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Highway Engineering

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CLASS TEST 2019-2020

CIVIL ENGINEERING

Date of Test : 31/08/2019

ANSWER KEY ➤ Highway Engineering

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

DETAILED EXPLANATIONS

1. (d)
For mixed traffic conditon, super elevation is provided for 75% of design speed. Emergency escapes are provided on down grades so that in case of brake failure or system failure vehicle can be controlled.

2. (d)

3. (a)
Given: $n_a = 21,\ n_w = 350,\ V = 70$ kmph

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

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

4. (a)
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, $$\text{Min PHF10 min} = \frac{V}{\left(\frac{60}{10}\right) \times V} = \frac{1}{6} = 0.167$$

5. (c)
Time mean speed,

$$V_t = \frac{46 + 56 + 40 + 92 + 63}{5} = 59.4 \text{ km/hr}$$

Space mean speed,

$$V_S = \frac{5}{1/46 + 1/56 + 1/40 + 1/92 + 1/63}$$

$$= 54.74 \text{ km/hr}$$

So, difference between time mean and space mean velocity

$$= V_t - V_s = 59.4 - 54.74 = 4.66 \text{ km/hr}$$

6. (b)
Capacity of the road, if only cars use the road

$$q = KV$$

$$q = \left(\frac{1000}{5}\right) \times 80 \times 4 = 64000 \text{ vehicles/hr}$$

Capacity of the road, if only trucks use the road

$$= \left(\frac{1000}{10}\right) \times 40 \times 4 = 16000 \text{ vehicles/hr}$$

$$\text{PCU of the truck} = \frac{64000}{16000} = 4$$

7. (b)

The theoretical specific gravity of the mix is given by,

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

8. (c)

$$\text{Capacity} = \text{Velocity} \times \text{Density}$$

$$C = u \times k = 65\,k - 0.65\,k^2$$

Now,

$$\frac{dC}{dk} = 65 - 1.3\,k = 0$$

$$k = \frac{65}{1.3} = 50$$

$\therefore$ $$\text{Capacity, } C = 65 \times 50 - 0.65 \times 50^2 = 1625 \text{ veh/hr}$$

9. (d)

10. (b)

The modulus of subgrade reaction for 76 cm diameter rigid plate,

$$k_1 = \frac{P}{\Delta} = \frac{0.88\,\text{kg/cm}^2}{0.125\text{ cm}} = 7.04 \text{ kg/cm}^3$$

$\therefore$ Modulus of subgrade reaction for standard plate of diameter 75 cm.

$$k = \frac{k_1 a_1}{a} = \frac{7.04 \times 76}{75} = 7.13 \text{ kg/cm}^3$$

11. (b)

$\delta = 2.5$ mm, $\sigma = 3.5$ N/mm^2 = 35 kg/cm^2

$\delta = 5.0$ mm, $\sigma = 7.0$ N/mm^2 = 70 kg/cm^2

Standard load,

At 2.5 mm penetration = 70 kg/cm^2 (1370 kg)

At 5.0 mm penetration = 105 kg/cm^2 (2055 kg)

$$\text{CBR\%} = \frac{\text{Actual load/stress}}{\text{Standard load/stress}} \times 100$$

$$= \text{Maximum} \begin{cases} \frac{35}{70} \times 100 = 50\% \\ \frac{70}{105} \times 100 = 66.66\% \end{cases}$$

$\therefore$ $$\text{CBR (\%)} = 66.66\%$$

12. (a)

Practical capacity of rotary (Q_P),

$$Q_P(\text{veh/hr}) = \frac{280w\left(1+\frac{\rho}{w}\right)\left(1-\frac{P_{max}}{3}\right)}{\left(1+\frac{w}{L}\right)}$$

$$\therefore \quad Q_P \propto \left(1-\frac{P_{max}}{3}\right)$$

$$\therefore \quad \frac{Q_{P_1}}{Q_{P_2}} = \frac{\left(1-\frac{P_{max}}{3}\right)_1}{\left(1-\frac{P_{max}}{3}\right)_2}$$

$$\Rightarrow \quad \frac{2500}{Q_{P_2}} = \frac{\left(1-\frac{0.45}{3}\right)}{\left(1-\frac{0.6}{3}\right)}$$

$$\Rightarrow \quad Q_{P_2} = 2352.94 \simeq 2353$$

13. (d)

$$G_t = \frac{W_1+W_2}{\frac{W_1}{G_1}+\frac{W_2}{G_2}} = \frac{100}{\frac{97.5}{2.5}+\frac{2.5}{1}} = 2.4096$$

Theoretical unit weight $= 2.4096 \times 1000 = 2409.6\ \text{kg/m}^3 \simeq 2410\ \text{kg/m}^3$

14. (b)

Overtaking sight distance for one way traffic $= d_1 + d_2$

$$d_1 = 0.278\ V_b \times t_R = 0.278 \times 50 \times 2 = 27.8\ \text{m}$$

$$d_2 = 0.278\ V_b T + 2S$$

$$S = 0.7\ V_b + 6 = 0.2\left(\frac{50\times1000}{3600}\right)+6 = 16\ \text{m}$$

$$T = \sqrt{\frac{4s}{a}} = \sqrt{\frac{4\times16}{1}} = 8\ \text{sec}$$

$$d_2 = 0.278 \times 50 \times 8 + 2 \times 16 = 143.2\ \text{m}$$

$$\therefore \quad \text{OSD} = d_1 + d_2 = 27.8 + 143.2 = 171\ \text{m}$$

15. (d)

Modulus of subgrade reaction k_1 for 30 cm diameter plate is

$$k_1 = \frac{P_1}{\Delta} = \frac{2250\pi}{\pi\times15^2\times0.125} = 80\ \text{kg/cm}^3$$

Modulus of subgrade reaction k for standard plate of diameter 75 cm is

$$k_2 = \frac{80\times30}{75} = 32\ \text{kg/cm}^3$$

16. (c)

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

$$N = \frac{1}{30}-\left(-\frac{1}{40}\right) = \frac{1}{30}+\frac{1}{40} = \frac{7}{120} = 0.0583$$

$$\therefore \quad L = 2\left[\frac{0.0583\times(0.278\times70)^3}{0.6}\right]^{1/2} = 53.52\ \text{m}$$

17. (a)

The individual thickness of each layer is converted to their respective gravel equivalent.

We know that,

For bituminous concrete,

$$\frac{t_g}{t} = \left(\frac{C}{C_g}\right)^{\frac{1}{5}}$$

$$\Rightarrow \quad \frac{t_g}{16} = \left(\frac{80}{20}\right)^{\frac{1}{5}}$$

$$\therefore \quad t_g = 21.11 \text{ cm}$$

For base course,

$$\frac{t_g}{15} = \left(\frac{180}{20}\right)^{\frac{1}{5}}$$

$$\Rightarrow \quad t_g = 23.28 \text{ cm}$$

For sub-base course,

$$\frac{t_g}{10} = \left(\frac{C}{C_g}\right)^{\frac{1}{5}} = \left(\frac{20}{20}\right)^{\frac{1}{5}}$$

$$\Rightarrow \quad t_g = 10 \text{ cm}$$

Actual pavement thickness = 16 + 15 +20 = 41 cm

This is equivalent to gravel thickness

= 21.11 + 23.28 + 10 = 54.39 cm

Therefore, C equivalent, $\dfrac{t_g}{t_{eq}} = \left(\dfrac{C_{eq}}{C_g}\right)^{\frac{1}{5}}$

$$\Rightarrow \quad \frac{54.39}{41} = \left(\frac{C_{eq}}{20}\right)^{\frac{1}{5}}$$

$$\Rightarrow \quad C_{eq} = 82.17$$

18. (c)

Radius of relative stiffness, $l = \left[\dfrac{Eh^3}{12k(1-\mu^2)}\right]^{\frac{1}{4}}$

Modulus of subgrade reaction,

$$k = \frac{\text{Load}}{\text{Penetration}} = \frac{1.4}{1.25 \times 10^{-1}} = 11.2 \text{ kg/cm}^3$$

$$l = \left(\frac{3 \times 10^5 \times 20^3}{12 \times 11.2(1-0.16^2)}\right)^{\frac{1}{4}} = 65.43 \text{ cm}$$

19. (a)

Assume S is less than L

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

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

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

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

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

Hence assumption is correct.
Equation of parabola is,

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

20. (a)
Given: A = 5500 vehicles, r = 6.5% per annum, construction period = 3 years
Traffic flow after 3 year,

$$= 5500 \times \left(1 + \frac{6.5}{100}\right)^3 = 6643.72 \text{ cvpd}$$

$$\simeq 6644 \text{ cvpd}$$

$$\text{VDF} = \left(\frac{L}{L_s}\right)^4 = \left[\frac{3000}{8160}\right]^4 = 0.018, \text{ where } L = \frac{2500 + 3500}{2} = 3000 \text{ kg}$$

$$\text{Equivalent axle load} = 365 \times 6643.72 \times \frac{\left[(1+0.065)^{15} - 1\right]}{\left(\frac{6.5}{100}\right)} \times 0.018 \times 1 = 1.05 \text{ msa}$$

22. (b)
Maximum expansion allowed,

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

$$\Delta T = T_2 - T_1 = 30°\text{C}$$

Coefficient of thermal expansion,

$$\alpha = 10 \times 10^{-6}/°\text{C}$$

$\therefore$ Spacing of expansion joint, L

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

23. (a)

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

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

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

24. (d)

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

where, λ = 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.

$$\Rightarrow \quad \lambda = \frac{200}{30\times 60} = \frac{1}{9} \text{ vehicle/sec}$$

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

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

25. (c)

Braking distance for travelling upgrade,

$$S_1 = \frac{V^2}{254(f+0.01n)}$$

Braking distance for travelling downgrade

$$S_2 = \frac{V^2}{254(f-0.01n)}$$

Give, $S_2 = 2S_1$

$$\Rightarrow \quad \frac{1}{(f-0.01n)} = \frac{2}{f+0.01n}$$

$$\Rightarrow \quad 2f - 0.02\,n = f + 0.01\,n$$

$$\Rightarrow \quad n = \frac{f}{0.03} = \frac{0.3}{0.03} = 10\%$$

26. (b)

$$C_0 = 45 \text{ sec}$$

$$g_i = G_i + A_i - t_L$$
$$= 30 + 4 - 2 - 2 = 30 \text{ sec}$$

$$\text{Green ratio} = \frac{g_i}{C_0} = \frac{30}{45} = \frac{2}{3}$$

$$\text{Traffic capacity of lane} = S\times\frac{g_i}{C_0} = \frac{3600}{2.5}\times\frac{2}{3} = 960 \text{ veh/hr}$$

27. (a)

Normal flow on road A, q_a = 600 PCU/hr

Normal flow on road B, q_b = 400 PCU/hr

Saturation flow on road A, S_a = 1600 PCU/hr

Saturation flow on road B, S_b = 1200 PCU/hr

All red time, R = 12 sec.

Number of phases, n = 2

$$y_a = \frac{q_a}{S_a} = \frac{600}{1600} = 0.375$$

$$y_b = \frac{q_b}{S_b} = \frac{400}{1200} = 0.333$$

$$Y = y_a + y_b = 0.375 + 0.333 = 0.708$$

Total lost time, $L = 2n + R = 2 \times 2 + 12 = 16$ sec.

$$\text{Optimum cycle time, } C_o = \frac{1.5L+5}{1-Y}$$

$$= \frac{1.5 \times 16 + 5}{1 - 0.708} = 99.315 \text{ sec} \simeq 100 \text{ sec}$$

28. (a)

Traffic capacity and traffic volume have same units.

Traffic volume tend to zero when traffic density reaches to maximum.

29. (d)

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

$$= \frac{30+100}{100} \le \frac{75}{100} = 1.3 \ge 0.75$$

As $1.3 > 0.75$

$\therefore$ Grade compensation = 0.75

Note : Here grade compensation is asked, not the compensated gradient, so no need to subtract it from the given grade.

30. (c)

Green-Shield model (linear model) is given by

$$v = v_f\left(1 - \frac{k}{k_j}\right)$$

$$\Rightarrow \quad \frac{v}{v_f} + \frac{k}{k_j} = 1$$

$$\Rightarrow \quad vk_j + kv_f = v_f k_j$$

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