Answer + Solution

Test ID - 003

Soil Mechanics Paper

1. **(d)**

Given,

Volume of Air i.e. V_a = (1/7) of total volume V

Volume of Water i.e. V_W = (1/8) of total volume V

: Volume of voids i.e. $V_v = V_a + V_W$

Hence, $V_v = (1/7)V+(1/8)V$

$V_v = (15/56)V = 0.268V$

2. **(c)**

Given,

The ratio of saturated unit weight to dry unit weight is equal to 1.2

$V_{sat} / V_d = 1.2$

Specific gravity of solids G is 2.65

$V_{sat} = (G+e)\gamma_w / (1+e)$ and $V_d = G\gamma w / (1+e)$

$V_{sat} / V_d = (G+e) / G = 1.2$

$(G+e) / G = 1.2$

$e = 1.2G - G$

$e = 1.2 \times 2.65 - 2.65$

$e = 0.53$

3. **(b)**

The porosity n and void ratio e are given by,

$e = V_v/V_s = n/(1+n)$

$n = V_v/V = e/(1+e)$

$\therefore\ 1-n=1/(1+e)$

4. **(c)**

Given,

Porosity of 30% = 0.3

voids ratio in the loosest state, e_{min} = 0.35

voids ratio in the densest state, e_{max} = 0.92

As we know that,

$e = n / (1-n)$

So, $e = 0.3 / (1-0.3)$

$e = 0.429$

Hence,

$I_D = (e_{max}-e) / (e_{max}-e_{min})$

$I_D = (0.92-0.429) / (0.92-0.35)$

$I_D = 0.861$

5. **(c)**

The relative compaction is given by,

$R_c=V_d / V_{d,max}$

Since $V_{d,max} = G\gamma_w / (1+e_{min})$

$V_d = G\gamma_w / (1+e)$

$\therefore\ R_c = V_d / V_{d,max} = (1+e_{min}) / (1+e)$

6. (b)

Consider a unit cube of soil having spherical particles of diameter d.

Volume of each spherical particle = $(\pi/6)d^3$

Total volume of container = 1*1*1 = 1

No. of solids in the container = (1/d)*(1/d)*(1/(d) = $(1/d^3)$

Volume of the solids, $V_s = (\pi/6)*d^3*(1/d^3) = (\pi/6) = 0.523$

Volume of the voids, $V_v = 1-(\pi/6) = 0.476$

Voids ratio, $e = V_v / V_s = 0.476 / 0.523 = 0.91$

Hence, Porosity, n = e / (1+e) = 0.91 / (1 + 0.91) = 0.4764

In percentage, n = 47.64%

7. (d)

The pipette method is the standard sedimentation method used in laboratory for wet mechanical or sedimentation analysis.

8. (b)

$M_1 = 573$
$M_2 = 973$
$M_3 = 1605$
$M_4 = 1480$
G = 2.65

$$\therefore \quad w = \left[\left(\frac{M_2 - M_1}{M_3 - M_4}\right) * \left(\frac{G-1}{G}\right) - 1\right] \times 100$$

$$w = \left[\left(\frac{973-573}{1605-1480}\right) * \left(\frac{2.65-1}{2.65}\right) - 1\right] \times 100$$

= 46.504%

9. (c)

The soil is treated with hydrogen peroxide to remove organic matter.

10. (c)

Liquid limit, plastic limit, shrinkage limit are useful for engineering purpose.

11. (b)

The average hygroscopicity of sands, silts and clay is 1%, 6% and 16%.

12. (a)

As the surface tension decreases with the temperature increase, the capillary rise which is directly proportional to the surface tension, would decrease with the increase in the temperature.

13. (a)

The hydrodynamic pressure, hydrostatic pressure and pore pressure are all the same and they represent the pressure that builds up in pore water due to load. The hydrodynamic lag is the delay caused in consolidation by the slow drainage of water out of a saturated soil mass.

14. (b)

The use of square root of fitting method was suggested by Taylor in 1948. Darcy did his research in the permeability of soils. Skempton is Known for his pore pressure coefficients A and B.

15. (a)

As we know that, hydrostatic pressure i.e. U is

$U = h \times y_w$

So, $U = 10 \times 9.81$

$U = 98.1 \text{ kN/m}^2$

16. (c)

In hydrometer analysis
- Meniscus correction – Always positive
- Temperature correction – Positive & negative both
- Dispersing agent correction – Always Negative

17. (b)

Given -

$$e = 1.3$$
$$w = 50\%$$
$$G = 2.60$$

As we know that -

$$Se = wG$$

So, $S \times 1.3 = 0.50 \times 2.60$

$$S = 1$$

Hence the soil is in fully saturation phase.

18. (b)

Given -

Moist mass = 625.2 gm
Dry mass = 589.9 gm
Absorption = 1.6%

So, Water content in soil $= \frac{W_W}{W_S} \times 100$

$$= \frac{625.2 - 589.9}{589.9} \times 100$$

$= 5.98\%$

Absorption of water is 1.6% so free moisture content = 5.98 - 1.6 = 4.38%

19. (b)

Relative density is the measure of compactness of cohesionless soil. Relative density or density index is the ratio of the difference between the void ratios of a cohesionless soil in its loosest state and existing natural state to the difference between its void ratio in the loosest and densest states.

Determination of relative density is helpful in evaluating compaction state of coarse grained soils and also assessing the safe bearing capacity in case of sandy soils.

Relative Density = $(e_{max} - e)/(e_{max} - e_{min})$

Where,

e_{max} = Void ratio of coarse grained soil (cohesionless) in its loosest state.

e_{min} = Void ratio of coarse grained soil (cohesionless) in its densest state.

e = Void ratio of coarse grained soil (cohesionless) in its natural existing state in the field

20. (c)

Toughness Index : Toughness index is defined as the ratio of plasticity index (I_p) of the soil to the flow index (I_F) of the soil.

Toughness index varies between 0 to 3.

Toughness Index gives us an idea of shear strength of soil at its plastic limit

21. (a)

$$W_L = 65\%$$
$$I_P = 50\%$$

(W_L > 50, hence high compressible)

A-Line $I_P = 0.73\ (W_L - 20)$

$I_P = 0.73\ (65 - 20) = 32.85 > 7\%$

Given soil I_P (50%) is more than A-Line I_P (32.85%)

Hence soil is high plastic clay.

22. (d)

The coefficient of uniformity is given by:

$$Cu = D_{60} / D_{10}$$

For a soil having particles of nearly the same size, $D_{10} = D_{60}$

Therefore, $C_u = 1$.

The value of Uniformity coefficient for different soils

For Cu = 1 (Uniformly graded soil)

For Cu > 6 (Well-graded sand)

For Cu > 4 (Well graded gravel)

23. (c)

In the Indian Standard Soil Classification System (ISSCS) or BIS, soils are classified according to their grain size as boulder, cobble, gravel, sand, silt, or clay as shown below in the tabulated form.

Soil Group	Type of Soil	Sub-Group	Size Range
Very Coarse Soils	Boulder		> 300 mm
	Cobble		80 - 300 mm
Coarse Soils	Gravel	Coarse	20 - 80 mm
		Fine	4.75 - 20 mm
	Sand	Coarse	2 - 4.75 mm
		Medium	0.425 - 2 mm
		Fine	0.075 - 0.425 mm
Fine Soils	Silt		0.002 - 0.075 mm
	Clay		< 0.002 mm

24. (b)

Height of jar = 30 cm

From stokes' law,

$$V_S = \frac{(G-1)\gamma_w d^2}{18\mu}$$

If the lighter particle from the group of particle would have settled at bottom that means every particle would have settled at bottom.

Here, diameter (d) = 0.004 is taken

$$V_S = \frac{(2.7-1)\times 9.81\times\left(0.004\times10^{-3}\right)^2}{18\times10^{-6}}$$

$= 14.28 \times 10^{-6}$ m/s

If H is height of jar than time taken t to settle the partical with settling velocity V_S is-

$$t = H/Vs = \frac{30\times10^{-2}}{14.284\times10^{-6}}$$

= 20215 sec

= 5hr 37min

25. (d)

$K_H = 9 \times 10^{-7}$ cm/sec

$K_V = 4 \times 10^{-7}$ cm/sec

$$K_{eq} = \sqrt{K_H \times K_V} = \sqrt{9\times10^{-7}\times4\times10^{-7}}$$

$= 6 \times 10^{-7}$ cm/sec

26. (c)

Quantity(Discharge) of flow is:

$$q = (k.h)(N_f/N_d)$$

Where,

K = permeability

H = head loss due to seepage

N_f = Number of flow channels

N_d = Number of equipotential drops

27. (c)

Sample length L = 25 cm

Sample area A = 30 cm^2

Discharge V = 120 cm^3 in 1 minute

Time t = 1 min = 60 second

Head H = 40 cm

Then permeability = $K = \frac{VL}{tAH}$

$$K = \frac{120 \times 25}{60 \times 30 \times 40} = \frac{1}{24} \text{cm/sec}$$

28. (c)

$$e = \frac{n}{1-n}$$

$$= \frac{0.35}{1-0.35}$$

$$= \frac{0.35}{0.65} = 0.538$$

Critical hydraulic gradient i.e. i_{cr} is

$$i_{cr} = \frac{G-1}{1+e} = \frac{2.5-1}{1+0.538} = 0.975$$

∴ Maximum Permissible exit gradient

$$= \frac{0.975}{5}$$

$$= 0.195$$

29. (c)

Flow nets : It is graphical solutions to the laplace equation for two-dimensional seepage. A flow net is formed by two orthogonal sets of curves:

1. **Equipotential lines :** connecting points of the equal total head
2. **Flow lines :** Indicating the direction of seepage down under a hydraulic gradient.

Application of flow net is as follows :

- Determination of hydrostatic/uplift pressure
- Determination of seepage pressure
- Determination of exit gradient
- Determination of seepage

Note : From a flow net we cannot measure coefficient of permeability.

30. (a)

Rise of water table above the ground surface does not affect the effective stress because there is equal increase in pore water pressure and total stress.

∵ Effective stress = Total stress - Pore water pressure

31. (c)

$$h = 6m$$

$$N_d = 10$$

$$B = 1.5$$

Head loss per field is

$$\Delta h = \frac{h}{N_d}$$

$$\Delta h = \frac{6}{10} = 0.6$$

So, exit gradient i.e.

$$i_e = \frac{\Delta h}{B_n}$$

$$i_e = \frac{0.6}{1.5} = 0.4$$

32. (c)

Standard Proctor test

Volume of standard mould = 944 cc or $\frac{1}{30}ft^3$

Weight of hammer = 2.495 kg (5.5 lbs)

Height of free fall = 304.8 mm (12 inches)

Number of layer = 3

Number of blow each layer = 25

33. (a)

IS code specification for permissible settlement:

(i) Total Permissible settlement :

For isolated footing on clay = 65 mm

For isolated footing on sand = 40 mm

For raft footing on clay = 65-100 mm

For raft footing on sand = 40-65 mm

(ii) Permissible Differential settlement :

For isolated footing on clay = 40 mm

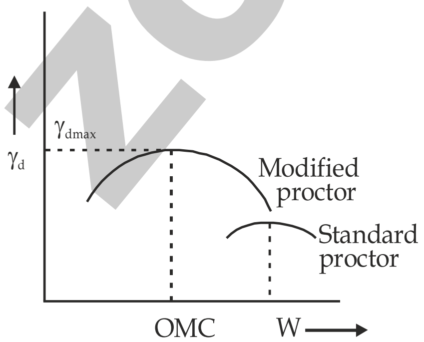
For isolated footing on sand = 25 mm

(iii) Permissible angular settlement :

For high framed structure < 1/500

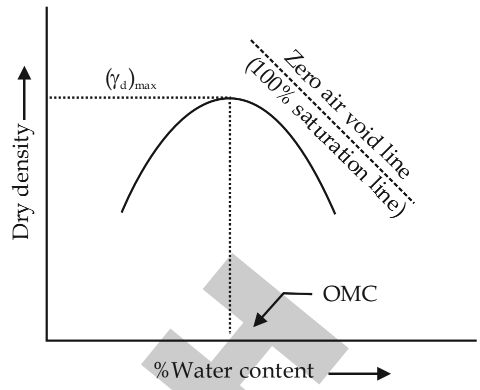
To prevent all type of minor damage < 1/ 1000

34. (c)



When compacting effort is increased then maximum dry density increases and optimum moisture content decreases.

35. (b)



36. (a)

As we know that -

$$T_V = C_V \frac{t}{d^2}$$

$$\frac{T_V}{C_V} = \frac{t}{d^2}$$

$$t \propto \frac{1}{C_V}$$

Coefficient of permeability i.e. $k = C_V m_V \gamma_W$

Hence, $k \propto C_V$

Hence, $t \propto \frac{1}{k}$

So, consolidation time of a soil sample increases with a decrease in permeability.

37. (d)

For degree of consolidation < 60%

$$T_{v_1} = \frac{\pi}{4}U_1^2 \quad \& \quad T_{v_2} = \frac{\pi}{4}U_2^2$$

$$T_{v_1} = \frac{c_v t_1}{d^2} \quad \& \quad T_{v_2} = \frac{c_v t_2}{(d/2)^2}$$

It is given that $U_1 = U_2 = 50\%$

So, $T_{v_1} = T_{v_2}$

$$\frac{c_v t_1}{d^2} = \frac{c_v t_2}{\left(\frac{d^2}{4}\right)}$$

$$t_1 = 4t_2 \text{ or } t_2 = \frac{t_1}{4}$$

$$t_2 = \frac{4}{4} = 1 \text{ year}$$

38. (b)

- Constant head permeability test is used for sand.
- Consolidation test is conducted for clay soil
- Pycnometer test is conducted for specific gravity
- Hydrometer test is conducted for grain size analysis.

39. (b)

$e_{initial}$ i.e. $e_0 = 1$, e_{final} i.e. $e_f = 0.5$

$$H_0 = 2.4 \text{ cm}$$

$$\Delta e = e_0 - e_f = 0.5$$

$$\frac{\Delta H}{H_0} = \frac{\Delta e}{1+e_0}$$

$$\frac{\Delta H}{2.4} = \frac{0.5}{1+1}$$

$$\Delta H = 0.6 \text{ cm}$$

$$H_{final} = 2.4 - 0.6 = 1.8 \text{ cm}$$

40. (d)

$$T_V = \frac{\pi}{4} \times U^2$$

$$= \frac{\pi}{4} \times (0.25)^2$$

$$= \pi/64$$

41. (b)

$$C_c = 0.007(50 - 10)$$
$$= 0.28$$

42. (a)

Angle between failure plane and major principal plane is given as

$$\theta_f = \left(45 + \frac{\phi'}{2}\right)$$

Where,

ϕ' = Angle of internal friction

43. (c)

Skempton pore pressure parameters

$$\Delta u_1 = B\Delta\sigma_3$$
$$\Delta u_2 = B.A \times (\Delta\sigma_1 - \Delta\sigma_3)$$
$$\Delta u = \Delta u_1 + \Delta u_2$$

For a fully saturated soil, B = 1

44. (b)

Force of attraction between same particles is known as cohesion and force of attraction between different particles is known as adhesion.

45. (d)

$$\sigma_3 = 20 \text{ kPa}$$

$$\sigma_d = 40 \text{ kPa}$$

$$\sigma_1 = 20 + 40 = 60 \text{ kPa}$$

As soil is cohesionless, c = 0

$$\sigma_1 = \sigma_3 \tan^2\left(45 + \frac{\phi}{2}\right)$$

$$60 = 20 \tan^2\left(45 + \frac{\phi}{2}\right) \Rightarrow 45 + \frac{\phi}{2} = 60°$$

$$\phi = 30°$$

46. (a)

$$K_a \times K_p = 1$$

$$K_a = \frac{1}{K_p} = \frac{1}{4}$$

47. (b)

Active earth pressure $= P_a = K_a\sigma_v - 2C\sqrt{K_a}$

At depth Z,

$$\sigma_v = (\gamma z + q)$$

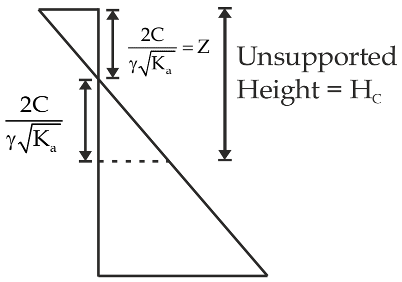
For $p_a = 0$

$$K_a(\gamma z + q) = 2C\sqrt{K_a}$$

$$\sqrt{K_a} \times (\gamma z + q) = 2C$$

$$\therefore \quad z = \frac{2C}{\gamma\sqrt{K_a}} - \frac{q}{\gamma} = \frac{2C}{\gamma}\tan\alpha - \frac{q}{\gamma}$$

48. (a)



Active earth pressure i.e. $P_a = \gamma z K_a - 2C\sqrt{K_a}$

For obtaining 'Z depth', put above equation equal to zero -

$$\gamma Z K_a = 2C\sqrt{K_a}$$

$$Z = \frac{2C}{\gamma\sqrt{K_a}}$$

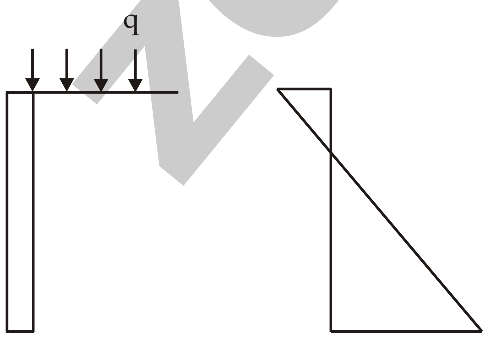
Total unsupported height i.e. $H_C = 2Z$

$$H_C = 2Z = \frac{4C}{\gamma\sqrt{K_a}}$$

$\because \quad K_a = \frac{1}{K_p} = \frac{1}{\tan^2\left(45+\frac{\phi}{2}\right)}$

Hence, $\quad Z = \frac{4C}{\gamma}\tan\left(45+\frac{\phi}{2}\right)$

49. (b)



Active pressure intensity with surcharge 'q' at top is

$$P_a = qK_a - 2C\sqrt{K_a}$$

For zero active pressure intensity at the top put above equation equal to zero

$$K_a q = 2C\sqrt{K_a}$$

$$q = \frac{2C\sqrt{K_a}}{K_a}$$

$$= \frac{2C}{\sqrt{K_a}}$$

$$= \frac{2C}{\sqrt{\cot^2\left(45+\frac{\phi}{2}\right)}}$$

$$= 2C\tan\alpha$$

50. (d)

$$H = 4m$$
$$\gamma = 20\ kN/m^3$$
$$\phi = 30°$$

$$K_p = \frac{1+\sin\phi}{1-\sin\phi} = \frac{1+\sin 30°}{1-\sin 30°} = \frac{3/2}{1/2}$$

$$P_a = \frac{1}{2}K_P\gamma H^2 = \frac{1}{2}\times 3\times 20\times 4^2$$
$$= 480\ kN/m$$