DETAILED SOLUTIONS

MADE EASY

India's Best Institute for IES, GATE & PSUs

Test Centres: Delhi, Hyderabad, Bhopal, Jaipur, Bhubaneswar, Pune, Kolkata

ESE 2024 : Prelims Exam
CLASSROOM TEST SERIES

CIVIL ENGINEERING

Test 2

Section A : Geo-technical & Foundation Engineering
Section B : Environmental Engineering

1.	(d)	16.	(d)	31.	(d)	46.	(b)	61.	(d)
2.	(d)	17.	(b)	32.	(a)	47.	(d)	62.	(b)
3.	(c)	18.	(c)	33.	(b)	48.	(a)	63.	(b)
4.	(c)	19.	(d)	34.	(c)	49.	(b)	64.	(b)
5.	(a)	20.	(b)	35.	(c)	50.	(b)	65.	(d)
6.	(b)	21.	(a)	36.	(b)	51.	(c)	66.	(a)
7.	(c)	22.	(a)	37.	(b)	52.	(b)	67.	(a)
8.	(a)	23.	(c)	38.	(d)	53.	(c)	68.	(c)
9.	(d)	24.	(a)	39.	(d)	54.	(c)	69.	(d)
10.	(d)	25.	(c)	40.	(b)	55.	(b)	70.	(a)
11.	(c)	26.	(b)	41.	(a)	56.	(d)	71.	(c)
12.	(b)	27.	(b)	42.	(b)	57.	(c)	72.	(a)
13.	(b)	28.	(b)	43.	(c)	58.	(a)	73.	(b)
14.	(d)	29.	(b)	44.	(b)	59.	(d)	74.	(a)
15.	(b)	30.	(c)	45.	(c)	60.	(b)	75.	(d)

DETAILED EXPLANATIONS

2. (d)

Specific gravity of solids, G_S is given as

$$G_S = \frac{W_s}{V_s \cdot \gamma_w}$$

where, W_S is weight of solids; V_S is volume of solids; γ_w is unit weight of water = 1 gm/cc

$$\therefore \quad 2.65 = \frac{60}{V_s \times 1}$$

$$\Rightarrow \quad V_S = 22.64 \text{ ml}$$

Now, $V_V + V_S = V_T$ [where, V_V is volume of voids]

$$\Rightarrow \quad V_V + 22.64 = 40$$

$$\Rightarrow \quad V_V = 17.36 \text{ ml}$$

3. (c)

Given :

$$W_2 - W_1 = 1060 \text{ gm}$$
$$W_3 = 1800 \text{ gm}$$
$$W_4 = 1305 \text{ gm}$$
$$G_S = 2.65$$

Now, water content, w is given as

$$w = \left[\left(\frac{W_2 - W_1}{W_3 - W_4}\right)\left(\frac{G_s - 1}{G_s}\right) - 1\right] \times 100$$

$$= \left[\left(\frac{1060}{1800 - 1305}\right) \times \left(\frac{2.65 - 1}{2.65}\right) - 1\right] \times 100 = 33.33\%$$

4. (c)

These are two curve fitting methods:

(i) Logarithmic time fitting method based on T_{50}.

(ii) Square root of time fitting method based on T_{90}.

6. (b)

Capillary rise (h_c) is given as

$$h_c = \frac{C}{e \cdot D_{10}} \quad \text{[where } D_{10} \text{ is effective size of particles]}$$

$$\Rightarrow \quad h_c \propto \frac{1}{D_{10}}$$

$$\therefore \quad \frac{h_{c_1}}{h_{c_2}} = \frac{(D_{10})_2}{(D_{10})_1}$$

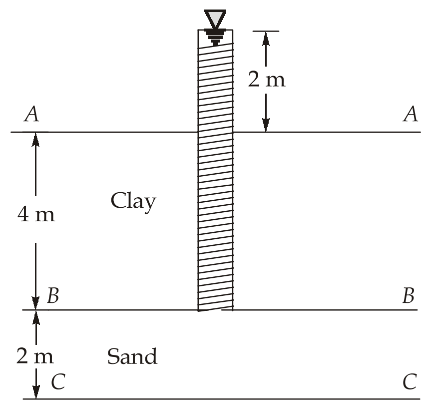
$$\Rightarrow \quad \frac{50}{h_{c_2}} = \frac{0.04}{0.02}$$

$$\Rightarrow \quad h_{c_2} = 25 \text{ cm}$$

8. (a)

Soil is laterally confined, and the consolidation takes place only in axial direction. Drainage of water also occurs only in the vertical direction.

9. (d)



At section A-A,

- Total stress, $\sigma = 0$
- Pore water pressure, $u = 0$
- Effective stress, $\bar{\sigma} = \sigma - u = 0 - 0 = 0$

At section B-B,

(i) Just above section B-B

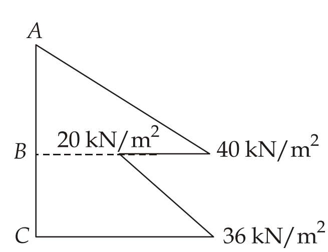
$$\sigma = 4 \times 20 = 80 \text{ kN/m}^2$$
$$u = 4 \times 10 = 40 \text{ kN/m}^2$$
$$\therefore \quad \bar{\sigma} = \sigma - u = 80 - 40 = 40 \text{ kN/m}^2$$

(ii) Just below section B-B

$$\sigma = 4 \times 20 = 80 \text{ kN/m}^2$$
$$u = (4 + 2) \times 10 = 60 \text{ kN/m}^2$$
$$\therefore \quad \bar{\sigma} = 80 - 60 = 20 \text{ kN/m}^2$$

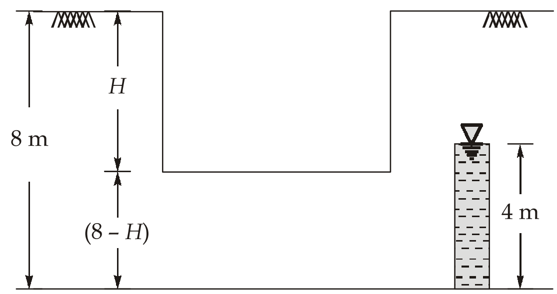
At section C-C,

$$\sigma = 4 \times 20 + 2 \times 18 = 116 \text{ kN/m}^2$$
$$u = (4 + 2 + 2) \times 10 = 80 \text{ kN/m}^2$$
$$\therefore \quad \bar{\sigma} = 116 - 80 = 36 \text{ kN/m}^2$$



10. (d)

Let 'H' is depth of cut that can be made without causing a heave.



$$(8 - H)\gamma_{sat} = (4)\gamma_w$$

$$\Rightarrow \quad (8 - H) \times 20 = 4 \times 10$$

$$\Rightarrow \quad H = 6 \text{ m}$$

11. (c)

According to Boussinesq's equation, vertical stress (σ_v) is given as

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

Here, $r = 0$

Hence, $$\sigma_v = \frac{3Q}{2\pi z^2}$$

$$\therefore \quad \sigma_v \propto \frac{1}{z^2}$$

$$\therefore \quad \frac{(\sigma_v)_1}{(\sigma_v)_2} = \frac{(z_2)^2}{(z_1)^2}$$

$$= \frac{(6)^2}{(4)^2} = 2.25$$

13. (b)

Settlement, ΔH is given as

$$\Delta H = \frac{C_c H_0}{1+e_0}\log\left[\frac{\bar{\sigma}_2}{\bar{\sigma}_1}\right]$$

where C_c and e_o are compression index and initial void ratio respectively

$$\therefore \quad \Delta H \propto \log\left[\frac{\bar{\sigma}_2}{\bar{\sigma}_1}\right]$$

$$\therefore \quad \frac{\Delta H_1}{\Delta H_2} = \frac{\log\left[\frac{\bar{\sigma}_2}{\bar{\sigma}_1}\right]}{\log\left[\frac{\bar{\sigma}_3}{\bar{\sigma}_2}\right]}$$

$$\Rightarrow \quad \frac{3\text{ cm}}{\Delta H_2} = \frac{\log\left[\frac{200}{100}\right]}{\log\left[\frac{400}{200}\right]}$$

$$\Rightarrow \quad \frac{3\text{ cm}}{\Delta H_2} = \frac{\log(2)}{\log(2)}$$

$$\Delta H_2 = 3\text{ cm}$$

$$\Rightarrow \quad \text{Total settlement, } \Delta H = \Delta H_1 + \Delta H_2$$

$$= 3\text{ cm} + 3\text{ cm} = 6\text{ cm}$$

14. (d)

- Vane shear test is ideally suited for the determination of the in-situ undrained shear strength of non-fissured, fully saturated clay.
- This test does not give accurate results when the failure envelope is not horizontal.

15. (b)

- Confining pressure, $\sigma_3 = 100\text{ kN/m}^2$
- Deviator stress, $\sigma_d = 200\text{ kN/m}^2$

Now,

$$\sigma_1 = \sigma_3 \tan^2\left(45° + \frac{\phi}{2}\right) + 2c\tan\left(45° + \frac{\phi}{2}\right) \quad (2c \to 0)$$

$$\Rightarrow \quad \sigma_3 + \sigma_d = \sigma_3 \tan^2\left(45° + \frac{\phi}{2}\right) + 0$$

$$\Rightarrow \quad 100 + 200 = 100\tan^2\left(45° + \frac{\phi}{2}\right)$$

$$\Rightarrow \quad \tan^2\left(45° + \frac{\phi}{2}\right) = 3$$

Now, for same soil sample,

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

$$\Rightarrow \quad \sigma_1' = 150 \cdot (3)$$

$$\Rightarrow \quad \sigma_1' = 450\text{ kN/m}^2$$

$$\Rightarrow \quad \sigma_d' + \sigma_3' = 450\text{ kN/m}^2$$

$$\Rightarrow \quad \sigma_d' = 450 - \sigma_3' = 450 - 150 = 300\text{ kN/m}^2$$

19. (d)

- Ultimate load carrying capacity, Q_u of friction pile is given as

$$Q_u = \alpha C \cdot (\pi d l)$$

$$= 0.7 \times 50 \times \pi \times 0.3 \times 10$$

$$= 329.867\text{ kN} \simeq 330\text{ kN}$$

$$\therefore \quad \text{Safe load, } Q_s = \frac{Q_u}{FOS} = \frac{330}{3}\text{ kN} = 110\text{ kN}$$

21. (a)

The ultimate bearing capacity, q_u of a strip footing is given as

$$q_u = CN_C + \gamma D_f \cdot N_q + 0.5B \cdot \gamma \cdot N_\gamma$$
$$= 10 \times 50 + 20 \times 1 \times 40 + 0.5 \times 2 \times 20 \times 42$$
$$= 2140 \text{ kN/m}^2$$

22. (a)

The allowable angular distortion in case of steel structure is more than that of RCC structure.

23. (c)

Net ultimate bearing capacity (q_{nu}) is given as

$$q_{nu} = q_u - \gamma D_f \qquad \text{[where, } q_u \text{ is gross bearing capacity]}$$
$$= 300 - 20 \times 1$$
$$= 280 \text{ kN/m}^2$$

24. (a)

- Coefficient of compressibility, $a_v = \frac{-\Delta e}{\Delta \sigma} = \frac{-(1.44 - 1.50)}{120} = 5 \times 10^{-4} \text{ m}^2/\text{kN}$
- Coefficient of volume compressibility,

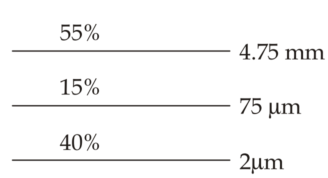
$$m_v = \frac{a_v}{1 + e_0}$$
$$= \frac{5 \times 10^{-4}}{1 + 1.5} = 2 \times 10^{-4} \text{ m}^2/\text{kN}$$

Now, final settlement, $\Delta H = H_0 \cdot m_v \cdot \Delta\sigma$
$$= (6 \times 10^3 \times 2 \times 10^{-4} \times 120) \text{ mm}$$
$$= 144 \text{ mm}$$

26. (b)

Vibroflotation is effective for coarse grained soil i.e. sand.

28. (b)



- As more than 50% is retained on 75μ sieve, and thus the soil is coarse-grained.
- As more than half of coarse-fraction is larger than 4.75 mm IS sieve, the soil is gravel (G).

$$I_P \text{ of } A \text{ line} = 0.73\,[w_L - 20] = 0.73\,[40 - 20] = 14.6$$

But I_P of soil mass is 10.

Hence, $(I_P)_{\text{Aline}} > (I_P)_{\text{Soil mass}}$

∴ Soil is classified as GM.

30. (c)

In a constant head permeability test, permeability is given as

$$Q = kiA$$

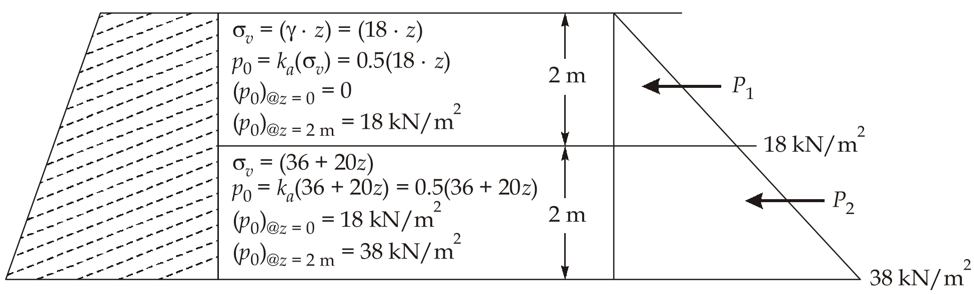
$$\Rightarrow \quad \frac{V}{t} = k\left(\frac{h_L}{L}\right)\cdot A$$

$$\Rightarrow \quad \frac{240 \text{ cm}^3}{100 \text{ sec}} = k\left(\frac{60}{100}\right)\cdot 80$$

$$\Rightarrow \quad k = 0.05 \text{ cm/s}$$

32. (a)

- $$k_o = 1 - \sin\phi = 1 - \sin 30° = 0.5$$



- Total lateral earth pressure at rest is given as

$$P = P_1 + P_2$$

$$= \left(\frac{1}{2}\times 2\times 18\right) + \left(\frac{18+38}{2}\right)\times 2$$

$$= 74 \text{ kN/m}$$

33. (b)

Factor of safety (FOS) is given as

$$\text{FOS} = \frac{c' + \bar{\sigma}\tan\phi}{\tau}$$

$$= \frac{c' + \gamma' \cdot H \cdot \cos^2\beta \cdot \tan\phi}{\gamma_{sat} \cdot H\cos\beta\,\sin\beta}$$

$$= \frac{10 + (20-10)\times 5\times(\cos 30°)^2\tan 45°}{20\times 5\times\cos 30°\times\sin 30°}$$

$$= 1.097 \simeq 1.1$$

38. (d)

Under identical conditions, Rankine active earth pressure is more than that of Coulomb's active earth pressure.

41. (a)

Discharge per meter through gallery $(q) = k\frac{H^2 - H_0^2}{2R}$

where, k = 0.5 cm/sec = 0.005 m/sec, R = 15 m, H = 6 m, H_0 = 2 m

$$\therefore \quad q = 0.005 \times \frac{6^2 - 2^2}{2 \times 15} = 0.00533 \text{ m}^3/\text{sec}/\text{m}$$

$$= 0.32 \text{ m}^3/\text{min}/\text{m}$$

42. (b)

- The rate of filtration through slow sand filter is 100 to 200 $l/\text{h}/\text{m}^2$.
- Back washing is not done in slow sand filter. Cleaning of slow sand filter is done by scrapping and removing the 1.5 cm to 3 cm of top sand layer.

43. (c)

Average daily water demand = 20000 × 150

= 3×10^6 l/day

∴ Amount of chlorine required daily = 0.3 mg/l × 3×10^6 l = 0.9×10^6 mg = 0.9 kg

Now, chlorine content in bleaching power is 30%.

∴ Amount of bleaching power required daily = $\frac{0.9 \times 100}{30} = 3$ kg

∴ Annual consumption of bleaching powder = 3 × 365 = 1095 kg ≃ 1.1 tonnes

45. (c)

Removal of solids in primary clarifier = 0.6 × 250 = 150 mg/l

BOD of influent entering trickling filter = (1 – 0.3) × 220 = 154 mg/l

Production of solids in the secondary treatment unit = 0.5 × 154 = 77 mg/l

Total solids production = 150 + 77 = 227 mg/l/day

$$= \frac{227 \times 1200 \times 10^3}{10^6} = 272.4 \text{ kg/day}$$

46. (b)

London smog is known as sulphurous smog which results from a high concentration of sulphur oxides in air.

48. (a)

The chemical reaction which is involved in treating water with alum is given by,

$$Al_2(SO_4)_3 \cdot 18H_2O + 3Ca(HCO_3)_2 \rightarrow 2Al(OH)_3 + 3CaSO_4 + 18H_2O + 6CO_2$$

Molecular mass of alum = 666 gm

Molecular mass of CO_2 = 44 gm

∴ If 666 mg alum is used, then it will release = 6 × 44 mg of CO_2 = 264 mg of CO_2

∴ 12.5 mg of alum will release = $\frac{264}{666} \times 12.5 = 4.955$ mg of CO_2 ≃ 5 mg of CO_2

49. (b)

Continuous noise is an uninterrupted sound level that varies less than 5dB during the entire period of observation.

50. (b)

$$\text{Equivalent pressure, } p_{\text{rms}} = \sqrt{4000^2 + 4000^2} = 4000\sqrt{2}\ \mu\text{Pa}$$

Now,

$$\text{Sound (in dB)} = 20\log_{10}\left(\frac{p_{rms}}{20\mu Pa}\right) = 20\log_{10}\left(\frac{4000\sqrt{2}}{20}\right)$$

$$= 20\log_{10}\left(200\sqrt{2}\right) = 20\left[\log_{10}(2) + \log_{10}\left(\sqrt{2}\right) + \log_{10}(100)\right]$$

$$= 20\left[\frac{3}{2}\log_{10}(2) + 2\right] = 20 \times 2.4515 = 49.03 \text{ dB}$$

51. (c)

Free ammonia can be determined by simple boiling and noting the amount of nitrogen gas liberated.

52. (b)

At 273 K and 1 atm pressure, volume occupied by 1 mole of any gas is 22.4 L.
Now, 10^6 m^3 of air contains 1 m^3 of gaseous chemical.
So, 1 m^3 of air contains 10^{-6} m^3 of gaseous chemical.
Now, number of moles in $22.4L$ = 1

So, $$\text{number of moles in } 10^{-6}\ m^3 = \frac{1\times10^{-6}}{22.4\times10^{-3}} = 44.64 \times 10^{-6} \text{ moles}$$

$$= 44.64\ \mu\text{moles}$$

53. (c)

$$F = \text{Mass of BOD entering in plant}$$

$$= QY_0$$

$$= \frac{35000\times250}{1000} = 8750 \text{ kg/day}$$

$$M = \text{Mass of MLSS}$$

$$= VX$$

$$= \frac{10900\times2500}{1000} = 27250 \text{ kg}$$

$$\therefore \quad \frac{F}{M} = \frac{8750}{27250} = 0.32 \text{ kg BOD per day/kg of MLSS}$$

54. (c)

Ultimate BOD is the oxygen required for oxidising the biodegredable organics of a given waste water while COD is the oxygen required to oxidize the both biodegradable organics and non biodradable organics.

55. (b)

$$\text{Total sewage produced per day} = 70000 \times 150 \times 0.75 \times 240 \times 10^{-6}$$
$$= 1890 \text{ kg/day}$$
$$\text{Per capita BOD of sewage per day} = 75 \text{ gm}$$
$$\text{Population equivalent} = \frac{1890 \times 10^3}{75} = 25200$$

56. (d)

$$\text{Vinyl chloride} = C_2H_3Cl$$

The carbon content of vinyl chloride is 24 mg per 62.5 mg of vinyl chloride

$\therefore$ Total organic carbon content of the solution containing 100 mg/l of vinyl chloride = $\frac{24}{62.5} \times 100$

$$= 38.4 \text{ mg}/l$$

57. (c)

- These are automatically operated.
- Air relief valve is provided at the summit to release the air pressure.

58. (a)

59. (d)

$$\text{Efficiency, } \eta = \frac{V_s}{V_o} \times 100$$
$$\Rightarrow \quad 85 = \frac{0.13}{V_o} \times 100$$
$$\Rightarrow \quad V_o = 0.153 \text{ cm/sec}$$
$$Q = 532 \text{ m}^3/\text{hr} = 0.148 \text{ m}^3/\text{s}$$

Now, $V_o = \frac{Q}{B.L.}$ where B.L. = Plan area

$$\Rightarrow \quad B.L. = \frac{Q}{V_o} = \frac{0.148}{0.153 \times 10^{-2}}$$
$$= 96.73 \text{ m}^2$$

60. (b)

Using Kuichling's formula, Q (in litre/min) = $3182\sqrt{P}$ [where, P is population in thousand]

$$= 3182 \times \sqrt{400} = 3182 \times 20 = 63640 \; l/\text{min}$$
$$= \frac{63640 \times 1440}{10^6} = 91.64 \text{ MLD}$$

61. (d)

$$\text{Total hardness }(TH) = \left[\frac{66}{20}+\frac{28}{12}\right]\times 50 = 281.67 \text{ mg}/l$$

$$\text{Alkalinity} = \frac{244}{61}\times 50 = 200 \text{ mg}/l$$

Carbonate hardness = Minimum (TH, Alkalinity)
= 200 mg/l

∴ Non carbonate hardness = 281.67 – 200
= 81.67 mg/l

62. (b)

$$\text{DO of diluted sample} = \frac{3\times 0.6+97\times 3}{100} = 2.93 \text{ mg}/l$$

$$(\text{BOD})_5 = (2.93-0.8)\times\frac{100}{3} = 71 \text{ mg}/l$$

$$\therefore \quad L_0 = \frac{L_t}{1-10^{-k_D\times t}} = \frac{71}{1-10^{-0.1\times 5}}$$

$$= \frac{71}{1-10^{-0.5}} = \frac{71}{1-0.32} = 104.4 \text{ mg}/l$$

64. (b)

Distribution system is designed for the maximum of coincident draft and maximum hourly draft.

Now, coincident draft, $Q_{CD} = Q_{MD} + Q_{FD}$
= 25 + 35 = 60 MLD

$$\therefore \quad Q_D = \text{Maximum}\begin{cases}60\text{ MLD}\\65\text{ MLD}\end{cases} = 65 \text{ MLD}$$

65. (d)

Solids removed = Suspended solids removed + Precipitate of alum

1 gm of alum gives a precipitate of 0.234 gm

∴ 23 mg/l of alum will give = 23 × 0.234 = 5.38 mg/l of precipitate

Suspended solids removed = 37 – 12 = 25 mg/l

Total solids removed = 25 + 5.38 = 30.38 mg/l

Total dry weight of solids removed = $30.38 \times 10^{-6} \times 0.5 \times 10^3 \times 86400$
= 1312.416 kg/day

66. (a)

Solid content = 1% i.e. 1 kg solids combine with 99 kg of water

∴ 1312.416 kg solids will require = 1312.416 × 99 kg of water
= 129929 kg of water

$\therefore$ Volume of water $= 129.929 \text{ m}^3/\text{day}$

$$\text{Volume of solids} = \frac{1312.416}{3.01 \times 10^3} = 0.436 \text{ m}^3/\text{day}$$

$\therefore$ Total volume of sludge produced per day = 129.93 + 0.436

$= 130.366 \text{ m}^3/\text{day}$

$\simeq 130.4 \text{ m}^3/\text{day}$

67. (a)

Activated alumina is an excellent medium for removal of excess fluoride.

69. (d)

Refer table 2 of IS Code 10500 : 2012.

70. (a)

$$C_{mix} = \frac{C_S \times Q_S + C_R \cdot Q_R}{Q_S + Q_R}$$

$$\Rightarrow 50 = \frac{200 \times Q_S + 20 \times 100}{Q_S + 100}$$

$$\Rightarrow 50Q_S + 5000 = 200Q_S + 2000$$

$$\Rightarrow 150Q_S = 3000$$

$$\Rightarrow Q_S = 20 \; l/s$$

$$\therefore \text{Dilution ratio} = \frac{Q_R + Q_S}{Q_S} = \frac{100 + 20}{20} = \frac{120}{20} = 6$$

72. (a)

Foul gases are released in case of spray nozzle application. In rotary distribution, no such foul gases are released.

73. (b)

During zone of active decomposition, DO falls down to zero which leads to activate anaerobic decomposition, which results in formation of layer of acid, alcohol, gases on surface of stream, known as scum layer. This layer does not allow penetration of sunlight in stream. That's why growth of algae does not occur.

75. (d)

Water with heavy algae growth is often having pH of 9 to 10 and therefore alkaline in nature.

❍❍❍❍

