCC-2022]

Solution:

$$e + f = \frac{v^2}{gR}$$

$$\Rightarrow e + 0.14 = \frac{132^2}{32.2 \times 300}$$

$\therefore e = 1.66 > e_{max}$ (Not OK)

So, use $e = e_{max} = 0.067$

$v = 90$ mi/hr
$= 90 \times 1.61$ K/hr
$= \frac{90 \times 1.61}{3.6}$ m/s
$= \frac{90 \times 1.61}{3.6} \times 3.28$ ft/s
$\therefore v = 132$ ft/s
$g = 32.2$ ft/s²
$R = 300$ ft

Now, Super Elevation,

$$E = e \times B$$

$= 0.067 \times 20$

$= 1.34$ ft. (Am.)

Stopping Sight Distance (SSD):

৬] Calculate the stopping sight distance for a highway for which the design speed is 50 mph. Assume $f = 0.42$ and also assume reasonable values for other data items involved in calculations.

[WRGCL-2014, BPDB-2015, BWDB-2013, LGD-2018]

৭] Calculate the safe stopping sight distance of a vehicle traveling at a speed of 80 Km/hr on an upward gradient of 2%. Assume perception and brake reaction time $t = 2.5$ sec and coefficient of friction $= 0.36$,

[40th BCS]

৮] একটি 5.1% grade রাস্তার Stopping Sight Distance নির্নয় করুন যখন এর গতিবেগ 30 mph.

[HED-2020]

Hints :

$V \rightarrow$ Km/hr

$v \rightarrow$ m/s

$V \rightarrow$ ft/s

$u \rightarrow$ mile/hr

$f_{max} = 0.15$ for Super Elevation

$f_{max} = 0.35$ for SSD

SSD : Stopping Sight Distance

[a] SSD = ? $u = 50$ mph

$f = 0.42$,

$t = 2.5$ sec

$u = 50$ mph $= \frac{50 \times 1.61}{3.6}$ m/s

$\therefore v = 22.36$ m/s

Solution:

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

$$= 22.36 \times 2.5 + \frac{22.36^2}{2 \times 9.81 \times 0.42}$$

$= 116.57$ m (Ans.)

[b] SSD = ? $V = 80$ Km/hr

$n = +2\%$ $t = 2.5$ sec

$f = 0.36$

$V = 80$ Km/hr

$\therefore v = 22.22$ m/s

$n = +2\% = +0.02$

Solution:

$$SSD_{(m)} = vt + \frac{v^2}{2g(f \pm n)}$$

$$= 22.22 \times 2.5 + \frac{22.22^2}{2 \times 9.81 \times (0.36 + 0.02)}$$

$= 121.77$ m (Ans.)

[b] $n = 5.1\%$, SSD = ? $u = 30$ mph

Let, $n = 5.1\% = 0.051$, $f = 0.35$, $t = 2.5$ sec

Solution:

$$SSD_{(ft)} = 1.47\,ut + \frac{u^2}{30\left(\frac{a}{g} \pm n\right)}$$

$$\Rightarrow SSD_{(ft)} = 1.47\,ut + \frac{u^2}{30(f \pm n)}$$

When gradient is positive:

$$SSD_{(ft)} = 1.47\,ut + \frac{u^2}{30(f+n)}$$

$$= 1.47 \times 30 \times 2.5 + \frac{30^2}{30 \times (0.35 + 0.051)}$$

$= 185.06$ ft

When gradient is negative:

$$SSD_{(ft)} = 1.47\,ut + \frac{u^2}{30(f-n)}$$

$$= 1.47 \times 30 \times 2.5 + \frac{30^2}{30 \times (0.35 - 0.051)}$$

$= 210.58$ ft (Ans.)

19| A car is travelling at 50 mph during perception and reaction time. Perception and reaction time is 2.5 sec and deceleration rate is 11.2 ft/sec². Determine the stopping sight distance.

[EGCB - 2020]

20| A motorist travelling at ~~50~~ 55 mi/hr down grade 5% on a highway observes a crash ahead of him, involving an overturned truck that is completely blocking the road. If the motorist was able to stop his vehicle 30 ft from the overturned truck, what was his distance from the truck when he first observes the crash? Assume perception reaction time = 2.5 sec.

[NHA - 2020]

21| A car travelling at 50 mph on a highway observes a crash ahead of it. If the driver stopped the car 5m in front of the crash, find the distance it has travelled. Perception time 2.5 sec.

[DESCO - 2015]

19] $u = 50$ mph, $t = 2.5$ sec, $a = 11.2$ ft/sec^2, SSD = ?, $g = 32.2$ ft/s^2

Solution:

$$SSD_{(ft)} = 1.47\,ut + \frac{u^2}{30\left(\frac{a}{g} \pm n\right)}$$

$$\Rightarrow SSD_{(ft)} = 1.47\,ut + \frac{u^2}{30 \times \frac{a}{g}} \quad [\because n = 0]$$

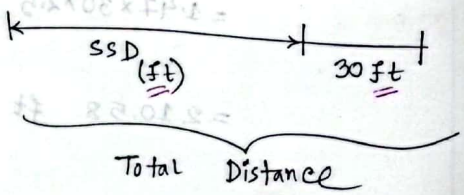
$$= 1.47 \times 50 \times 2.5 + \frac{50^2}{30 \times \frac{11.2}{32.2}}$$

$$= 423.33 \text{ ft} \quad (\text{Am.})$$

20] $u = 55$ mi/h, Distance = ?

$n = (-)5\% = -0.05$

$t = 2.5$ sec



$$f = \frac{a}{g} = \frac{11.2}{32.2} = 0.35$$

Solution:

$$SSD_{(ft)} = 1.47\,ut + \frac{u^2}{30\left(\frac{a}{g} \pm n\right)}$$

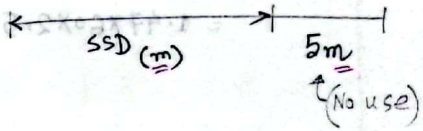
$$= 1.47\,ut + \frac{u^2}{30\,(f - n)}$$

$$= 1.47 \times 55 \times 2.5 + \frac{55^2}{30 \times (0.35 - 0.05)}$$

$$= 538.24 \text{ ft}$$

$\therefore$ Distance $= 538.24 + 30 = 568.24$ ft (Am.)

22] $u = 50$ mph, SSD = ?, $t = 2.5$ sec



Solution:

$$SSD_{(m)} = vt + \frac{v^2}{2g(f \pm n)}$$

$$\Rightarrow SSD_{(m)} = vt + \frac{v^2}{2gf}$$

$$= 22.36 \times 2.5 + \frac{22.36^2}{2 \times 9.81 \times 0.35}$$

$$= 128.7 \text{ m} \quad (\text{Am.})$$

$u = 50$ mph

$= \frac{50 \times 1.61}{3.6}$ m/s

$= \frac{50 \times 1.61}{3.6}$ m/s

$v = 22.36$ m/s

$g = 9.81$ m/s^2

$f = 0.35$

Vertical curve :

২২। A crest vertical curve is to be designed to join a +3% grade with a -2% grade at a section of a two-lane highway. Determine the minimum length of the curve if the design speed of the highway is 60 mi/hr, $S < L$, and a perception-reaction time of 2.5 sec. The deceleration rate for braking is 11.2 ft/sec^2.

[SUFL - 2021]

Hints : ২৬। , ২৪। ও ২৫। নং সমাধানের জন্য,

* Constant corresponding to Level of confidence :

Confidence Level (%)	Constant Z
68.3	1.00
86.6	1.50
90.0	1.64
95.0	1.96
95.5	2.00
98.8	2.50
99.0	2.58
99.7	3.00

Vertical Curve

22| Crest vertical curve. $S < L$,

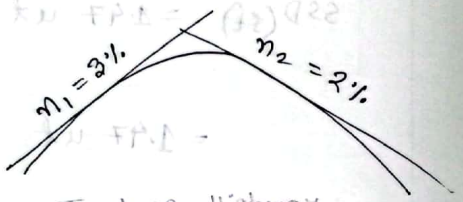
$n_1 = +3\%$

$n_2 = -2\%$

$u = 60$ mi/h

$t = 2.5$ sec

$a = 11.2$ ft/sec^2



Two Lane Highway.

Solution: SSD calculation for worst case ($n = 3\%$)

$$SSD_{(ft)} = 1.47\,ut + \frac{u^2}{30\left(\frac{a}{g} - n\right)}$$

$$= 1.47 \times 60 \times 2.5 + \frac{60^2}{30\left(\frac{11.2}{32.2} - 0.03\right)}$$

$$\therefore SSD_{(ft)} = 598.1 \text{ ft} = S$$

Now, when $S < L$,

$$L_{min} = \frac{NS^2}{2158} \quad \text{(FPS)}$$

$$\Rightarrow L_{min} = \frac{5 \times (598.1)^2}{2158}$$

$$\therefore L_{min} = 828.83 \text{ ft} \quad \text{(Ans.)}$$

$N = n_1 - n_2$

$= 3 - (-2)$

$= 5\%$

$S = SSD$ (ft)

Hints:

- When $S > L$

$$L_{min} = 2S - \frac{2158}{N} \quad \text{(FPS)}$$

Spot Speed sample size:

26| As part of a class project, a group of students collected a total of 120 spot speed samples at a location and determined from this data that the standard variation of the speeds was ± 6 mi/hr. If the project required that the confidence level be 95% and the limit of acceptable error was ± 1.5 mi/hr. Determine whether these students satisfied the project requirement.

[BWDB-2016]

28| An engineer wishing to obtain the speed characteristics on a bypass around her city at a confidence level of 95%, and an acceptable limit of ± 1.0 mi/h collected a total of 130 spot speed samples and determined that the variance is 25 $(mi/h)^2$. Has the engineer met with all of the requirements of the study?

[DESCO-2015, BWDB-2016, BWDB-2018, DPDC-2019]

29| Speed data were collected at a section of highway during and after utility maintenance work. Determine whether there was any significant difference between the average speeds at the 95% confidence level.

$\overline{u_1} = 35.3$ mi/h
$S_1 = 7.5$ mi/h
$n_1 = 250$

$\overline{u_2} = 38.7$ mi/h
$S_2 = 7.4$ mi/h
$n_2 = 280$

[BIWTA-2023]

Speed Data & Confidence Level:

27| $N_{max} = 120$ spot speed

Standard variation, $\sigma = \pm 6$ mi/hr

$C = 95\%$ so, $Z = 1.96$

Acceptable error limit, $d = \pm 1.5$ mi/hr

Solution: Minimum sample size,

$$N = \left(\frac{Z\sigma}{d}\right)^2$$

$$= \left(\frac{1.96 \times 6}{1.5}\right)^2$$

$$= 61.47 \quad < \quad N_{max} \quad (OK)$$

This Data satisfied the project requirement. (Am.)

28| $C = 95\%$ so, $Z = 1.96$

$d = \pm 1$ mi/hr , $N_{max} = 130$ spot speed

Variance, $\sigma^2 = 25$ $(mi/hr)^2$

$Z_c \rightarrow$ maximum data

$\rightarrow$ এর থেকে বড় হওয়া যাবে না.

Solution: Minimum sample size,

$$N = \left(\frac{Z\sigma}{d}\right)^2$$

$$\Rightarrow N = \frac{Z^2 \times \sigma^2}{d^2} = \frac{(1.96)^2 \times 25}{(\pm 1)^2}$$

$$= 96.04 \quad < \quad N_{max} \quad (OK)$$

The engineer has met the requirement. (Am.)

29| Solution:

$$S_d = \sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}$$

$$\Rightarrow S_d = \sqrt{\frac{7.5^2}{250} + \frac{7.4^2}{280}} = 0.65$$

Now, $$Z = \left|\frac{u_1 - u_2}{S_d}\right|$$

$$\Rightarrow Z = \left|\frac{35.3 - 38.7}{0.65}\right|$$

$\therefore Z = 5.23 \quad > Z_c$ (Not OK)

$Z_c = 1.96 = Z$ at $C = 95\%$.

So, The difference in mean speeds is significant, at 95% confidence Level. (Am.)

CBR reliability:

2(b) CBR value found of 10 Kms length as 3.8, 2.8, 3.2, 4.3, 2.8, 4.7, 4.3, 3.9, 4.1 and 4.5%, Find the average CBR, standard deviation, CBR at 50% and 85% reliability.

[BWDB-2014, BPDB-2016, CPGCBL-2018]

2a] CBR value found of 10 Km length as 3.8, 2.8, 3.2, 4.3, 2.8, 4.7, 4.3, 3.9, 4.1 and 4.5%, Find the average CBR, standard deviation, CBR at 50% and 90% reliability.

[PGCB-2018]

Hints:

Percentile	Z
99 th	2.326
97.5 th	1.96
95 th	1.645
90 th	1.282
75 th	0.675
50 th	0
85 th	1.04

#CBR reliability :

[24] $\bar{x} = ?$ $x_{50} = ?$ $x_{85} = ?$ $S_d = ?$

Solution: Average CBR,

$$\bar{x} = \frac{\sum x_i}{n}$$

$$= \frac{3.8+2.8+3.2+4.3+2.8+4.7+4.3+3.9+4.1+4.5}{10}$$

$\therefore \bar{x} = 3.84\ \%$

standard deviation, $S_d = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}}$

$$S_d = \sqrt{\frac{(3.8-3.84)^2 + (2.8-3.84)^2 + (3.2-3.84)^2 + (4.3-3.84)^2 + (2.8-3.84)^2 + (4.7-3.84)^2 + (4.3-3.84)^2 + (3.9-3.84)^2 + (4.1-3.84)^2 + (4.5-3.84)^2}{10-1}}$$

$\therefore S_d = 0.6867$

CBR, $x \rightarrow \%$

CBR at 50% reliability,

$$x_{50} = \bar{x} - z_{50} \times S_d$$

$= 3.84 - 0 \times 0.6867$

$= 3.84\ \%$

$z_{50} = 0$

$z_{85} = 1.04$

CBR at 85% reliability,

$$x_{85} = \bar{x} - z_{85} \times S_d$$

$= 3.84 - 1.04 \times 0.6867$

$= 3.126\ \%$

Ans: $\bar{x} = 3.84\ \%$, $x_{50} = 3.84\ \%$,

$x_{85} = 3.126\ \%$

Hints:

$z_{50} = 0$

$z_{85} = 1.04$

$z_{90} = 1.282$

29] $\bar{x} = ?$ $S_d = ?$ $x_{50} = ?$ $x_{90} = ?$

Solution:- Average CBR,

$$\bar{x} = \frac{\Sigma x_i}{n}$$

$$\Rightarrow \bar{x} = \frac{3.8+2.8+3.2+4.3+2.8+4.7+4.3+3.9+4.1+4.5}{10}$$

$$\therefore \bar{x} = 3.84\ \%$$

standard deviation, $S_d = \sqrt{\frac{\Sigma (x_i - \bar{x})^2}{n-1}}$

$$S_d = \sqrt{\frac{(3.8-3.84)^2+(2.8-3.84)^2+(3.2-3.84)^2+(4.3-3.84)^2+(2.8-3.84)^2+(4.7-3.84)^2+(4.3-3.84)^2+(3.9-3.84)^2+(4.1-3.84)^2+(4.5-3.84)^2}{10-1}}$$

$$\therefore S_d = 0.6867$$

$$x_{50} = \bar{x} - Z_{50} \times S_d$$

$$= 3.84 - 0 \times 0.6867$$

$$= 3.84\ \%$$

$Z_{50} = 0$

$Z_{90} = 1.282$

$$x_{90} = \bar{x} - Z_{90} \times S_d$$

$$= 3.84 - 1.282 \times 0.6867$$

$$= 2.96\ \%$$

Ans:- $\bar{x} = 3.84\ \%$, $S_d = 0.6867$,

$x_{50} = 3.84\ \%$, $x_{90} = 2.96\ \%$,

Time Mean Speed (TMS) and Space Mean Speed (SMS) :

26] Collect time required by 4 vehicles for travelling 1 Km were 1.6, 1.2, 1.5 & 1.7 minute respectively. Find space and time mean speed. [PGCL-2017]

27] Find space and time mean speed for the values of 55, 60, 45, 95 and 60 mile/hr. [TGTDCL - 2018]

20] Find the Time mean speed and space mean speed from the following data –

Time (sec)	20	18	21	16	20	20
Distance (m)	300	300	300	300	300	300

[NPCBL- 2019, BCIC-2019]

Utility by Logit method :

22] If utilities for auto, bus and walk are 0.47, −1.525, and −2.5 respectively. Determine their mode share probabilities using a basic logit model. [DTCA- 2018]

TMS , SMS :

21) $V_1 = \frac{1\text{ Km}}{1.6\text{ min}} = \frac{1\times1000}{1.6\times60} = 10.416\ \text{m/s}$

$V_2 = \frac{1\text{ Km}}{1.2\text{ min}} = \frac{1\times1000}{1.2\times60} = 13.88\ \text{m/s}$

$V_3 = \frac{1\text{ Km}}{1.5\text{ min}} = \frac{1\times1000}{1.5\times60} = 11.11\ \text{m/s}$

$V_4 = \frac{1\text{ Km}}{1.7\text{ min}} = \frac{1\times1000}{1.7\times60} = 9.8\ \text{m/s}$

Solution:

$$V_{TMS} = \frac{\Sigma V}{N}$$

Normal STP

$$= \frac{10.416 + 13.88 + 11.11 + 9.8}{4}$$

$\therefore V_{TMS} = 11.3\ \text{m/s}$

$$V_{SMS} = \frac{N}{\Sigma \frac{1}{V}}$$

$$= \frac{4}{\frac{1}{10.416} + \frac{1}{13.88} + \frac{1}{11.11} + \frac{1}{9.8}}$$

$\therefore V_{SMS} = 11.1\ \text{m/s}$ (Am.)

$V_{TMS} > V_{SMS}$

22) $V_1 = 55\ \text{mile/hr}$ ~~$= 55$~~

$V_2 = 60\ \text{mi/hr}$

$V_3 = 45\ \text{mi/hr}$

$V_4 = 95\ \text{mi/hr}$

$V_5 = 60\ \text{mi/hr}$

Solution:

$$V_{TMS} = \frac{\Sigma V}{N}$$

$$= \frac{55 + 60 + 45 + 95 + 60}{5}$$

$\therefore V_{TMS} = 63\ \text{mi/hr}$

$$V_{SMS} = \frac{N}{\Sigma \frac{1}{V}}$$

$$= \frac{5}{\frac{1}{55} + \frac{1}{60} + \frac{1}{45} + \frac{1}{95} + \frac{1}{60}}$$

$\therefore V_{SMS} = 59.34\ \text{mi/hr}$

(Am.)

$S = Vt$

20| $V = \frac{S}{t}$

$V_1 = \frac{300}{20}\ \frac{m}{s} = 15\ m/s$

$V_2 = \frac{300}{18}\ \frac{m}{s} = 16.67\ m/s$

$V_3 = \frac{300}{21}\ \frac{m}{s} = 14.29\ m/s$

$V_4 = \frac{300}{16}\ \frac{m}{s} = 18.75\ m/s$

$V_5 = \frac{300}{20}\ \frac{m}{s} = 15\ m/s$

$V_6 = \frac{300}{20}\ \frac{m}{s} = 15\ m/s$

Solution:

$$V_{TMS} = \frac{\Sigma V}{n}$$

$$= \frac{15 + 16.67 + 14.29 + 18.75 + 15 + 15}{6}$$

$\therefore V_{TMS} = 15.785\ m/s$

$$V_{SMS} = \frac{n}{\Sigma \frac{1}{V}}$$

$$= \frac{6}{\frac{1}{15} + \frac{1}{16.67} + \frac{1}{14.29} + \frac{1}{18.75} + \frac{1}{15} + \frac{1}{15}}$$

$= 15.65\ m/s$ (Am.)

Utility by Logit method:

20| Auto = 0.47

Bus = −1.525

Walk = −2.5

Mode share probabilities = ?

Solution:

$$P_{Auto} = \frac{e^{Auto}}{e^{Auto} + e^{Bus} + e^{Walk}}$$

$$= \frac{e^{0.47}}{e^{0.47} + e^{-1.525} + e^{-2.5}}$$

$= 0.842$

$$P_{Bus} = \frac{e^{Bus}}{e^{Auto} + e^{Bus} + e^{Walk}}$$

$$= \frac{e^{-1.525}}{e^{0.47} + e^{-1.525} + e^{-2.5}} = 0.114$$

$$P_{Walk} = \frac{e^{Walk}}{e^{Auto} + e^{Bus} + e^{Walk}}$$

$$= \frac{e^{-2.5}}{e^{0.47} + e^{-1.525} + e^{-2.5}} = 0.043$$

(Am.)

Toll of Bridge :

22] A toll bridge carries 5000 vehicle/day. The current toll is 150 taka. When the toll is increased by 25 taka, traffic volume decreases by 500 vehicle/day. Determine the amount of toll that should be charged such that revenue is maximized.

[DTCA-2018, BUET MSc-2018, DMTCL-2019]

Hints : x increases, y decreases.

Vehicle	Toll (Taka)	R
5000	150	5000 × 150
(5000 − 500)	(150 + 25)	V × T
(5000 − y)	(150 + x)	V × T

Pedestrians on Sidewalk :

20] A new office building is expected to add 800 pedestrians at peak hour at its 15' sidewalk during the peak 10 minutes. The sidewalk already has a flow 1400 pedestrians during the peak period. Around 3' of the width of the sidewalk is used for light posts and other obstruction. Determine the new flow rate and maintain the unit measurement.

[PGCL-2014, SGFCL-2017, BIWTA-2019]

Toll of Bridge:

22|

Veh	Toll (Taka)
5000	150
5000 - 500	150 + 25
5000 - y	150 + x

Total Toll amount for maximum Revenue = ?

Solution: Revenue, $R = (5000 - y) \times (150 + x)$

$= \left(5000 - \frac{500}{25} x\right)(150 + x)$

$= (5000 - 20x)(150 + x)$

$\therefore R = 750000 + 2000x - 20x^2$

For Maximum revenue,

$$\frac{d}{dx}(R) = 0$$

$\Rightarrow \frac{d}{dx}(750000 + 2000x - 20x^2) = 0$

$\Rightarrow 0 + 2000 - 20 \times 2x = 0$

$\therefore x = 50$

So, Toll amount $= 150 + x$

$= 150 + 50$

$= 200$ taka (Ans.)

Pedestrians on sidewalk:

26| $P = 800$, $W = 15'$, $t = 10$ min

$P_{Peak} = 1400$, $W_{LP} = 3'$.

Solution: Flow rate,

$$q = \frac{P_{Total}}{W_{eff.} * t}$$

$= \frac{(800 + 1400)}{(15 - 3) \times 10}$ $\frac{\text{Ped.}}{\text{ft} \times \text{min}}$

$= 18.33 \approx 19$ Pedes/min/ft.

(Ans.)

(P.T.O.)

Angularity Number:

28| Calculate the angularity number for the aggregate sample from the following data- relative density of aggregate 2.8, mass of water required to fill the cylinder 2500 gm, mass of cylinder filled with compacted aggregate 5150 gm and mass of cylinder 1100 gm.

[PGCB-2015, DNCC-2016, BPDB-2018]

Specific gravity by Pycnometer:

29| Determine the specific gravity of a bituminous material from pycnometer test.

Mass of pycnometer = 30.48 gm,

Mass of pycnometer filled with water = 57.66gm

Mass of pycnometer filled $\frac{3}{4}$ part with bitumen = 57.68 gm.

[BADC - 2020]

Angularity Number:

28] Relative density, $G_s = 2.8$

$W_w = 2500$ gm

$W_{cyl+Agg} = 5150$ gm

$W_{cyl} = 1100$ gm

$\therefore W_{Agg} = W_{cyl+Agg} - W_{cyl}$

$= 4050$ gm

$67 - \frac{W_{agg}/W_w \times 100}{G_s}$

Angularity Number,

$$AN = 67 - \frac{100 \times W_{agg}}{G_s \times W_w}$$

$$= 67 - \frac{100 \times 4050}{2.8 \times 2500}$$

$= 9.14$

$AN \approx 9$ (round) (Ans.)

Hints:

AN = 7 to 11.

Specific gravity by- Pycnometer:

28] Specific gravity, $G_s = ?$

$M_p = 30.48$ gm

$M_{p+w} = 57.66$ gm

$M_{(p+\frac{3}{4}B)} = 57.68$ gm

Solution:

$$M_w = M_{p+w} - M_p$$

$= 57.66 - 30.48$

$= 27.18$ gm

$$M_{\frac{3}{4}w} = \frac{3}{4} \times M_w$$

$= 20.385$ gm

$$M_{\frac{3}{4}B} = M_{(p+\frac{3}{4}B)} - M_p$$

$= 57.68 - 30.48 = 27.2$ gm

$$G_s = \frac{M_{\frac{3}{4}B}}{M_{\frac{3}{4}w}} = \frac{27.2 \text{ gm}}{20.385 \text{ gm}}$$

$\therefore G_s = 1.334$ (Am.)

Flow, Density, Velocity:

26| The free mean speed on a roadway is found to be 80 Kmph. Under stopped condition the average spacing between vehicles is 6.9m. Determine the capacity flow.

29| Estimate the mean speed at point where the density is 175 vehicle/mile and flow is 10000 vehicle/hrc.

[EGCB-2020, JGTDSL-2021]

25| In speed density relationship, $V_s = 65\left(1 - \frac{K}{116}\right)$, determine the following condition.

(i) Flow density and flow speed.

(ii) Free flow, jam density and capacity.

[DESCO-2015]

(P. T. O.)

Flow, Density, Velocity:

26] $V_f = 80$ Km/hr

Jamming Spacing, $S_j = 6.9$ m

Capacity Flow, $q = ?$

Solution: $S_j = 6.9$ m

$= 6.9 \times 10^{-3}$ Km

Jam Density, $\boxed{K_j = \frac{1}{S}}$ (veh/Km)

$= \frac{1}{6.9 \times 10^{-3}}$

$= 144.93$

$K_j \approx 145$ veh/Km

Maximum flow, / Capacity Flow,

$\boxed{q = \frac{K_j}{2} \times \frac{V_f}{2}}$

$= \frac{145}{2} \times \frac{80}{2}$ $\left(\frac{\text{veh}}{\text{Km}} \times \frac{\text{Km}}{\text{hr}}\right)$

$= 2900$ veh/hr [Per Lane]

(Ans)

29] Density, $K = 175$ veh/mile

Flow, $q = 10000$ veh/hr

Mean speed, $v = ?$

Solution: Flow = Density × Velocity

$\Rightarrow \boxed{q = K \times v}$

$\Rightarrow 10000 = 175 \times v$

$\therefore v = 57.14$ mile/hr (Ans.)

28] $V_s = 65\left(1 - \frac{K}{116}\right)$

$V_f = ?$ $K_j = ?$ Capacity $= ?$

Solution: Comparing with,

$\boxed{V_s = V_f \times \left(1 - \frac{K}{K_j}\right)}$

we get, $V_f = 65$ Km/hr, $K_j = 116$ veh/Km

$\therefore$ Capacity flow, $\boxed{q = \frac{K_j}{2} \times \frac{V_f}{2}}$ $\left(\frac{\text{Km}}{\text{hr}} \times \frac{\text{veh}}{\text{Km}}\right)$

$= \frac{116}{2} \times \frac{65}{2}$ [P.T.O.]

$= 1885$ veh/hr (Ans)

ESAL; EALF; Wheel Pressure :

2nd Determine ESAL for load repetition is 1.5 million and axle load is 120 KN.
[WARPO - 2017]

(01) A Two way two lane road ADT is 4000. If the commercial vehicle is 45% and load 27 Kip, calculate the ESAL for commercial vehicle in one direction.
[ERL - 2017, MPL - 2017, JOCL - 2018]

(02) Axle load of 27 Kip and 36 Kip are repeated 30 and 15 times respectively on pavement of 24 hours. What will be the Equivalent Single Axle Load (ESAL) in a year?
[WASA - 2017]

(02) Two close wheel imparted 20.5 KN load on each road. The applied pressure is 0.7 MPa. If the two wheel is replaced by a single wheel of same property, then find out the imparted effective diameter on soil (by considering circular imparted effect) by the single wheel.
[BPDB - 2016, CPGCBL - 2018]

(01) The radius of a tyre imprint is approximated to a circle of 150 mm. What is the maximum loading duration on a particular point of pavement by a truck moving at a speed of 60 Kmph ?
[RPGCL - 2017, GTCL - 2018]

Now, Flow speed, $V = \frac{V_f}{2}$

$\Rightarrow V = \frac{65}{2} = 32.5$ Km/hr

And, $q = K \times V$

$\Rightarrow 1885 = K \times 32.5$

$\therefore K = 58$ veh/Km (Am.)

ESAL, EALF, Wheel pressure:

2q] ESAL = ?

Load Repetition = 1.5 million

$= 1.5 \times 10^6$

Axle Load = 120 KN

Solution: Equivalent Axle Load Factor,

$$EALF = \left(\frac{\text{Axle Load}}{\text{Std. Axle Load}}\right)^4$$

$$= \left(\frac{120 \text{ KN}}{80 \text{ KN}}\right)^4$$

$\therefore EALF = 5.0625$

Std. Axle Load = 80 KN
= 18 KiP
= 18×10^3 lb

Equivalent Single Axle Load,

$ESAL = EALF \times$ No. of Repetition

$= 5.0625 \times (1.5 \times 10^6)$

$= 7.59 \times 10^6$

$\therefore ESAL = 7.59$ million (Am.)

Q] Two Way Two Lane Road

ADT = 4000

Commercial veh. = 45%

Load = 27 KiP, ESAL = ? (one direction)

Solution: Commercial veh. (one direction) $= 4000 \times \frac{45}{100} \times \frac{1}{2}$

$= 900$ veh.

$ESAL = EALF \times$ Repetition

$= \left(\frac{27}{18}\right)^4 \times 900$

$= 4556.25$ (Am.)

(03) Axle load = 27 kip , 36 kip

Repetition = 30 times, 15 times (24 hrs)

ESAL (year) = ?

Solution:

$$ESAL_{(Daily)} = \left(\frac{27}{18}\right)^4 \times 30 + \left(\frac{36}{18}\right)^4 \times 15$$

$$= 391.875$$

$$ESAL_{(Yearly)} = ESAL_{(Daily)} \times 365$$

$$= 391.875 \times 365$$

$$= 143034$$

$$= 0.143 \times 10^6$$

$$= 0.143 \text{ MSA}$$

(Am.)

Hints:

MSA = Million Std. Axle

$= (10^6)$ or million

MSA = Million Std. Axle

Wheel pressure

(02) Load, $F = 2 \times 20.5$ kN

$= 2 \times 20.5 \times 10^3$ N

Pressure, $P = 0.7$ MPa ; Dia, $D = ?$

$= 0.7 \times 10^6$ Pa

$= 0.7 \times 10^6$ N/m²

1 MPa = 1 N/mm²

" $= 10^6$ N/m²

Solution:

Now, Pressure, $P = \frac{F}{A}$

$$\Rightarrow 0.7 \times 10^6 = \frac{2 \times 20.5 \times 10^3}{\frac{\pi}{4} D^2}$$

$\therefore D = 0.273$ m (Am.)

(06) Tyre imprint circle, $S = 150$ mm $\times 2$ (সামনের চাকা ও পিছনের চাকা 2 বার ছাপ দেয়)

$V = 60$ Km/hr

Duration, $t = ?$

Solution: $S = V \times t$

$\Rightarrow 0.3 = 16.67 \times t$

$\therefore t = 0.018$ sec

(Am.)

$S = 150 \times 2$ mm

$= 0.3$ m

$V = 60$ Km/hr

$= 16.67$ m/s

Intersection; Cycle time ; Green time:

08| Determine the minimum yellow interval at an intersection whose width is 40 ft, if the maximum allowable speed on the approach roads is 30 mi/h. Assume average length of vehicle is 20 ft.

[DNCC - 2020]

07| Vehicles approaching an intersection with 60 Km/h have to cross a 12m street. If the average reaction time of a driver is 1.5 sec, the deceleration rate is $3m/sec^2$, the average length of a vehicle is 6m, Determine the clearance interval required. If the desired yellow interval is 4 seconds, should there be an all red indication?

06| Let the cycle time of an intersection is 60 sec. The green time for a phase is 27 sec and corresponding yellow time is 4 sec. If the saturation headway is 2.4 sec/veh, startup loss time is 2sec per phase and clearance lost time is 1 sec/phase, find the capacity of the movement per lane?

[BWDB - 2018, BUET MSc - 2018, NHA - 2020, BIWTA - 2023]

09| Determine the total inter green time for two phase traffic having cycle time C = 66s, Green time for NS direction G_{NS} = 24 sec and for EW direction G_{EW} = 27 sec.

[PGCL - 2017]

Intersection ; Cycle time ; Green time:

08| Minimum yellow interval , I_{min} = ?

Width , W = 40 ft

Speed , v = 30 mi/hr

$= \frac{30 \times 1.61}{3.6} \times 3.28$ ft/s

$= 44$ ft/s

Vehicle Length, L = 20 ft

Solution: Minimum clearance interval,

$$I_{min} = t + \frac{W+L}{v} + \frac{v}{2a}$$

$= 1 + \frac{40+20}{44} + \frac{44}{2 \times 11.2}$

$= 4.33$ sec

≈ 4.50 sec (Am.)

∴ Minimum yellow interval of 4.50 sec will be needed.

$t = 1$ sec

$a = 11.2$ ft/s²

06| V = 60 Km/hr ∴ v = 16.67 m/s

Street width, W = 12m

Reaction time , t = 1.5 sec

Deceleration rate, a = 3 m/s²

Vehicle Length, L = 6m

clearance interval , I_{min} = ?

y = 4sec

R = ?

Solution:

$$I_{min} = t + \frac{W+L}{v} + \frac{v}{2a}$$

$= 1.5 + \frac{12+6}{16.67} + \frac{16.67}{2 \times 3}$

∴ I_{min} = 5.4 sec

And, $I_{min} = y + R$

⇒ $5.4 = 4 + R$

∴ R = 1.4 sec (Am.)

Hints:

Minimum clearance Interval = Yellow interval + Red interval .

Using a 4 sec yellow, the remaining 1.4 seconds should be accommodated using an all red indication.

(06) Cycle time, $C = 60$ sec

green time, $g_a = 27$ s

yellow time, $y = 4$ s

Saturation headway, $h = 2.4 \frac{\text{sec}}{\text{veh}}$

t_L = time loss = Startup lost time + Clearance lost time

$= 2\text{ s} + 1\text{ s}$

$= 3\text{ s}$

Lane Capacity (per lane), $LC = ?$

Solution: Saturation flow rate,

$$S = \frac{1}{h}$$

$$= \frac{1}{2.4} \frac{\text{veh}}{\text{sec}}$$

$$= \frac{1}{(2.4/3600)} \frac{\text{veh}}{\text{hr}}$$

$\therefore S = 1500$ veh/hr

Effective green, $g_e = g_a + y - t_L$

$= 27 + 4 - 3$

$= 28$ sec

Lane capacity, $LC = \frac{g_e}{C} \times S$

$= \frac{28}{60} \times 1500$ $\left(\frac{\text{sec}}{\text{sec}} \times \frac{\text{veh}}{\text{hr}}\right)$

$= 700$ veh/hr (Per Lane)

(Ans.)

(09) $C = 66$ s

$G_{NS} = 24$ s, $G_{EW} = 27$ s

Inter green time = ?

Solution: Cycle time = (Total Green time) + (Inter Green time)

$\Rightarrow C = (G_{EW} + G_{NS}) + I$

$\Rightarrow 66 = (24 + 27) + I$

$\therefore I = 15$ sec (Ans.)

Extra & Important

ADT

(96) In a place, no of vehicles passes per hour is shown in the table –

Vehicle Type	PCU Factor	Flow (veh/hr)
Bus	3	41
Car, Jeep, Microbus, Taxi	1	263
3-Wheeler	0.5	55
NMT	0.5	48
Motor cycle	0.1	43

Calculate ADT when hourly expansion factor 42.

[PGCB-2019]

Solution:

Service Flow Rate = Σ (PCU Factor x Flow)

$= (3 \times 41) + (1 \times 263) + (0.5 \times 55) + (0.5 \times 48) + (0.1 \times 43)$

$= 441.8$ veh/hr

Hourly Expansion Factor, HEF = 42

ADT = Avg. Daily Traffic

Avg. Daily Traffic,

ADT (veh/Day) = Service Flow Rate x HEF

$= 441.8 \times 42$

$= 18556$ veh/Day (Ans.)

Hints:

ADT = Avg. Daily Traffic → veh/Day

Service Flow Rate → veh/hr

Car Crash

(07) It is observed that 40 crashes occured on a 17.5 miles long section of highway in one year, ADT on the section is given as 5000 vehicles. Determine —

a) The rate of total crashes per 100 millions vehicles miles.

b) The rate of Fatal crashes per 100 millions vehicles miles, if 5% of the crashes involved in fatalities. [DPDC-2019]

Solution:

Crash no. = 40

Length = 17.5 miles

ADT = 5000 veh

(a) [100 million = 100×10^6 VM]

Rate of Car crash,

$$R = \frac{\text{no. of crash} \times (100 \times 10^6)}{\text{ADT} \times \text{Length} \times 365}$$

$$= \frac{40 \times (100 \times 10^6)}{5000 \times 17.5 \times 365}$$

= 125.24 crashes (Per 100 MVM)

Capacity → Veh./hr

(b) Fatal Crash Rate = Fatality (%) × R

= 5% × 125.24

= 6.26 Crashes/100 MVM. (Ans.)

Theoretical Traffic Capacity:

(08) Determine the theoretical capacity of 4 Lane national highway per hour. The speed of vehicle is 60 Km/hr. Spacing of vehicle is 4m.

Solution:

Lane, n = 4

V = 60 Km/hr

Spacing, S = 4 m = 4×10^{-3} Km

Theoretical capacity,

$$C = \frac{V}{S} \times n$$

$$= \frac{60}{4 \times 10^{-3}} \times 4$$

= 60000 veh./hr (Ans.)

80| Determine theoretical capacity of road if design speed 100 Km/hr with reaction distance 2m and average length of vehicle is 6m.

Solution: $V = 100$ Km/hr

$R = SSD = 2$ m

$L = 6$ m

Vehicle spacing, ~~$S = SSD + L$~~

$$S = R + L$$

$= 2 + 6 = 8$ m $= 8 \times 10^{-3}$ Km

Theoretical capacity,

$$C = \frac{V}{S}$$

[Lane বলা নাই]

$$= \frac{100}{8 \times 10^{-3}}$$

$= 12500$ veh/hr (per lane)

(Am.)

$t = 2.5$ s

$f = 0.35$

82| Calculate the theoretical maximum traffic capacity for a traffic lane at speed of 80 Km/hr. Avg length of the vehicle may be assumed as 6m.

Solution: $V = 80$ Km/hr

$\therefore V = 22.22$ m/s

$L = 6$ m

$L = 6$m
$\therefore L = 6 \times 10^{-3}$ Km

$S = L + SSD$

Now, $$SSD_{(m)} = Vt + \frac{V^2}{2gf}$$

$$= 22.22 \times 2.5 + \frac{22.22^2}{2 \times 9.81 \times 0.35}$$

$= 127.45$ m

Spacing, $$S = SSD + L$$

$= 127.45 + 6$

$= 133.45$ m $= 133.45 \times 10^{-3}$ Km

Theoretical maximum traffic capacity,

$$C = \frac{V}{S}$$

$$= \frac{80}{133.45 \times 10^{-3}}$$

$= 600$ veh/hr (Am.)