DETAILED SOLUTIONS

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ESE 2023 : Prelims Exam
CLASSROOM TEST SERIES

CIVIL ENGINEERING

Test 2

Section A : Geo-technical & Foundation Engineering

Section B : Environmental Engineering

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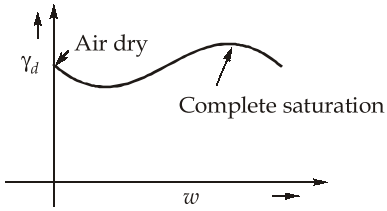
DETAILED EXPLANATIONS

2. (d)

- Decomposition of vegetative matter – Humus
- Extraction of minerals from natural rock – Mine tailings
- Heavy runoff –Varved clay

3. (c)

For cohesionless soil/sand,



4. (b)

- Core of an earthern dam – Wet side of optimum
- Homogeneous earthern dam – Dry side of optimum
- Subgrade of pavement – Wet side of optimum

5. (c)

For the given condition, the flow is upward and thus, consider datum at the base of soil mass

$$(TH)_{entry} = PH + DH = (40 + 10 + 40) + 0 = 90 \text{ cm}$$

$$i = \frac{90 - 50}{40} = 1$$

$$(TH)_x = 90 - 1 \times 10 = 80 \text{ cm}$$

But, $(TH)_x = (PH)_x + (DH)_x$

$\Rightarrow$ $(PH)_x = (TH)_x - (DH)_x = 80 - 10 = 70$ cm

6. (c)

$$\text{Volume of excavated soil hole} = \frac{M_1 - M_3 - M_2}{\rho_s}$$

where,

M_1 = Mass of cylinder and sand before pouring into the hole

M_2 = Mass of sand in cone only

M_3 = Mass of cylinder after pouring sand into the hole

ρ_s = Mass density of sand, as found from calibration

7. (b)

$$G = \frac{M_2 - M_1}{(M_2 - M_1) - (M_3 - M_4)}$$

where,

$M_2 - M_1$ = Mass of oven-dried soil sample

M_3 = Mass of jar (completely filled with water and soil sample)

M_4 = Mass of jar (completely filled with water)

$$G = \frac{0.2}{0.2 - (1.65 - 1.53)} = 2.5$$

8. (a)

$$a_c = \frac{V_a}{V_v} = \frac{V_a}{V_a + V_w}$$

$$= \frac{\frac{V}{6}}{\frac{V}{6} + \frac{V}{3}} = \frac{\frac{V}{6}}{\frac{V}{2}} = \frac{1}{3}$$

9. (b)

Hydrometer determines specific gravity of suspensions/liquid.

10. (a)

Plasticity in soils is due to presence of clay minerals. Water molecules being dipolar get attracted to clay particles (negatively charged) surfaces. Water molecules get adsorbed on the surfaces of clay particles, which helps clay particles to slide over each other. But kerosene and paraffin oil are non-polar and hence they do not interact with clay minerals.

11. (c)

At shrinkage limit, $eS = wG$

But $S = 1$

$0.7 \times 1 = w_s \times 2.65$

$\Rightarrow$ $w_s = 0.264 = 26.4\%$

12. (a)

For coarse grained soil:

1. If the percentage of fines is in between 5 to 12% then symbols, GW - GM, SP - SM, GP - GM, SW - SM are used.
2. If percentage of fines is less than 5% then symbols GW, GP, SW, SP are used.
3. If percentage of fines is greater than 12% then symbols GM, GC, SM, SC are used.

13. (d)

As per Terzaghi and Peck, $h = \frac{C}{eD_{10}}$

C = Constant, depending upon the shape of the grain and impurities

e = Void ratio

D_{10} = Effective diameter (depends upon diameter of the particle)

14. (c)

(i) Undisturbed samples: These are samples in which care is taken to cause minimal disturbance to the density, structure and water content of the soil. They are obtained by carefully designed samplers and sampling techniques. They can be tested in the laboratory to determine both the physical and the engineering properties.

(ii) **Disturbed representative samples:** These are samples in which care is taken to ensure that at least the composition of the soil as it exists in nature remains unaltered. They are obtained by samplers that are more rugged but relatively crude. They can be used to determine mineralogy, grain size distribution and liquid and plastic limits.

(iii) **Disturbed non-representative samples:** These are not obtained by samplers but are recovered during drilling operations. They give a broad idea of the soil type but cannot be used for laboratory testing.

15. (d)

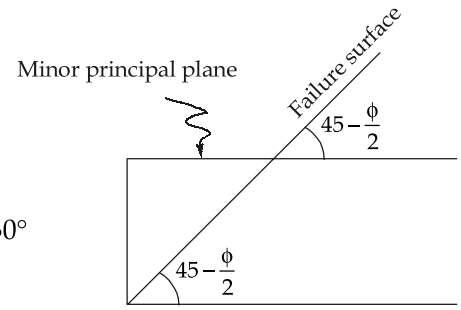
Elastic settlement is considered both in sand and clay considering the elastic behaviour of soil. Immediate settlement is a combination of elastic settlement and settlement due to explusion of air.

16. (a)

Depth factors are function of depth and width of footing.

17. (c)

For passive case,



$$\alpha = 45 - \frac{\phi}{2}$$

$$= 45 - \frac{30}{2} = 45 - 15 = 30^\circ$$

18. (b)

$$\frac{(D_{15})_{\text{filter}}}{(D_{15})_{\text{protected soil}}} = \frac{0.0025}{0.001} = 2.5 < 5$$

The filter does not ensure higher permeability of the filter.

$$\frac{(D_{15})_{\text{filter}}}{(D_{85})_{\text{protected soil}}} = \frac{0.0025}{0.006} = 0.42 \leq 5$$

It ensures that fine particles do not mitigate.

19. (d)

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

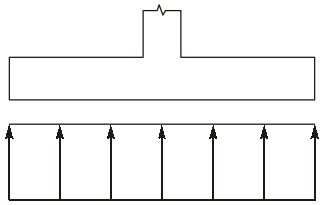
At, $x = 0$

$$\sigma_z = \frac{2q}{\pi z} = \frac{2\times 10}{\pi \times 2} = \frac{10}{\pi}\ \text{kN/m}^2$$

20. (d)

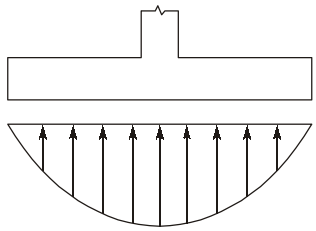
Contact Pressure Distribution (CPD) on sand

1. Flexible footing



Contact pressure diagram

2. Rigid footing



Contact pressure diagram

21. (a)

$$q = kiA$$

$$\Rightarrow \quad \frac{q}{A} = ki = \frac{10^{-4}}{100} \times \frac{6}{4} = 1.5 \times 10^{-6}\ \text{m}^3/\text{s}/\text{m}^2 \qquad \left[i = \frac{12-6}{4}\right]$$

$$= 0.1296\ \text{m}^3/\text{d}/\text{m}^2$$

22. (c)

The following assumptions are made in the derivation of the Laplace equation:

1. The flow is two-dimensional.
2. Water and soil are incompressible.
3. Soil is isotropic and homogeneous.
4. The soil is fully saturated.
5. The flow is steady, i.e., flow conditions do not change with time.
6. Darcy's law is valid.

23. (c)

Newmark's charts are based on Boussinesq's solution.

24. (c)

One dimensional consolidation equation:

$$\frac{\partial \bar{u}}{\partial t} = C_v \frac{\partial^2 \bar{u}}{\partial z^2}$$

It gives distribution of hydrostatic excess pore water pressure $\bar{u}$ with depth (z) and time (t).

25. (b)

$$C_c = \frac{\Delta e}{\log\left(\frac{\sigma_2'}{\sigma_1'}\right)} \qquad [\sigma_2' = \sigma_1 + \Delta\sigma = 150 + 350 = 5000\ \text{kN/m}^2]$$

$$\Rightarrow \quad C_c = \frac{0.3}{\log\left(\frac{500}{150}\right)} = \frac{0.3}{\log\left(\frac{10}{3}\right)} = \frac{0.3}{\log 10 - \log 3} = \frac{0.3}{1 - 0.48} = 0.577 \simeq 0.58$$

27. (c)

IS heavy compaction test:

Hammer weight = 4.9 kg
Height of fall = 450 mm
Compactive effort = 2700 kJ/m^3 = 2700 J/litre

The soil is compacted in five equal layers, each layer is given 25 blows.

28. (c)

For strip footing

$$N_c = 5\left[1 + 0.2\frac{D}{B}\right] \le 7.5$$

$$\Rightarrow \quad N_c = 5\left[1 + 0.2 \times \frac{1.5}{2}\right] = 5.75 \le 7.5 \qquad \text{(OK)}$$

$$\therefore \quad q_{net} = cN_c$$
$$= 30 \times 5.75 = 172.5\ \text{kN/m}^2$$

$$\therefore \quad Q_{load} = 172.5 \times 1 \times 2 = 345\ \text{kN}$$

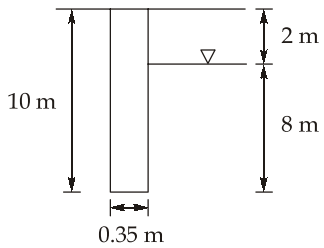
29. (a)

Point resistance, $Q_b = q_b A_b$

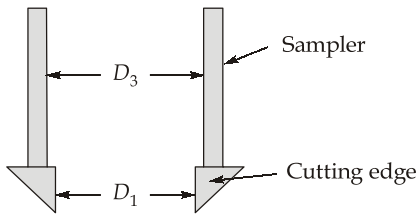
$$= \sigma_v' N_q \times \frac{\pi}{4} \times 0.35^2$$

$$\sigma_v' = 20 \times 2 + (20 - 10) \times 8 = 120\ \text{kN/m}^2$$

$$Q_b = 120 \times 55 \times \frac{\pi}{4} \times \frac{35}{100} \times \frac{35}{100}$$
$$= 634.99\ \text{kN} \simeq 635\ \text{kN}$$



30. (d)



$$\text{Inside clearance ratio} = \frac{D_3 - D_1}{D_1} = \frac{50 - 49.5}{49.5} \times 100 = 1.01\% \simeq 1\%$$

31. (a)

- **Ground heaving :** When precast driven piles are installed in groups in soft clay (which might occur near about the ground level to shallow depths) a volume of soil equal to the volume of the penetration of the pile has to be displaced by the pile. In situations where the pore pressure developed cannot be dissipated quickly there will be no volume change in the soil. This makes the soil to heave up.
- **Ground surface condition before pile driving operations:** For any pile driving operation, the equipment should be able to move freely to and fro at the site.
- **Quality of concrete piles :** Precast driven piles are superior to cast in-situ concrete piles.
- **Sensitivity of soil strata :** If the soil is sensitive, it breaks up during pile driving. Steel H bearing piles are preferable in sensitive soil.

32. (c)

Refer IS 8009 (Part-I) : 1976, Clause 8.3

33. (d)

- Determination of bearing capacity of footing on clay requires strength parameters (c and ϕ) corresponding to both drained and undrained conditions.
- **Short-term situation**: When no excess pore water is dissipated (undrained condition).
- **Long-term situation**: When complete dissipation would have occurred (drained condition).
- The ultimate bearing capacity for both the situation will be different.

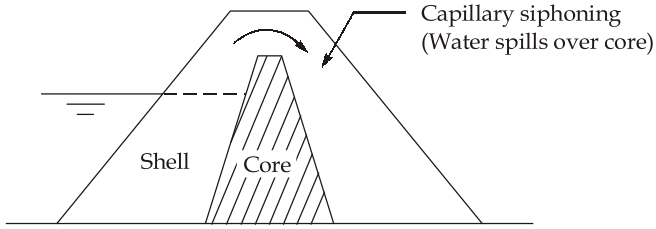
$$q_{ult} = \min (q_{ult,\,ud} ; q_{ult,\,d})$$

35. (d)

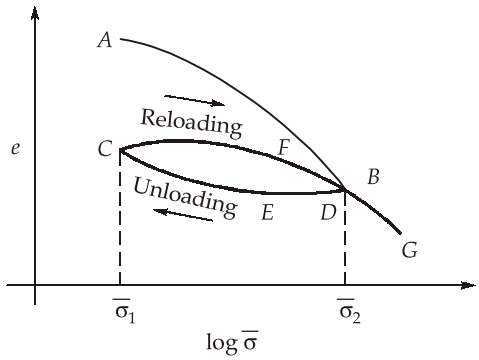
Permeability depends on void ratio of soil and with increase of effective stress, the void ratio decreases which causes permeability to decreas. Therefore permeability depends on effective stress.

36. (a)

In an earth dam with an impervious core, capillary siphoning may occur. The water rises in the outer shell due to capillary action. If the crest (top level) of the impervious core is in the reach of capillary rise, water flows from the storage reservoir to the downstream over the core.



37. (a)



NC soils and OC soils are not different types of soils but these are conditions in which a soil exists. The same type of soil can behave as normally consolidated in a certain stress range and as an over-consolidated in some other stress range.

For $\sigma > \bar{\sigma}_2$ the soil will behave as NC soil.

For $\sigma < \bar{\sigma}_2$ the soil will behave as OC soil.

38. (b)

$$\text{Average increase in population per decade } (\bar{x}) = \frac{8000+7000+8500+6500}{4} = \frac{30000}{4} = 7500$$

$$\text{Population in 2040 } (P_{2040}) = P_{2020} + 2 \times \bar{x} = 70000 + 2 \times 7500 = 85000$$

39. (c)

Asbestos pipes require less joints in their layout.

40. (c)

(i) Aquifer is homogeneous, isotropic and of infinite aerial extent.

(ii) Near the well's face the piezometric surface attains a greater slope and velocity of flow also increases due to which Dupuit's theory ceases to be valid in that region.

41. (a)

$$\begin{aligned} \text{Carbonate hardness} &= \min \{\text{Total hardness, alkalinity}\} \\ &= \min \{400, 150\} = 150 \text{ mg/}l \\ \text{Non-carbonate hardness} &= \text{Total hardness} - \text{Carbonate hardness} \\ &= 400 - 150 = 250 \text{ mg/}l \end{aligned}$$

42. (b)

$$\begin{aligned} [OH^-] &= 170 \text{ mg/}l \\ &= \frac{170 \times 10^{-3}}{17} \text{ mol/}l = 10^{-2} \text{ mol/}l \\ pOH &= -\log [OH^-] = -\log (10^{-2}) = 2 \\ pH &= 14 - pOH = 14 - 2 = 12 \\ \therefore \quad -\log [H^+] &= 12 \\ [H^+] &= 10^{-12} \text{ mol/}l \\ &= 10^{-12} \text{ g/}l = 10^{-9} \text{ mg/}l \end{aligned}$$

43. (c)

Refer IS 10500 : 2012 Table 1 Organoleptic and Physical Parameters.

44. (b)

$\because$ 1 ml of 0.02 N H_2SO_4 will neutralize 1 mg alkalinity as $CaCO_3$.

So, for x ml of 0.02 N H_2SO_4, we can write

$$\Rightarrow \quad x \times \frac{1000}{250} = 100$$

$$\Rightarrow \quad x = \frac{250 \times 100}{1000} = 25 \text{ m}l$$

45. (a)

Volume of water to be disinfected = 10000 litres

Total chlorine required per lire = 2 + 0.2 = 2.2 mg

$$\text{For 10000 } l\text{, total chlorine} = \frac{2.2\times 10000}{1000}\text{ g} = 22\text{ g}$$

If x % is the percentage of available chlorine in bleaching powder, then

$$\frac{x}{100}\times 100 = 22$$

$$\Rightarrow \quad x = 22$$

So, percentage of available chlorine = 22%

46. (b)

$$\text{Weir loading rate} = \frac{Q}{\pi D} = 2\ l/\text{s/m} = 2\times 10^{-3}\ \text{m}^2/\text{s}$$

$$\text{Surface overflow rate} = \frac{Q}{\frac{\pi}{4}D^2} = \frac{Q}{\pi D\left(\frac{D}{4}\right)}$$

$$= \frac{2\times 10^{-3}}{\frac{16}{4}} = 0.5\times 10^{-3}\ \text{m/s} = 0.05\ \text{cm/s}$$

47. (b)

Daily water requirement = 11 MLD

$= 11 \times 10^6\ l/\text{day}$

Given 7% of daily filtered water is required for backwashing and backwashing time is 30 minutes.

Filtered water required each day $= 11 \times 10^6 \times 1.07$

$$\text{Filtered water required per hour} = \frac{11\times 10^6\times 1.07}{23.5}\ l/\text{hr}$$

Rate of filtration $= 5000\ l/\text{hr/m}^2$

$$\text{Area of filter required} = \frac{11\times 10^6\times 1.07}{23.5\times 5000} = \frac{11.77\times 10^6}{23.5\times 5000} = \frac{11.77\times 10^6}{117.5} \approx 100\ \text{m}^2$$

48. (a)

Additonal alkalinity required = 10 – 6 = 4 mg/l as $CaCO_3$

$$= \frac{4}{50}\text{ milli equivalents of } CaCO_3/\text{litre}$$

$$\text{Equivalent weight of CaO} = \frac{56}{2} = 28$$

$$\text{Amount of CaO required} = \frac{4}{50}\times 28 = 2.24\ \text{mg}/l$$

$$\text{For 100 MLD, CaO required} = \frac{2.24\times 100\times 10^6}{10^6} = 224\ \text{kg}$$

49. (d)

Tuberculosis gets spread through coughing or sneezing of an infected person. It is spread by Mycobacterium tuberculosis.

50. (b)

- **Air valve:** Provided at summit of pipe to remove the accumulated air which is carried by the flowing water with it.
- **Butterfly valve:** Used to regulate and stop the flow especially in large sized conduits. They are cheaper than sluice valves for larger sizes and occupy less space.
- **Relief valve:** They are also known as pressure relief valves or safety valves. There are adjusted to open out automatically as soon as the pressure in pipe exceeds a certain fixed predetermined value.
- **Ball valve:** These are used to maintain a constant level in a service reservoir or elevated tank. In this, a float is used which permits the valve to admit additional water on a falling level and less water on a rising level and to close entirely when the overflow level is reached.

52. (b)

$$\frac{r}{R} = \frac{\frac{\alpha}{360^\circ} - \frac{\sin\alpha}{2\pi}}{\frac{\alpha}{360^\circ}}$$

where, r = Hydraulic radius for prevailing flow condition and R = Hydraulic radius for pipe running flow.

As the sewer is running half full.

$$\alpha = 180^\circ = \pi \text{ radians}$$

and
$$R = \frac{D}{4} \quad \{D \text{ is diameter of sewer}\}$$

$$= \frac{4}{4} = 1 \text{ m}$$

$\therefore$
$$\frac{r}{R} = \frac{r}{1} = \frac{\frac{180^\circ}{360^\circ} - \frac{\sin 180}{2\pi}}{\frac{180^\circ}{360^\circ}} = \frac{1/2}{1/2}$$

$\Rightarrow$
$$r = 1 \text{ m}$$

53. (b)

$$\underset{78g}{C_6H_6} + \underset{240g}{7.5O_2} \longrightarrow \underset{264g}{6CO_2} + \underset{54g}{3H_2O}$$

Corresponding to 78 g benzene, oxygen required = 240 g

and amount of carbon in 78 g benzene = 12 × 6 = 72 g

$$\frac{TOC}{COD} = \frac{72}{240} = 0.3$$

55. (b)

$$\text{BOD of sewage} = (DO_i - DO_f) \times \text{Dilution factor}$$

$$= (7-2)\times\frac{600}{4} = 750 \text{ mg/L}$$

$$\text{Discharge of sewage} = 1000 \text{ m}^3/\text{day} = 10^6 \text{ L/day}$$

$$\text{Population equivalent of sewage} = \frac{\text{BOD of sewage per day}}{\text{Standard per capita BOD}}$$

$$= \frac{750\times10^6}{75} = 10\times10^6 = 10 \text{ million}$$

56. (c)

The correct order is given by

Oligotrophic < Mesotrophic < Eutrophic < Senescent

57. (b)

Maximum permissible BOD_5 values at 20°C are given as

Disposal on	BOD_5 (Maximum value)
River	20 mg/L
Sea	100 mg/L
Land	500 mg/L

58. (b)

$$V_1(100 - p_1) = V_2(100 - p_2)$$

{p_1 and p_2 are the moisture contents at corresponding volumes of sludge V_1 and V_2}

Here, $p_1 = 99\%, \quad p_2 = 97\%$

$\Rightarrow \quad V_1(100 - 99) = V_2(100 - 97)$

$\Rightarrow \quad V_1 = 3V_2 \Rightarrow V_2 = \frac{V_1}{3}$

$$\text{Percentage reduction in volume of sludge} = \frac{V_1 - V_2}{V_1}\times100 = \frac{V_1 - \frac{V_1}{3}}{V_1}\times100$$

$$= \frac{2V_1}{3V_1}\times100 = 66.67\%$$

59. (a)

$$R = 2 \text{ \{Recirculation ratio\}}$$

$$\text{Recirculation factor, } F = \frac{1+R}{(1+0.1R)^2} = \frac{1+2}{(1+0.1\times2)^2}$$

$$= \frac{3}{1.2\times1.2} = \frac{2.5}{1.2} = 2.0833 \approx 2.1$$

60. (b)

If SVI is too high, it indicates a sludge with poor settling characteristics and excellent flowability. If SVI is too low, it indicates a sludge with excellent settling characteristics and poor flowability.

61. (d)

Bio towers are an advancement over trickling filters containing plastic media with a high surface area such as randomly filled polypropylene shapes or modular blocks of corrugated PVC. Effluent is pumped on the top of the tower using rotary distributors. From where it trickles down over the media, which becomes coated with microbial films that consume the organic material.

62. (b)

Rate of accumulation of sludge is nearly equal to 30 litres/capita/year.

63. (b)

Plume type	Environment type
Looping plume	Super-adiabatic
Neutral plume	Neutral
Coning plume	Sub-adiabatic
Fanning plume	Inversion
Lofting plume	Super-adiabatic environment over inversion
Fumigating plume	Inversion over super-adiabatic environment.
Trapping plume	Super-adiabatic environment between two inversion layers

64. (d)

Refer Table 2 of IS : 4954 – 1968.

65. (d)

Refer annexure 2: National ambient air quality standard (National ambient air quality status and trends 2019).

66. (b)

Unit	Type of settling
Primary sedimentation tank (in raw water supply)	Type-I
Primary sedimentation tank (in wastewater supplies)	Type-II
Grit chamber	Type-I
Secondary sedimentation tank (followed by activated sludge process)	Type-III
Secondary sedimentation tank (followed by trickling filter)	Type-IV

67. (b)

Intercepting trap is provided at the junction of house drain with public sewer or septic tank. It has a deep water seal of 100 mm so as to effectively prevent the entry of sewer gases from public sewer line in to the house drain.

68. (d)

Indore process of composting is an aerobic process and in this method refused in placed in small brick lined pits of size 3 m × 3 m × 1 m in alternates layers 7.5 cm to 10 m in height, and the material is turned regularly for a period of about 8-12 weeks and then stored on ground for 4-6 weeks. The composts becomes ready to use in a period of about 3-4 months.

69. (b)

$$G = \sqrt{\frac{P}{\mu V}}$$

But, $\nu = \frac{\mu}{\rho}$

So, $\mu = \nu \times \rho$

$= 10^{-2} \times 10^{-4} \times 10^{3} = 10^{-3}\ \text{Ns/m}^2$

$\therefore \quad G = \sqrt{\frac{2500}{10^{-3} \times 10}} = 500\ \text{sec}^{-1}$

70. (a)

$$L_t = L_0\left(1 - 10^{-k_D t}\right)$$

$\Rightarrow \quad 450 = L_0\left(1 - 10^{-0.1 \times 10}\right)$

$\Rightarrow \quad 450 = L_0\left(1 - \frac{1}{10}\right)$

$\Rightarrow \quad L_0 = \frac{450}{0.9} = 500\ \text{mg/L}$

71. (b)

The pH of septic sewage lies in the range of 4.5 – 6.5 and it is acidic in nature.
The pH of fresh sewage lies in the range of 7.5 – 9.5 and it is basic in nature.

72. (d)

Iron salts cause staining and promote the growth iron bacteria in water which causes pitting and tuberculation. They are used more frequently in treating sewage as concrete pipes are used in sewer construction which are unaffected by iron bacteria.

73. (d)

Capillary zone is considered a part of zone of aeration, as it may or may not be completely saturated. Depending on soil, zone of saturation is the region below the ground level where voids are completely filled with water and pressure is hydrostatic everywhere.

74. (c)

Geometric increase method gives a higher value of population as compared to arithmetic increase method and therefore is generally recommended for young cities where population is increasing at a faster rate as compared to old cities.

75. (c)

The digestion of sludge is mostly carried out in Mesophilic range (20 – 40°C) because this temperature is easily available in most part of the India and also digestion in thermophilic range (> 45°C) will not only require an external heat source but will also generate a large amount of odorous gases owing to its shorter digestion period thus making it difficult to control the digestion process.

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