CLASS TEST

Sl. : 01IGCE_DEF_16052024

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SOIL MECHANICS

CIVIL ENGINEERING

Date of Test : 16/05/2024

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (a)

Angle from minor principal plane = $45 - \frac{\phi'}{2} = 31.5°$

Angle from major principal plane = $45 + \frac{\phi'}{2} = 58.5°$

2. (c)

Given: D_{60} = 0.45 mm
D_{30} = 0.2 mm
D_{10} = 0.04 mm

$\therefore$ Uniformity coefficient, $C_u = \frac{D_{60}}{D_{10}} = \frac{0.45}{0.04} = 11.25$

Coefficient of curvature, $C_c = \frac{D_{30}^2}{D_{60} \times D_{10}} = \frac{0.2^2}{0.45 \times 0.04} = 2.22$

3. (b)

Relative density, $I_D = \left(\frac{e_{max} - e}{e_{max} - e_{min}}\right) \times 100 = \left(\frac{0.75 - 0.5}{0.75 - 0.25}\right) \times 100 = 50\%$

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

4. (c)

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

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

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

$= \frac{30}{21 \times 0.05} = 28.6\,m$

5. (c)

6. (b)

Given, W = 20 kN
S = average penetration per blow of pile in last 5 – blows

$$= \frac{25}{5} = 5 \text{ mm} = 0.5 \text{ cm}$$

$$H = 1 \text{ m} = 100 \text{ cm}$$

$$C = 2.5 \text{ cm (for drop hammer)}$$

∴ From Engineering News formula

$$Q = \frac{WH}{6(S+C)} = \frac{20\times100}{6(0.5+2.5)} = 111.11 \text{ kN}$$

7. (c)

Dispersion of soil particles reduces the size of voids available for flow because of which permeability gets reduced.

8. (b)

9. (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

$$= 18 \times 6 = 108 \text{ kN/m}^2 \not> 280 \text{ kN/m}^2 \quad \text{(OK)}$$

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

10. (b)

$$G_{sat} = 1.90$$

We know $$G_{sat} = \frac{\gamma_{sat}}{\gamma_w}$$

$$= \frac{G+e}{1+e}$$

$$\Rightarrow \quad 1.90 = \frac{G+0.4G}{1+0.4G} \qquad \left\{\begin{matrix} Se = wG \\ (1)e = 0.4G \end{matrix}\right\}$$

$$\Rightarrow \quad 1.90 + 1.90(0.4G) = 1.4G$$

$$\Rightarrow \quad 1.90 = 0.64G$$

$$\therefore \quad G = 2.97$$

11. (b)

$$T_V = \frac{\pi}{4}U^2 \qquad \text{if } U \le 60\%$$

For same clay layer at different times t_1 and t_2 relationship reduces to

$$\frac{t_2}{t_1} = \left(\frac{U_2}{U_1}\right)^2$$

$$t_2 = \left(\frac{60}{40}\right)^2 \times 178$$

$$= 400.5 \text{ days}$$

Additional time required = 400.5 – 178 = 222.5 days

12. (c)

Shrinkage limit,
$$W_s = w_1 - \Delta w$$
$$= w_1 - \frac{\Delta V \cdot \rho_w}{M_S}$$
$$= \frac{M_1 - M_d}{M_d} - \frac{(V_1 - V_d)\rho_w}{M_d}$$
$$= \frac{55.4 - 39.8}{39.8} - \frac{(29.2 - 21.1) \times 1}{39.8}$$
$$= 0.188$$
i.e. $= 18.8\%$

13. (d)

$$\gamma_b = \left(\frac{G + Se}{1 + e}\right)\gamma_w$$
$$\Rightarrow \quad 1800 = \left(\frac{G + wG}{1 + e}\right)\gamma_w = \left(\frac{2.65 + 0.11 \times 2.65}{1 + e}\right)\gamma_w$$
$$\frac{1800}{1000} = \frac{2.9415}{1 + e}$$
$$\Rightarrow \quad e = 0.634$$

$\therefore$ Relative density,
$$I_D = \frac{e_{max} - e}{e_{max} - e_{min}} \times 100$$
$$= \frac{0.88 - 0.634}{0.88 - 0.48} \times 100$$
$$= 61.5\%$$

14. (d)

$$\frac{\Delta H}{H} = \frac{\Delta e}{1 + e_o}$$
$$\frac{26 - 24}{26} = \frac{\Delta e}{1 + 1.22}$$
$$\Delta e = 0.171$$
$$e_i - e_f = \Delta e$$
$$e_f = 1.22 - 0.171 = 1.05$$

15. (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, $r = 0$

$$\therefore \quad \sigma_z = 0.4775 \times \frac{Q}{z^2}$$
$$\therefore \quad \frac{\sigma_2}{\sigma_5} = \frac{\frac{1}{2^2}}{\frac{1}{5^2}} = 6.25 \qquad [\because \text{ Q is same}]$$

16. (b)

$$\gamma_{sat} = \left(\frac{G+e}{1+e}\right)\gamma_w = \left(\frac{2.67+0.9}{1+0.9}\right)9.81 = 18.43\ \text{kN/m}^3$$

$\therefore$ $$\gamma' = \gamma_{sat} - \gamma_w = 18.43 - 9.81 = 8.62\ \text{kN/m}^3$$

Now, $$S_n = \frac{C_m}{\gamma' H}$$

$\Rightarrow$ $$0.06 = \frac{C_m}{8.62 \times 6}$$

$\Rightarrow$ $$C_m = 3.10\ \text{kN/m}^2$$

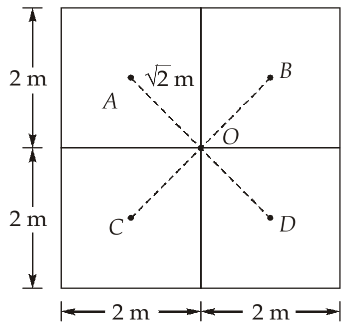
$\therefore$ Factor of safety with respect of cohesion,

$$F = \frac{C}{C_m} = \frac{15}{3.10} = 4.84$$

17. (b)

Total load, $Q = 200 \times 4 \times 4 = 3200$ kN

Divide this load in four equal squares of 2 m × 2 m size, as shown in figure,



$\therefore$ Load in each part square $= \dfrac{3200}{4} = 800$ kN

The distance from A to O *i.e.* $AO = \sqrt{2}$ m

By symmetry, the stress σ_z at O at 4 m depth is four times of that caused by one load.

$$\sigma_z = \frac{4 \times 800}{4^2} \times \frac{3}{2\pi} \times \left[\frac{1}{1+\left(\frac{\sqrt{2}}{4}\right)^2}\right]^{5/2}$$

$$= 71.14\ \text{kN/m}^2$$

18. (c)

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

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

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,

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

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

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

19. **(a)**

Adhesion factor, α = 0.5.

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

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

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

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

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

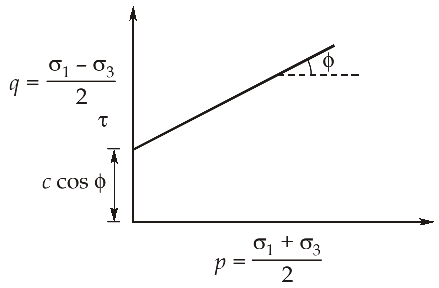
$$\Rightarrow \quad 760 = 254.8 + 62.8 \times L_2$$

$$\Rightarrow \quad L_2 = \frac{760 - 254.8}{62.8} = 8.044 \text{ m} \approx 8 \text{ m}$$

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

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

20. **(b)**



$$\frac{\sigma_1 - \sigma_3}{2} = C\cos\phi + \frac{\sigma_1 + \sigma_3}{2}\sin\phi \qquad \text{...(i)}$$

As, $$q = 8\sqrt{3} + 0.7p \qquad \text{...(ii)}$$

$\therefore \quad C \cos\phi = 8\sqrt{3}$ (on comparing equations (i) and (ii)

and $\quad \sin\phi = 0.7$

$\Rightarrow \quad \phi = \sin^{-1}(0.7) = 44.43°$

$\therefore \quad C \cos 44.43° = 8\sqrt{3}$

$\Rightarrow \quad C = 19.40$ kPa

21. **(a)**

$$\because \quad q_u = CN_C F_{cs} F_{ci} F_{cdt} + qN_q F_{qs} F_{q_i} F_{qd} + 0.5\gamma B' N_\gamma F_{\gamma s} F_{\gamma i} F_{\gamma d}$$

$$= (1.5 \times 16.5)\, 64.2 \times 1 \times 1 \times 1.16 + 0.5 \times 16.5 \times (2 - 0.2 \times 2) \times 109.41$$

[$\because$ c = 0]

$$= 3287.394 \text{ kN/m}^2$$

$$\therefore \quad Q_{ult} = q_u \cdot A = (2 - 0.2 \times 2) \times 1 \times 3287.39 = 5259.83 \text{ kN}$$

22. (b)

$$\text{Ultimate pull} = \alpha \bar{C} A_s + W_P$$

$$= 0.5 \times 120 \times (\pi \times 0.5 \times 12) + \frac{\pi}{4} \times 0.5^2 \times 12 \times 25$$

$$= 1189.88 \text{ kN}$$

23. (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,

$$q_s = q_{ns} + \gamma D_f$$

$$= \frac{480}{3} + 20 \times 1 = 160 + 20$$

$$= 180 \text{ kN/m}^2$$

$\therefore$ Total safe load $= 180 \times 2 \times 10$

$= 3600$ kN

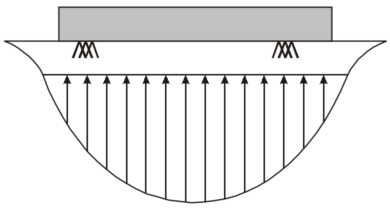
24. (d)

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

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

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

25. (a)



Rigid footing on sand

26. (b)

$$\text{Load intensity, } q = \frac{Q}{A} = \frac{600}{2 \times 3} \text{ kN/m}^2 = 100 \text{ kN/m}^2$$

$\because$ Immediate settlement in sand,

$$S_i = \frac{q.B\left(1 - \mu^2\right)}{E} I_F$$

$$\Rightarrow \quad S_i = \frac{100 \times 2}{20 \times 10^3} \times \left(1 - 0.25^2\right) \times 1.1 = 0.0103125 \text{ m}$$

$$\Rightarrow \quad S_i = 10.31 \text{ mm}$$

27. (d)

$$\because \quad k = CD\left(\frac{\gamma_w}{\mu}\right)\left(\frac{e^3}{1+e}\right)$$

$$\therefore \quad k \propto \frac{e^3}{1+e}$$

$$\Rightarrow \quad \frac{k_1}{k_2} = \frac{e_1^3}{1+e_1} \times \frac{1+e_2}{e_2^3}$$

$$\Rightarrow \quad \frac{k_1}{k_2} = \frac{(0.27)^3}{1+0.27} \times \frac{1+0.15}{(0.15)^3}$$

$$k_1 = 5.28\, k_2$$

$\therefore$ Percentage change in permeability $= \dfrac{k_2 - k_1}{k_1} \times 100$

$$= \frac{k_2 - 5.28k_2}{5.28k_2} \times 100 = -81.06$$

$\therefore$ Percentage decrease $= 81.06\%$

28. (b)

For falling head permeability test,

Permeability, $K = 2.303\dfrac{aL}{At}\log_{10}\left(\dfrac{h_1}{h_2}\right)$

Take, $2.303\dfrac{aL}{A} = C$

$$\therefore \quad K = \frac{C}{t}\log_{10}\left(\frac{h_1}{h_2}\right)$$

when, $h_1 = 75$ cm, $h_2 = 75 - 12 = 63$ cm

$t = 8$ min $= 480$ sec

$$\therefore \quad \frac{K}{C} = \frac{1}{480}\log_{10}\left(\frac{75}{63}\right)$$

when $h_1 = 75$ cm, $h_2 = 30$ cm

$$\therefore \quad \frac{1}{480}\log_{10}\left(\frac{75}{63}\right) = \frac{1}{t}\log_{10}\left(\frac{75}{30}\right)$$

$$\Rightarrow \quad t = 2522.58 \text{ sec}$$

$$\simeq 42 \text{ min}$$

29. (c)

Negative skin friction in individual action = $n[\alpha \bar{c} A]$

$= 9 \times 0.9 \times 20 \times 1.3 \times 3$

$= 631.8$ kN

Negative skin friction for pile group = $\alpha\bar{c}(4BL)$ + weight of soil in negative zone

$= \alpha\bar{c}(4BL) + \gamma AL$

$= 1 \times 20(4 \times 2.5 \times 3) + 16 \times 2.5^2 \times 3$

$= 900$ kN

So, $Q = 900$ kN

Now, negative frictional load on pile graph = max(900 kN 631.8 kN) = 900 kN.

30. (a)

As more than 50% is retained on 75 μ IS sieve, the soil is coarse-grained.

Coarse fraction = 100 – 45 = 55%

Gravel fraction = 100 – 60 = 40%

Sand fraction = 55 – 40 = 15%

As more than half the coarse fraction is larger than 4.75 mm sieve, the soil is gravel.

Also, $I_P = w_L - w_P = 40 - 12 = 28\%$

A-line, $I_P = 0.73\,(w_L - 20)$

$= 0.73\,(40 - 20) = 14.6\%$

$\because$ I_P is above A-line, therefore the soil should be GC as per IS classification.

■■■■