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# HIGHWAY ENGINEERING

## CIVIL ENGINEERING

**Date of Test : 29/07/2022**

## ANSWER KEY ➤

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1. | (c) | 7. | (b) | 13. | (c) | 19. | (a) | 25. | (b) |
| 2. | (d) | 8. | (a) | 14. | (d) | 20. | (a) | 26. | (a) |
| 3. | (a) | 9. | (c) | 15. | (d) | 21. | (b) | 27. | (b) |
| 4. | (b) | 10. | (d) | 16. | (d) | 22. | (c) | 28. | (c) |
| 5. | (c) | 11. | (a) | 17. | (d) | 23. | (d) | 29. | (c) |
| 6. | (c) | 12. | (b) | 18. | (b) | 24. | (a) | 30. | (a) |

# DETAILED EXPLANATIONS

**1. (c)**

Curve (a) or (d) → For flow value

Curve (b) → Percent voids filled with bitumen (VFB)

Curve (c) → Percent voids in total mix

**2. (d)**

Radius of Horizontal curve = 75 m

$$\text{Grade compensation} = \frac{30 + R}{R} \leq \frac{75}{R}$$

$$= \frac{30 + 75}{75} = 1.4$$

and $\quad \dfrac{75}{R} = \dfrac{75}{75} = 1\%$

So, Grade compensation = 1%

∴ Compensated gradient

= Ruling gradient − grade compensation

= 6% − 1% = 5%

**3. (a)**

$$\text{Capacity} = \frac{1000\,V}{S}$$

$$S = 0.2V + L$$

$$= 0.2 \times 60 + 6 = 18 \text{ m}$$

$$\text{Capacity} = \frac{1000 \times 60}{18} \times 2 = 6666.7 \simeq 6700$$

The closest answer is 6800.

**4. (b)**

$$R = \frac{v^2}{127(e+f)} = \frac{362}{127(0.1+0.15)} = 40.82$$

**5. (c)**

$$\frac{\Delta_{flexible}}{\Delta_{rigid}} = \frac{1.5}{1.18} = 1.27$$

**6. (c)**

$$\text{CBR}_{2.5} = \frac{\text{Load sustained by specimen at 2.5 mm penetration}}{\text{Load sustained by standard aggregate at 2.5 mm penetration}} \times 100$$

$$= \frac{60}{1370} \times 100 = 4.379 \simeq 4.38\%$$

$$CBR_{5.0} = \frac{\text{Load sustained by specimen at 5.0 mm penetration}}{\text{Load sustained by standard aggregate at 5.0 mm penetration}} \times 100$$

$$= \frac{80}{2055} \times 100 = 3.89\%$$

**7. (b)**

Assuming $V$ volume passed in peak hour. And for minimum peak hour volume, all volume of that hour, was passed in 10 min only.

So, Min PHF10 min $= \dfrac{V}{\left(\dfrac{60}{10}\right) \times V} = \dfrac{1}{6} = 0.167$

**8. (a)**

Given: $n_a = 21$, $n_w = 350$, $V = 70$ kmph

$$T_w = T_a = \frac{8}{70} \text{ hr}$$

$$q = \frac{n_a + n_w}{T_a + T_w} = \frac{350 + 21}{\left(\dfrac{8}{70} + \dfrac{8}{70}\right)} \simeq 1624 \text{ vehicles/hr}$$

**9. (c)**

The theoretical specific gravity of the mix is given by,

$$G_t = \frac{100}{\dfrac{50}{2.56} + \dfrac{38.20}{2.65} + \dfrac{4.70}{2.70} + \dfrac{7.10}{1.10}} = 2.37$$

**10. (d)**

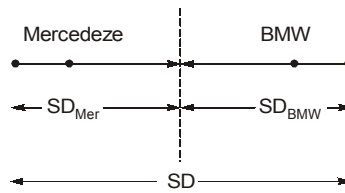Hourly expansion factor $= \dfrac{25000}{5000} = 5$

**11. (a)**

$$L = 2\left[\frac{NV^3}{c}\right]^{1/2}$$

$$= 0.38\left[NV^3\right]^{1/2} \qquad \left[\because c = 0.6 \text{ m/s}^3\right]$$

$$N = -\frac{1}{45} - \left(\frac{1}{60}\right) = \frac{-7}{180}$$

$\therefore$ 
$$L = 0.38\left[\frac{7}{180} \times 75^3\right]^{1/2}$$

$$= 48.67 \text{ m}$$

**12. (b)**



Stopping distance $= SD_{Mer} + SD_{BMW}$

Stopping distance for Mercedeze $= \left(0.278\,V_{Mer}\right)t + \dfrac{V_{Mer}^2}{254f}$

$$= 0.278 \times 220 \times 2 + \dfrac{220^2}{254 \times 0.7 \times 0.8}$$

$$= 462.59\,\text{m}$$

Stopping distance for BMW $= 0.278 \times 180 \times 3 + \dfrac{180^2}{254 \times 0.7 \times 0.75} = 393.09\,\text{m}$

$\therefore$ Total stopping distance required $= 462.59 + 393.09$

$$= 855.68\,\text{m}$$

**13. (c)**

| Speed Range | Mean | Frequency | $V_i q_i$ | $\dfrac{q_i}{V_i}$ |
|---|---|---|---|---|
| 2 – 6 | 4 | 2 | 8 | 0.5 |
| 7 – 11 | 9 | 5 | 45 | 0.555 |
| 12 – 14 | 13 | 1 | 13 | 0.0769 |
| 15 – 19 | 17 | 8 | 136 | 0.47 |
| Total | | 16 | 202 | 1.60 |

Time mean speed, $V_t = \dfrac{\sum q_i V_i}{\sum q_i} = \dfrac{202}{16} = 12.625$

Space mean speed, $V_s = \dfrac{\sum q_i}{\sum\left(\dfrac{q_i}{V_i}\right)} = \dfrac{16}{1.6} = 10$

Ratio of time mean speed to space mean speed $= \dfrac{12.625}{10} \simeq 1.26$

**14. (d)**

$$V_v = \dfrac{G_t - G_m}{G_t} \times 100$$

$$= \dfrac{2.464 - 2.318}{2.464} \times 100 = 5.925\%$$

Voids filled with bitumen, $V_b = G_m \times \dfrac{W(\%)}{G_b}$

$$= 2.318 \times \frac{5.5}{1.12} = 11.383\%$$

$$VMA = V_v + V_b$$
$$= 5.925 + 11.383 = 17.308\%$$

$\therefore$

$$VFB = \frac{V_b(\%)}{VMA} \times 100$$

$$= \frac{11.383}{17.308} \times 100 = 65.767\% \simeq 65.77\%$$

**15. (d)**

$$\text{Deflection, } \Delta = \frac{1.5\,pa}{E_s}$$

where, $p$ = Contact pressure due to wheel load = 0.5 MPa, $a$ = Radius of contact area

Now,

$$\text{Contact area} = \frac{\text{Wheel load}}{\text{Type pressure}}$$

$$= \frac{50 \times 10^3 \text{ N}}{0.5} = 100 \times 10^3 \text{ mm}^2$$

But

$$\text{Area} = \pi \times a^2$$
$$= 100 \times 10^3$$

$\therefore$

$$a = \sqrt{\frac{100 \times 10^3}{\pi}} = 178.41 \text{ mm}$$

$$E_s = 20 \text{ MPa}$$

So,

$$\Delta = \frac{1.5 \times 0.5 \times 178.41}{20} = 6.69 \text{ mm}$$

**16. (d)**

**17. (d)**

**18. (b)**

$$\text{Traffic flow, } q = uk$$
$$= 60k - 0.75k^2$$

For maximum $q$,

$$\frac{dq}{dk} = 0$$

$\Rightarrow$

$$\frac{dq}{dk} = 60 - 1.5k = 0$$

$\Rightarrow$

$$k = 40$$

$\therefore$

$$u = 60 - 0.75 \times 40 = 30 \text{ km/h}$$

$\therefore$

$$q = 30 \times 40 = 1200 \text{ veh/h}$$

**19. (a)**

**20. (a)**

Assume $S$ is less than $L$

$$L = \frac{NS^2}{4.4}$$

$$N_1 = \frac{1}{50} = 0.02$$

$$N_2 = -\frac{1}{40} = -0.025$$

$$\therefore \qquad N = N_1 - N_2 = 0.02 - (-0.025) = 0.045$$

$$\therefore \qquad L = \frac{0.045 \times 180 \times 180}{4.4} = 331.36 \text{ m}$$

Hence assumption is correct.
Equation of parabola is,

$$y = \frac{Nx^2}{2L}$$

$$= \frac{0.045x^2}{2 \times 331.36} = 6.79 \times 10^{-5} x^2$$

## 21. (b)

Maximum expansion allowed,

$$\delta = \frac{3}{2} = 1.5 \text{ cm} = 1.5 \times 10^{-2} \text{ m}$$

$$\Delta T = T_2 - T_1 = 30°C$$

Coefficient of thermal expansion,

$$\alpha = 10 \times 10^{-6}/°C$$

$\therefore$ Spacing of expansion joint, $L$

$$= \frac{\delta}{\alpha(T_2 - T_1)} = \frac{1.5 \times 10^{-2}}{10 \times 10^{-6} \times 30} = 50 \text{ m}$$

## 22. (c)

The capacity of rotary, $Q_P = \dfrac{280w\left(1+\dfrac{e}{w}\right)\left(1-\dfrac{p}{3}\right)}{\left(1+\dfrac{w}{L}\right)}$

$$w = 15 \text{ m}, p = 0.6, L = 75 \text{ m}, e = 5 \text{ m}$$

$$\Rightarrow \qquad Q_p = \frac{280 \times 15 \times \left(1+\dfrac{5}{15}\right)\left(1-\dfrac{0.60}{3}\right)}{\left(1+\dfrac{15}{75}\right)} = 3733.33 \simeq 3733 \text{ PCU/hr}$$

## 23. (d)

Given: $\qquad V = 60 \text{ kmph} = \dfrac{60 \times 1000}{60 \times 60} = 16.67 \text{ m/s}$

$$SSD = Vt + \frac{V^2}{2g\left(f + \dfrac{n\%}{100}\right)}$$

$$= 16.67 \times 2.5 + \frac{(16.67)^2}{2 \times 9.81 \times (0.36 + 0.02)}$$

$$= 78.948 \simeq 78.95 \text{ m}$$

$\therefore \qquad \text{ISD} = 2 \times \text{SSD} = 157.9 \text{ m}$

**24. (a)**

$$P(n) = \frac{(\lambda t)^n \, e^{-\lambda t}}{n!}$$

where,

$\lambda$ = Average rate of arrival,

$t$ = time interval

$n$ = Number of vehicles

$P(n)$, is the probability of $n$ events (vehicle arrival) in some time interval $t$.

$\Rightarrow \qquad \lambda = \dfrac{200}{30 \times 60} = \dfrac{1}{9}$ vehicle/sec

Now probability that the headway (into arrival time) greater than or equal to 5 sec is

$$P(n = 0) = \frac{\left(\dfrac{1}{9} \times 5\right)^0 \times e^{-\left(\dfrac{1}{9} \times 5\right)}}{0!} = e^{-\frac{5}{9}} = 0.573$$

**25. (b)**

We know that, $\qquad C_0 = \dfrac{1.5L + 5}{1 - Y}$

$$L = 9 \text{ sec}$$

$$Y = \frac{800}{2000} + \frac{900}{3000} = 0.7$$

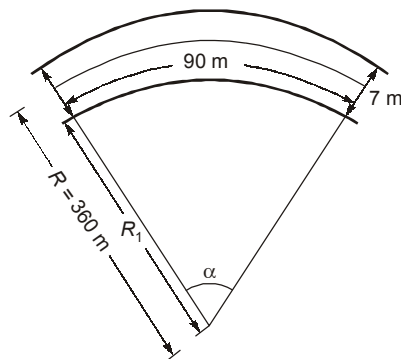$$C_0 = \frac{1.5 \times 9 + 5}{1 - 0.7} = 61.67 \simeq 62 \text{ sec}$$

**26. (a)**

Numbers of points of conflict:

Crossing : 4

Merging : 8

Weaving : 12

**27. (b)**

⇒ We know that, $\quad R_1 \alpha = SSD,$

$$R_1 = 360 - \frac{3.5}{2} = 358.25 \text{ m}$$

$$358.24 \times \alpha = 90$$

$$\alpha = 0.251 \text{ radian} = 14.39°$$

For set back distance

We know, $\quad m = R - (R - d)\cos\frac{\alpha}{2}$

$$= 360 - (360 - 1.75)\cos\left(\frac{14.39}{2}\right)$$

$$m = 4.57 \text{ m}$$

Set back distance from center line of inner lane = $m - d$ = 4.57 − 1.75 = 2.82 m

**28. (c)**

$$N_s = \frac{A \times 365 \times \left(\left(1 + \frac{r}{100}\right)^n - 1\right) \times L.D.F \times V.D.F}{\left(\frac{r}{100}\right)}$$

$$= \frac{2000 \times 365 \times [(1.1)^{15} - 1] \times 0.75 \times 2.8}{\left(\frac{10}{100}\right)}$$

$$= 48.70 \text{ msa}$$

**29. (c)**

During stoppage number of vehicle passes = 40

Stoppage time = 10 min

Stream flow $(q) = 40 \times \frac{60}{10} = 240$ veh/hr

$$\eta_y = \text{Number of overtaking vehicles} - \text{Number of overtaken vehicle}$$

$$= 70 - 25 = 45$$

⇒ We know that, $\quad \eta_y = q[t_w - \bar{t}]$

$$\bar{t} = t_w - \frac{\eta_y}{q} = \left(\frac{25}{60}\right) - \left(\frac{45}{240}\right) = 0.2285 \text{ hr}$$

$$\text{Average speed} = \frac{12}{0.2285} \simeq 52.52 \text{ km/hr}$$

**30. (a)**

| Axle load (kN) | Mean Axle load (kN) | Load factor ($L/80$)$^4$ | Repeation ($N$) | |
|---|---|---|---|---|
| 20-30 | 25 | $9.536 \times 10^{-3}$ | 2000 | 19.072 |
| 30-40 | 35 | 0.0366 | 1000 | 36.60 |
| 40-50 | 45 | 0.100 | 1500 | 150 |
| 50-60 | 55 | 0.223 | 500 | 111.5 |
| | | | $\Sigma N_s = 5000$ | 317.172 |

$$\text{Vehicle damage factor} = \frac{317.172}{2100} \simeq 0.15$$

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