CLASS TEST

Sl. : 04IGCE_MKNL_24102024

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# SOIL MECHANICS

## CIVIL ENGINEERING

**Date of Test : 24/10/2024**

## ANSWER KEY

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

## DETAILED EXPLANATIONS

**1. (b)**

- Fine silt possess honey comb structure.
- Gravel, sand and coarse silt possess single grained soil structure.
- Clay generally possess either flocculent or dispersed structure. If concentration of salt is larger in water then there is much tendency that the clay shall possess flocculent structure.

Marine clay would be the appropriate answer here while lacustrine clay is found at the bottom of lake which has less concentration of salt shall possess the dispersed structure.

**2. (b)**

According to Allen-Hazen equation,

$$k = C \cdot D_{10}^2 \text{ cm/sec}$$

$D_{10}$ must be in cm $\quad k = 100(0.01)^2$

$$= 10^{-2} \text{ cm/sec} = 10^{-4} \text{ m/sec}$$

**3. (d)**

**4. (c)**

- With decrease in size, maximum dry density is lower and occur at higher water content.
- With increase in compactive effort, maximum dry density is higher and occurs at lower water content.

**5. (d)**

$$\text{Influence factor} = \frac{1}{m \times n}$$

$$\frac{1}{m \times n} = \frac{1}{500}$$

$$m \times n = 500$$

**6. (c)**

$$T_v = 0.283$$

For $\quad T_v = 0.283$

Degree of consolidating,

$$U = 60\%$$

$$U = \frac{\Delta h}{\Delta H} \times 100$$

$$60 = \frac{\Delta h}{25} \times 100$$

$$\Delta h = 15 \text{ cm}$$

**7. (c)**

| Sieve size | Mass retained (gm) | % retained | % cumm | % finer |
|---|---|---|---|---|
| 4.75 mm | 400 | 40% | 40% | 60% |
| 75μ | 500 | 50% | 90% | 10% |
| Pan | 100 | 10% | 100% | 0 |

Size by which 60% of the particles are finer, $D_{60}$ = 4.75 mm

Size by which 10% of the particles are finer, $D_{10}$ = 0.075 mm

Coefficient of uniformity, $C_u = \frac{D_{60}}{D_{10}}$

$$C_u = \frac{4.75}{0.075} = 63.33$$

**8. (d)**

In a tetrahedral unit, 1 Si and (4 0) are involved and the net charge on silica sheet is –1 where silicon ion is having +4 charge. When $Si^{4+}$ is substituted by $Al^{3+}$, the net charge on the resulting particle will be – 2.

**9. (c)**

Initial consolidation or immediate settlement is computed using elastic theory of analysis.

**10. (c)**

According to ENR formula,

$$Q_{ap} = \frac{WH}{6(S+C)}$$

$$Q_{ap} = \frac{35 \times 80}{6\left(\frac{2.5}{10} + 0.25\right)}$$

$$Q_{ap} = \frac{2800}{6 \times 0.5} = 933.33\,\text{kN}$$

**11. (d)**

Given, $w = 0.4$

$G_s = 2.7$

$e = 1.2$

We know, $Se = SG_s$

$$S = \frac{0.4 \times 2.7}{1.2} = 0.9$$

We know, $S + a_c = 1$

Air content, $a_c = 1 - 0.9$

$a_c = 0.1$ (10%)

For percentage of air voids, $n_a = n.\ a_c$

$$\text{Porosity, } n = \frac{e}{1+e}$$

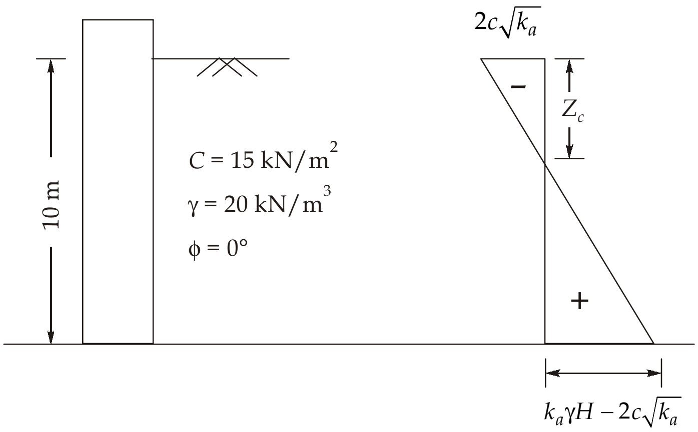
$$n = \frac{1.2}{1+1.2} = \frac{1.2}{2.2} = 0.545$$

$$n_a = n.a_c$$

$$= (0.545)(0.1) \times 100$$

$$= 5.45\%$$

**12. (c)**




Active earth pressure coefficient,

$$k_a = \frac{1-\sin\phi}{1+\sin\phi}$$

$$k_a = 1$$

For $Z_c \Rightarrow$

$$k_a\gamma Z_c = 2c\sqrt{k_a}$$

$$Z_c = \frac{2c}{\gamma\sqrt{k_a}}$$

$$Z_c = \frac{2\times 15}{20\times 1} = 1.5\text{ m}$$

If tension cracks are developed,

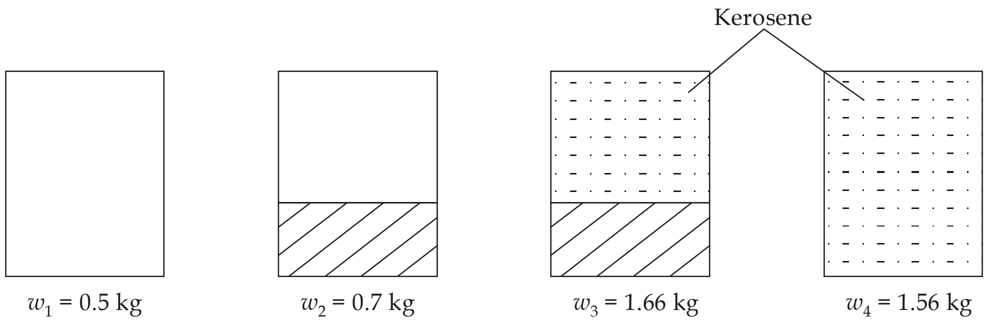
Active thrust,

$$P_a = \frac{1}{2}\times(H-Z_c)\times\left(k_a\gamma H - 2c\sqrt{k_a}\right)$$

$$P_a = \frac{1}{2}\times 8.5\times 170$$

$$P_a = 722.5\text{ kN/m}$$

**13. (c)**




$$G_s = \left(\frac{w_2 - w_1}{w_4 - w_3 + w_2 - w_1}\right) \times G_k$$

$$= \left(\frac{0.7 - 0.5}{1.56 - 1.66 + 0.7 - 0.5}\right) \times 0.8$$

$$= \left(\frac{0.2}{0.1}\right) \times 0.8$$

$$G_s = 1.6$$

**14. (c)**

Given, $\gamma_b = 19$ kN/m$^3$, $w = 17\%$

So, dry density, $$\gamma_d = \frac{\gamma_b}{1+w} = \frac{19}{1+0.17} = 16.24 \text{ kN/m}^3$$

Also, $$\gamma_d = \frac{G\gamma_w}{1+e} = \frac{2.7 \times 9.81}{1+e} = 16.24$$

$\Rightarrow$ $$e = \frac{2.7 \times 9.81}{16.24} - 1 = 0.631$$

When the soil is fully saturated, $S = 1$,

$\therefore$ $$S \cdot e = w \cdot G$$

So, new moisture content,

$$w = \frac{S \cdot e}{G} = \frac{1 \times 0.631}{2.7} = 0.2337 \text{ or } 23.37\%$$

$\therefore$ Additional moisture content required

$$= 23.37 - 17 = 6.37\%$$

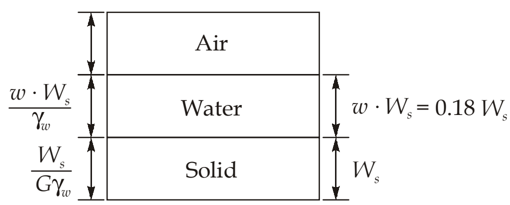
**15. (a)**

For the given condition,

$$\text{Final total volume} = \frac{\pi}{4} \times (0.045)^2 \times 0.1$$

$\Rightarrow$ $$V_T = 1.59 \times 10^{-4} \text{ m}^3$$

We know,



Water content, $w = \frac{W_w}{W_s}$

$\Rightarrow \quad 0.18 = \frac{W_w}{W_s}$

and % volume of air voids = $\frac{V_a}{V_T} = 0.18$

So, volume of air, $V_a = 0.18 \times 1.59 \times 10^{-4}\ m^3$

$= 2.862 \times 10^{-5}\ m^3$

Now, volume of solids + Volume of water + Volume of air = Total volume

$$\Rightarrow \frac{W_s}{2.7 \times 9.81} + \frac{0.18 \times W_s}{9.81} + 2.862 \times 10^{-5} = 1.59 \times 10^{-4}$$

$\Rightarrow \quad W_s = 2.324 \times 10^{-3}$ kN = 2.324 N

$\Rightarrow \quad W_s = 0.2369$ kg = 236.9 gm

$\therefore$ Weight of water = $wW_s = 0.18 \times 236.9$

$\Rightarrow \quad W_w = 42.64$ gm

**Alternatively:**

$$\gamma_d = \frac{(1-\eta_a)G\gamma_w}{1+wG} = \frac{W_s}{V_T}$$

$$\gamma_d = \frac{(1-0.18)2.7 \times 9.81}{1+0.18 \times 2.7} = \frac{W_S}{1.59 \times 10^{-4}}$$

$W_s = 0.002324$ kN $= 2.324 \times 10^{-3}$ kN

$W_s = 236.9$ gm

Mass of water $wW_s = 0.18 \times 236.9 = 42.68$

**16. (d)**

For constant head permeability test,

$$k = \frac{Q}{Ai} = \frac{626 \times 18}{\frac{\pi}{4} \times 7.5^2 \times 60 \times 24.7} = 1.72 \times 10^{-1} \text{ cm/s}$$

Discharge velocity, $V = ki$

$$= 1.72 \times 10^{-1} \times \frac{24.7}{18} = 0.236 \text{ cm/s}$$

Seepage velocity, $\frac{V}{n} = \frac{0.236}{0.44}$

$V_s = 0.536$ cm/s

**17. (c)**

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

$$T_v = \frac{k}{m_v \gamma_w} \times \frac{t}{d^2}$$

$\because$ Percentage consolidation required is same in both the cases.

$\therefore$ $$T_v = T_v'$$

$$\frac{k}{m_v \gamma_w} \times \frac{t}{d^2} = \frac{k'}{m_v' \gamma_w} \times \frac{t}{d^2}$$

$$\frac{k}{m_v} \times \frac{15}{d^2} = \frac{3k}{4m_v} \times \frac{t}{(d/2)^2} \qquad [\because k' = 3k \;\&\; m_v' = 4\text{m}]$$

$$15 = 3t$$

$$t = 5 \text{ years}$$

**18. (d)**

To prevent possibility of erosion and piping filter must have grain sizes that satisfy following requirements:

(i) $\dfrac{D_{15\,(\text{filter})}}{D_{85(\text{protected material})}} < 5$

It ensures that no significant invasion of particles from the protected material to the filter.

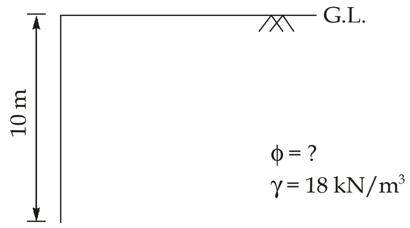
(ii) $4 < \dfrac{D_{15(\text{filter})}}{D_{15(\text{protected material})}} < 20$

It ensures that sufficient head is lost in filter without build-up of seepage pressure (specifies the lower limit of material.

(iii) $\dfrac{D_{50(\text{filter})}}{D_{50(\text{protected material})}} < 25$

This is the additional guideline for the selection of material.

**19. (b)**




$$p_a = K_a(\gamma z)$$

$\Rightarrow$ $$60 = K_a \times 18 \times 10$$

$\Rightarrow$ $$K_a = \frac{1}{3}$$

$\because$ $$K_a = \tan^2\left(45 - \frac{\phi}{2}\right) = \frac{1}{3}$$

$\Rightarrow$ $$\tan\left(45 - \frac{\phi}{2}\right) = \frac{1}{\sqrt{3}}$$

$\Rightarrow$ $$45 - \frac{\phi}{2} = 30°$$

$\Rightarrow$ $\frac{\phi}{2} = 45° - 30° = 15°$

$\Rightarrow$ $\phi = 15° \times 2 = 30°$

**Alternatively:**

$$K_a = \frac{1-\sin\phi}{1+\sin\phi} = \frac{1}{3}$$

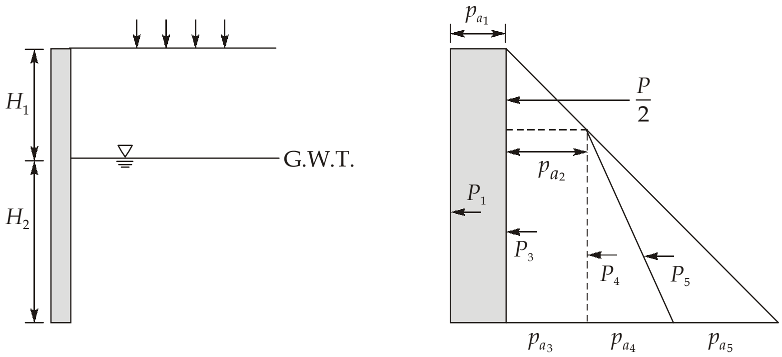
$\Rightarrow$ $\phi = 30°$

**20.** **(a)**

$$K_a = \tan^2\left(45 - \frac{\phi}{2}\right) = \frac{1-\sin\phi}{1+\sin\phi} = \frac{1}{3}$$

$$\gamma_{sat} = \frac{G+e}{1+e}\cdot\gamma_w = \frac{2.65+0.65}{1+0.65}\times 9.81 = 19.62 \text{ kN/m}^3$$

$\therefore$ $\gamma' = \gamma_{sat} - \gamma_w = 19.62 - 9.81 = 9.81 \text{ kN/m}^3$




$$p_{a_1} = K_a \times q = \frac{1}{3}\times 14 = 4.67 \text{ kN/m}^2$$

$$p_{a_2} = K_a \cdot \gamma_d \times H_1 = \frac{1}{3}\times 15.755\times 3 = 15.755 \text{ kN/m}^2$$

$$p_{a_3} = p_{a_2} = 15.755 \text{ kN/m}^2$$

$$p_{a_4} = K_a \gamma' H_2 = \frac{1}{3}\times 9.81\times 7 = 22.89 \text{ kN/m}^2$$

$$p_{a_5} = \gamma_w \cdot H_2 = 9.81 \times 7 = 68.67 \text{ kN/m}^2$$

$$P_1 = p_{a_1} \times \text{H} = 4.67 \times 10 = 46.7 \text{ kN/m}$$

$$P_2 = \frac{1}{2}\cdot p_{a_2}\times H_1 = \frac{1}{2}\times 15.755\times 3 = 23.633 \text{ kN/m}$$

$$P_3 = p_{a_3}H_2 = 15.755 \times 7 = 110.285 \text{ kN/m}$$

$$P_4 = \frac{1}{2}\times p_{a_4}\cdot H_2 = \frac{1}{2}\times 22.89\times 7 = 80.115 \text{ kN/m}$$

$$P_5 = \frac{1}{2}\times p_{a_5}H_2 = \frac{1}{2}\times 68.67\times 7 = 240.345 \text{ kN/m}$$

$\therefore$ Total $P_a = 46.7 + 23.633 + 110.285 + 80.115 + 240.345 = 501.08 \text{ kN/m}$

**21. (c)**

$$C_{u\,(\text{undisturbed})} = \frac{T}{\pi d^2\left[\frac{h}{2}+\frac{d}{6}\right]} = \frac{35\times 1000}{\pi\times 60^2\times\left[\frac{100}{2}+\frac{60}{6}\right]}$$

$$= 0.05158\ \text{N/mm}^2 = 51.58\ \text{kN/m}^2$$

$$C_{u\,(\text{remoulded})} = \frac{5\times 1000\times 10^3}{\pi\times 60^2\left[\frac{100}{2}+\frac{60}{6}\right]}\ \text{kN/m}^2 = 7.368\ \text{kN/m}^2$$

$$\therefore\ \text{Sensitivity of the clay} = \frac{C_{u\,(\text{undisturbed})}}{C_{u\,(\text{remoulded})}} = \frac{51.58}{7.368} = 7$$

**22. (b)**

$$\gamma_{sat} = \frac{G+e}{1+e}\times\gamma_w = \frac{2.65+1}{1+1}\times 9.81 = 17.9\ \text{kN/m}^3$$

$$\gamma' = \gamma_{sat} - \gamma_w = 17.9 - 9.81 = 8.1\ \text{kN/m}^3$$

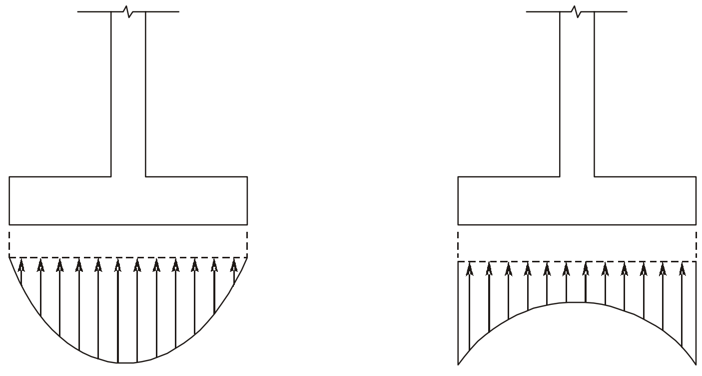
For sudden drawdown $\gamma = \gamma_{sat}$

$$\phi_w = \frac{\gamma'}{\gamma_{sat}}\times\phi_u = \frac{8.1}{17.9}\times 15 = 6.8^\circ$$

$$F_C = \frac{C_u}{S_n\times\gamma H} = \frac{12}{0.126\times 17.9\times 5} = 1.06$$

**23. (d)**

**Contact pressure distribution:**



Rigid footing on granular soil    Rigid footing on clayey soil

**24. (c)**

$$q_{safe} = \frac{q_{nu}}{FOS} + \gamma D_f$$

$$= \frac{160}{3} + 18\times 1.5 = 80.33\ \text{kN/m}^2$$

$\therefore$ Allowable load, $Q = q_{safe}\times \text{Area}$

$= 80.33 \times 3 \times 3 = 723$ kN

**25.** **(a)**

For clay
$$\frac{S_P}{S_F} = \frac{B_P}{B_F}$$

$\Rightarrow$
$$S_F = \left(\frac{B_F}{B_P}\right) \times S_P$$
$$= \frac{3000}{300} \times 4 = 40 \text{ mm}$$

**26.** **(b)**

Efficiency by Converse Lebarre Formula is:

$$\eta_g = 1 - \frac{\phi}{90}\left[\frac{m(n-1)+n(m-1)}{mn}\right]$$

Given: $m = n = 2$

$$\phi = \arctan\left(\frac{d}{s}\right) = 18.3$$

$\therefore$
$$\eta_g = 1 - \frac{18.3}{90}\left[\frac{2\times1+2\times1}{2\times2}\right] = 0.797 \approx 0.8 \text{ or } 80\%$$

**27.** **(b)**

Given:

Weight of pile, $P_s = 22$ kN

Shaft diameter, $D_0 = 340$ mm

Under-ream dia, $D_u = 700$ mm

Undrained shear strength, $C = 60$ kPa

$\alpha = 0.3$, $N_C = 9$

Ultimate tensile capacity will be due to

1. Friction along the length of pile ($P_1$)
2. Bearing action caused by under-reamed portion ($P_2$)
3. Self weight of pile ($P_3$)

Tensile capacity due to friction

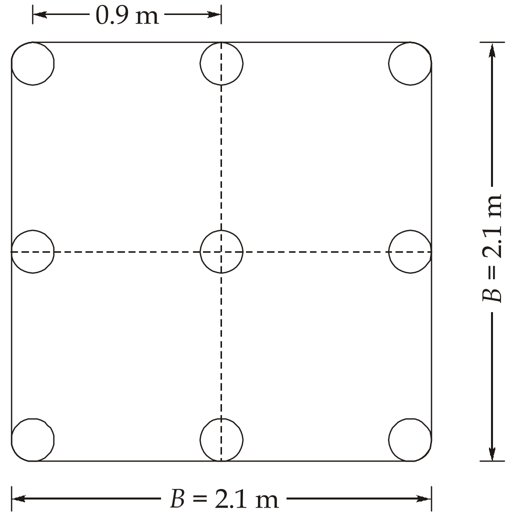
$$P_1 = f_s \times A_s$$
$$= \alpha \,.\, C\,(\pi D_0)\,(L - \text{Depth of under-ream})$$
$$= 0.3 \times 60 \times \pi \times 0.34 \times (10 - 0.42) = 184.19 \text{ kN}$$

Tensile capacity due to bearing action

$$P_2 = C N_C \cdot A$$
$$= \frac{60 \times 9\pi(D_u^2 - D_o^2)}{4}$$
$$= \frac{60 \times 9 \times \pi(0.7^2 - 0.34^2)}{4} = 158.79 \text{ kN}$$

$\therefore$
$$P = P_1 + P_2 + P_3$$
$$= 184.19 + 158.79 + 22$$
$$= 364.98 \simeq 365 \text{ kN}$$

**28.** **(c)**




$$C_u = \frac{q_u}{2} = \frac{1.5}{2} = 0.75 \text{ kg/cm}^2 = 7.5 \text{ t/m}^2$$

$$B = 2 \times 0.9 + 0.3 = 2.1 \text{ m}$$

(a) Pile acting individually

$$P_n = n \cdot \alpha \cdot C \cdot A_s$$
$$= 9 \times 0.9 \times 7.5 \times (\pi \times 0.3 \times 10)$$
$$= 572.6 \text{ t}$$

(b) Piles acting in a group

$$P_g = C\,(4\,\text{BL}) = 7.5 \times 4 \times 2.1 \times 10 = 630 \text{ t}$$

∴ Efficiency for pile group,

$$\eta = \frac{P_g}{P_n} = \frac{630}{572.6} = 1.1$$

**29.** **(c)**

- Local shear failure, generally occurs in soil having somewhat plastic stress-strain curve e.g., loose sand and soft clays.
- Cyclic pile load test is carried out when it is required to required to determine, skin friction and end bearing capacity separately for a pile load on a single pile.

**30.** **(d)**

Given: $B = 5$ m, $L = 7$ m, $D = 2.5$ m, $C = 100$ kN/m$^2$

∵ $$q_u = \left(1 + 0.3\frac{B}{L}\right) CN_C + qN_q + 0.5 \times \left(1 - 0.2\frac{B}{L}\right) \gamma B N_\gamma$$

In case of clay, $$N_C = 5.7,\ N_q = 1,\ N_\gamma = 0$$

∴ $$q_u = \left(1 + 0.3\frac{5}{7}\right) \times 100 \times 5.7 + \gamma D_f \times 1 + 0$$

∴ $$q_{nu} = q_u - \gamma D_f$$

$$= \left(1 + 0.3 \times \frac{5}{7}\right) \times 100 \times 5.7 = 692.14 \text{ kN/m}^2$$

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