CLASS TEST

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SOIL MECHANICS

CIVIL ENGINEERING

Date of Test : 22/07/2024

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (a)

Equivalent permeability, $k_{eq} = \sqrt{k_x \times k_z} = \sqrt{32 \times 8} = 16$ units

2. (c)

3. (a)

4. (b)

$$\text{Area radio, } A_r = \frac{D_0^2\text{-}D_i^2}{D_i^2} = \frac{50^2 - 40^2}{40^2} = 0.5625 \text{ or } 56.25\% \simeq 56\%$$

5. (d)

$$\frac{\Delta H}{H} = \frac{\Delta e}{1+e_o}$$

$$\Rightarrow \quad \frac{26-24}{26} = \frac{\Delta e}{1+1.22}$$

$$\Rightarrow \quad \Delta e = 0.171$$

$$\Rightarrow \quad e_i - e_f = \Delta e$$

$$\Rightarrow \quad e_f = 1.22 - 0.171 = 1.05$$

6. (a)

$$\text{Toughness index, } I_t = \frac{I_P}{I_f} = \frac{4 \times I_f}{I_f} = 4$$

7. (d)

The effect of overburden pressure on SPT value may be approximated by the equation.

$$N = N'\left(\frac{350}{\bar{\sigma}+70}\right)$$

$\bar{\sigma}$ = Effective overburden pressure at test level

= 18 × 6 = 108 kN/m^2 $\not>$ 280 kN/m^2 (OK)

$$\therefore \quad N = 28 \times \left(\frac{350}{108+70}\right) = 55$$

8. (c)

$$B = \frac{\Delta U_3}{\Delta \sigma_3} = \frac{0.19-0.09}{0.3-0.1} = \frac{0.1}{0.2} = 0.5$$

9. (c)

As per Taylor's method,

Stability number, $S_n = \dfrac{C}{F_C \gamma H}$

$$\Rightarrow \qquad S_n = \frac{C}{\gamma H_C} \qquad (\because F_C = 1 \text{ for critical height})$$

$$\Rightarrow \qquad H_C = \frac{C}{\gamma S_n}$$

$$= \frac{30}{24 \times 0.05} = 25\,\text{m}$$

10. (c)

Tap water contains a considerable amount of air. During permeability test, this air gets struck and remains trapped between sand grains thereby lowering the permeability.

11. (d)

$$\text{Factor of safety } F = \left(1 - \frac{\gamma_w h}{\gamma_{avg} z}\right)\frac{\tan\phi}{\tan\beta}$$

$$\gamma_{avg} = \frac{20 \times 5 + 15 \times 5}{10} = 17.5 \text{ kN/m}^3$$

$$\therefore \qquad F = \left(1 - \frac{10 \times 5}{17.5 \times 10}\right) \times \frac{\tan 45^\circ}{\tan 30^\circ} = \frac{5\sqrt{3}}{7} = 1.24$$

12. (b)

$$I_D = \frac{e_{max} - e}{e_{max} - e_{min}} \times 100 = \frac{0.75 - 0.5}{0.75 - 0.25} \times 100$$

$$= 50\%$$

I_D	Classification
<15	Very loose
15 – 35	Loose
35 – 65	Medium dense
65 – 85	Dense
>85	Very dense

13. (c)

Shrinkage limit, $W_s = w_1 - \Delta w$

$$= w_1 - \frac{\Delta V \cdot \rho_w}{M_S}$$

$$= \frac{M_1 - M_d}{M_d} - \frac{(V_1 - V_d)\rho_w}{M_d}$$

$$= \frac{55.4 - 39.8}{39.8} - \frac{(29.2 - 21.1) \times 1}{39.8}$$

$$= 0.39 - 0.20 = 0.19 = 19\%$$

14. (d)

$$\text{Weight of dry soil} = 450 - 9 = 441 \text{ gm}$$

$$\text{Volume of paraffin} = \frac{9}{0.9} = 10 \text{ cc}$$

$$\text{Volume of soil} = 295 - 10 = 285 \text{ cc}$$

$$\text{Dry density, } \gamma_d = \frac{441}{285} = 1.547 \text{ gm/cc}$$

Also,
$$\gamma_d = \frac{G\gamma_w}{1+e} = \frac{2.65 \times 1}{1+e} = 1.547$$

$\Rightarrow$
$$e = 0.713$$

15. (a)

16. (a)

Adhesion factor, a = 0.5.

Let L_1 and L_2 be the depths of embedment of pile in top both layers, respectively. Then,

$$Q_a = \frac{Q_u}{FOS}$$

$\Rightarrow$
$$Q_u = Q_a \times \text{FOS} = 380 \times 2 = 760 \text{ kN}$$

Also,
$$Q_u = \alpha(C_{u_1})\pi d L_1 + \alpha(C_{u_2})\pi d L_2 + +(C_{u_1})N_C \frac{\pi d^2}{4}$$

$$760 = 0.5 \times 45 \times \pi \times 0.4 \times 5 + 0.5 \times 100 \times \pi \times 0.4 \times L_2 + 100 \times 9 \times \frac{\pi \times 0.4^2}{4}$$

$$760 = 254.5 + 62.8 \times L_2$$

$$L_2 = \frac{760 - 254.8}{62.8} = 8 \text{ m}$$

Therefore, the length of the pile is as given below,

$$L_1 + L_2 = 5 + 8 = 13 \text{ m}$$

17. (c)

$$K_{P_1} = \frac{1 + \sin 30°}{1 - \sin 30°} = 3$$

$$K_{P_2} = \frac{1 + \sin 15°}{1 - \sin 15°} = 1.698$$

At $h = 0$ m, $p_1 = K_{P_1} q = 3 \times 20 = 60 \text{ kN/m}^2$

At $h = 4$ m, in top layer $p_2 = K_{P_1}(q + \gamma_1 h) = 3(20 + 4 \times 16) = 252 \text{ kN/m}^2$

At $h = 4$ m, in bottom layer,

$$p_3 = K_{P_2}(q + \gamma_1 h) + 2C\sqrt{K_{P_2}}$$

$$= 1.698(20 + 16 \times 4) + 2 \times 15\sqrt{1.698}$$

$$= 181.72 \text{ kN/m}^2$$

At $h = 8$ m i.e., at point A,

$$p_4 = K_{P_2}(q + \gamma_1 \times 4 + \gamma_2 \times 4) + 2C\sqrt{K_{P_2}}$$

$$= 1.698(20 + 16 \times 4 + 18 \times 4) + 2 \times 15\sqrt{1.698}$$

$$= 303.98 \text{ kN/m}^2$$

18. (d)

$$\sigma_z = \frac{3Q}{2\pi z^2}\left(\frac{1}{1+\left(\frac{r}{z}\right)^2}\right)^{5/2}$$

For stress vertically below the load, $r = 0$

$$\therefore \quad \sigma_z = \frac{3Q}{2\pi z^2}$$

$$\therefore \quad \frac{\sigma_{2\text{m}}}{\sigma_{5\text{ m}}} = \frac{\frac{1}{2^2}}{\frac{1}{5^2}} = 6.25$$

19. (c)

For strip footing,
$$q_u = cN_C + qN_q + 0.5\,\gamma\,BN_\gamma$$
$$= 50 \times 8 + 20 \times 1 \times 3 + 0.5 \times 20 \times 2 \times 2$$
$$= 500 \text{ kN/m}^2$$
$$\therefore \quad q_{nu} = q_u - \gamma D_f = 500 - 20 \times 1 = 480 \text{ kN/m}^2$$

$\therefore$ Safe bearing capacity,
$$q_s = q_{ns} + \gamma D_f$$
$$= \frac{480}{3} + 20 \times 1 = 160 + 20$$
$$= 180 \text{ kN/m}^2$$
$$\therefore \quad \text{Total safe load} = 180 \times 2 \times 10$$
$$= 3600 \text{ kN}$$

20. (b)

$$\text{Ultimate pull} = \alpha\bar{C}A_s + W_P$$
$$= 0.5 \times 120 \times (\pi \times 0.5 \times 12) + \frac{\pi}{4} \times 0.5^2 \times 12 \times 25$$
$$= 1189.88 \text{ kN}$$

21. (a)

Let k, $10k$ and $20k$ be the permeabilities of first, second and third soil layers respectively.
Let t, $t/2$ and $2t$ be the thicknesses of the first, second and third soil layers respectively.

$$\therefore \quad k_h = \frac{k_1z_1 + k_2z_2 + k_3z_3}{z_1 + z_2 + z_3}$$
$$= \frac{kt + 10k\cdot\left(\frac{t}{2}\right) + 20k\cdot 2t}{t + \frac{t}{2} + 2t}$$
$$= \frac{kt(1+5+40)}{t(1+0.5+2)} = \frac{46k}{3.5} = 13.143k$$

Also,
$$k_v = \frac{z_1 + z_2 + z_3}{\left(\frac{z_1}{k_1}\right) + \left(\frac{z_2}{k_2}\right) + \left(\frac{z_3}{k_3}\right)}$$

$$= \frac{t + \frac{t}{2} + 2t}{\left(\frac{t}{k}\right) + \left(\frac{t/2}{10k}\right) + \left(\frac{2t}{20k}\right)}$$

$$= \frac{t(1 + 0.5 + 2)}{\frac{t}{k}\left(1 + \frac{1}{20} + \frac{1}{10}\right)} = 3.043 \text{ k}$$

$$\therefore \quad \frac{k_h}{k_v} = \frac{13.143k}{3.043k} = 4.32$$

22. (a)

Load carrying capacity of each pile = $C_u N_C A_b + \alpha \bar{C}_u A_s$

For stiff clay, $C_u = \frac{Q_{undisturbed}}{2} = \frac{250}{2} = 125 \text{ kPa}$

For medium stiff clay, $\bar{C}_u = \frac{200}{2} = 100 \text{ kPa}$

Load carrying capacity of each pile

$$= 9 \times 125 \times \frac{\pi}{4} \times (0.3)^2 + 0.6 \times 100 \times \pi \times (0.3) \times 20$$

$= 79.52 + 1130.97$

$= 1210.49$ kN

$\simeq 1210.5$ kN

$\therefore$ Load carrying capacity of 9 piles = 9 × (load carrying capacity of one pile)

$= 10894.5$ kN

Ultimate load carrying capacity of pile group = 3 × 3800 = 11400 kN

Efficiency of pile group $= \frac{11400}{10894.5} \times 100 = 104.64\%$

23. (d)

Given, seepage head, h = 1.68 m

Factor of safety, F = 1.5

Specific gravity, G = 2.67

Porosity, n = 40%

Void ratio, $e = \frac{n}{1-n} = \frac{0.40}{1-0.40} = 0.67$

Critical hydraulic gradient,

$$i_c = \frac{G-1}{1+e} = \frac{2.67-1}{1+0.67} = 1$$

Actual exit hydraulic gradient,

$$i = \frac{i_c}{F} = \frac{1}{1.5} = 0.67$$

But $i = \frac{h}{L}$

$$\Rightarrow \quad L = \frac{h}{i} = \frac{1.68}{0.67} = 2.51 \text{ m}$$

$\therefore$ Depth of coarse sand required $= L - 1.5$

$$= 2.51 - 1.5 = 1.01 \text{ m}$$

24. (c)

Since it is a case of double drainage and thus, $d = \frac{4}{2} = 2 \text{ m} = 200 \text{ cm}$

For,

$$U = 70\% \text{ of total settlement}$$

$$T_v = -0.9332 \log_{10}(1 - U) - 0.0851$$

$$= -0.9332 \log_{10}(1 - 0.7) - 0.0851$$

$$= 0.403$$

$$C_v = \frac{T_v d^2}{t}$$

$$\Rightarrow \quad t = \frac{0.403 \times (200)^2}{0.03}$$

$$\Rightarrow \quad t = 537.33 \times 10^3 \text{ min}$$

$$\Rightarrow \quad t = 373 \text{ days}$$

25. (a)

The increased stress, $\bar{\sigma}_0 + \Delta\bar{\sigma}$ is equal to 70 + 80 = 150 kN/m^2. This is greater then $\bar{\sigma}_c = 120 \text{ kN/m}^2$. Thus soil is normally consolidated.

$$\therefore \quad s_c = C_r \frac{H_0}{1+e_0} \log \frac{\bar{\sigma}_c}{\sigma} + C_C \frac{H_0}{1+e_0} \log_{10} \frac{\bar{\sigma}_0 + \Delta\bar{\sigma}_c}{\bar{\sigma}_c}$$

$$s_c = 0.03 \frac{5 \times 10^3}{1+0.90} \log \frac{120}{70} + 0.27 \frac{5 \times 10^3}{1+0.90} \log_{10} \frac{150}{120}$$

$$= 18.48 + 68.86 = 87.34 \text{ mm}$$

26. (d)

$$\sigma_z = \frac{2q'}{\pi z} \left[\frac{1}{1 + \left(\frac{x}{z}\right)^2} \right]^2$$

$$= \frac{2 \times 120}{\pi \times 3.5} \left[\frac{1}{1 + \left(\frac{2}{3.5}\right)^2} \right]^2$$

$$= 12.40 \text{ kN/m}^2$$

27. (c)

Given: $B_f = 1.5 \text{ m}, B_p = 0.3 \text{ m}, S_p = 18 \text{ mm}, S_f = ?$

$$\because \quad \frac{S_f}{S_p} = \left[\frac{B_f}{B_p}\frac{(B_p+0.3)}{(B_f+0.3)}\right]^2$$

$$\Rightarrow \quad \frac{S_f}{18} = \left[\frac{1.5}{0.3}\times\frac{(0.3+0.3)}{(1.5+0.3)}\right]^2$$

$$\Rightarrow \quad S_f = 50 \text{ mm}$$

28. (c)

Given, square footing, $B = 1.8$ m

$\gamma = 16 \text{ kN/m}^3, C = 0, \phi = 30°$

$D_f = 0.8$ m

$N_C = 30.14, N_q = 18.4$ and $N_\gamma = 15.1$

We know for square footing,

$$q_u = 1.3CN_C + qN_q + 0.4\gamma BN_\gamma$$

$$= 0 + 16 \times 0.8 \times 18.4 + 0.4 \times 16 \times 1.8 \times 15.1 \qquad [\because C = 0]$$

$$= 409.472 \text{ kN/m}^2$$

So, the ultimate load that can be carried by the footing

$= q_u \times$ area

$= 409.472 \times 1.8 \times 1.8$

$= 1326.69$ kN

29. (b)

For a raft on clayey soil, for $\frac{D_f}{B} = \frac{5}{10} = 0.5 < 2.5$

$$q_{nu} = 5\left(1+0.2\frac{D_f}{B}\right)\left(1+0.2\frac{B}{L}\right)C_u$$

$$= 5\times\left(1+0.2\times\frac{5}{10}\right)\left(1+0.2\times\frac{10}{10}\right)\times 40$$

$$= 264 \text{ kN/m}^2$$

$$\therefore \quad q_{ns} = \frac{q_{nu}}{F} = \frac{264}{2.5} = 105.6 \text{ kN/m}^2$$

30. (a)

The criteria for determining the design load is that it should be taken as minimum of the following:

(i) Half the load at which settlement is 10% of the pile diameter.

10% of pile diameter = 30 mm

$$\text{Load at 30 mm settlement} = 140 + \frac{160-140}{34-27}(30-27)$$

$= 148.57$ kN

Half of this load = 74.29 kN

(ii) Two third of the load at which pile settlement is 12 mm.

Load corresponding to 12 mm settlement $= 60+\dfrac{80-60}{13-10}(12-10)$

$$= 73.33 \text{ kN}$$

$$\therefore \quad \frac{2}{3}\times 73.33 = 48.89 \text{ kN}$$

$\therefore$ Design load on pile $= 48.89$ kN

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