CHAPTER 8

Compressibility and Consolidation

Q.1 Which of the following statement is correct?
(a) Total settlement in sand is more than that in clay but in sand rate of settlement is slow.
(b) Total settlement and rate of settlement is more in sand than in clay.
(c) Total settlement in clay is more than that in sand but rate of settlement is slow in clay.
(d) Total settlement and rate of settlement is more in clay than that in sand.

Q.2 In consolidation, which of the following phenomenon occurs?
(a) Compression and explosion of pore air
(b) Expulsion of pore water
(c) Compression of water and solid molecules
(d) All of these

Q.3 The time required for primary consolidation depends on
1. Rate of application of load
2. Coefficient of permeability
3. Drainage facility available
4. Water content
(a) 1, 2, 3 and 4 (b) 1, 2 and 3
(c) 1, 2 and 4 (d) 2, 3 and 4

Q.4 Curve fitting method is used to determine
(a) Compression index
(b) Coefficient of consolidation
(c) Time factor
(d) Degree of consolidation

Q.5 Match the Column-I with Column-II

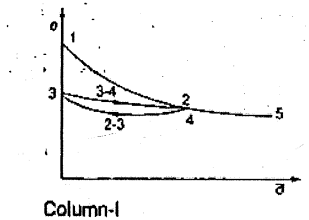
Column-I
A. Coefficient of compressibility
B. Coefficient of volume compressibility
C. Compression index
D. Time factor

Column-II
1. $\frac{c_v t}{H^2}$
2. $\frac{e_1 - e_2}{\log_{10}\left(\frac{P_2}{P_1}\right)}$
3. $\frac{a_v}{1+e_0}$
4. $\frac{e_1 - e_2}{P_2 - P_1}$

Codes:

	A	B	C	D
(a)	3	4	1	2
(b)	3	4	2	1
(c)	4	3	2	1
(d)	4	3	1	2

Q.6 The graph between void ratio and effective stress for cyclic recompression and compression is given below.
Using the graph, match the Column-I with Column-II



Column-I
A. Virgin compression curve
B. Swell curve
C. Recompression curve
D. 2nd stage compression curve

Column-II
1. 3-4
2. 4-5
3. 1-2
4. 2-3

Codes:

	A	B	C	D
(a)	3	1	4	2
(b)	3	4	1	2
(c)	4	3	2	1
(d)	4	2	3	1

Q.7 Which of the following are the assumptions of Terzaghi's theory of one-dimensional consolidation?
1. Soil is fully saturated and flow is turbulent.
2. Flow is one dimensional.
3. Hydrodynamic lag is considered while plastic lag is ignored.
4. Soil is homogeneous and isotropic.
(a) 1, 2, 3 and 4 (b) 1, 2 and 3
(c) 1, 2 and 4 (d) 2, 3 and 4

Q.8 Match the Column-I (cause) with Column-II (effect)

Column-I
A. Rise of water table
B. High compressibility
C. Montmorillonite
D. Sand drains

Column-II
1. Excessive settlement
2. High expansivety
3. Reduction of bearing capacity
4. Acceleration of consolidation

Codes:

	A	B	C	D
(a)	2	1	3	4
(b)	3	4	2	1
(c)	2	4	3	1
(d)	3	1	2	4

Q.9 Which of the following are the reasons for pore consolidation of a clay layer?
1. Desiccation of clay
2. Rising of water table
3. Removal of construction load
4. Withdrawn of a glacier
(a) 1, 2 and 3
(b) 1, 2, 3 and 4
(c) 1, 3 and 4
(d) 1, 2 and 4

Q.10 Assertion (A): Secondary consolidation takes place at a much slower rate than that of primary consolidation.
Reason (R): There is dissipation of excess pore water pressure during secondary consolidation.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

Q.11 Assertion (A): If drainage path is reduced to half, then ultimate settlement also gets reduced to half.
Reason (R): Ultimate settlement remains unchanged as it does not depend on drainage path.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

Q.12 Value of time factor for 90% consolidation is _____

Q.13 Which of the following statements about sand drains are correct?
1. Sand drain accelerates both primary and secondary consolidation.
2. It acts as a weak pile.
3. It densifies the sand.
(a) 1, 2 and 3
(b) 1 and 3
(c) 2 and 3
(d) 1 and 2

Q.14 Value of permissible total settlement for isolated foundation on clay is _____ mm.

Q.15 Which of the following is correct about contact pressure at the base of foundation?
(a) In rigid foundation, sand offers maximum pressure at centre
(b) In rigid foundation, clay offers maximum pressure at edge
(c) In rigid foundation, silt offers maximum pressure between centre and edge
(d) All of the above

Q.16 If initial excess pore pressure is u_i and at a particular instant is u, the consolidation (percent) v is

(a) $U=\left(1-\frac{u}{u_i}\right)$ (b) $U=\left(1-\frac{u}{u_i}\right)\times 100$

(c) $U=\frac{u}{u_i}\times 100$ (d) $U=\left(1+\frac{u}{u_i}\right)\times 100$

Linked Answers Q.17-Q.18

A saturated soil stratum 4 m lies above an impervious stratum and below pervious stratum. It has a compression index of 0.28 and coefficient of permeability of 3×10^{-4} cm/s. Its void ratio at a stress of 180 kN/m² is 2.2.

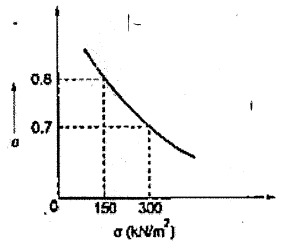
Q.17 Determine the change in void ratio due to increase in stress to 250 kN/m²
(a) 0.04 (b) 0.1
(c) 0.03 (d) 0.08

Q.18 Determine the time required for 60% consolidation
(a) 26.09 min. (b) 45.49 min.
(c) 52.18 min. (d) 10.87 min.

Q.19 A sand stratum and a clay stratum have the same thickness at 2 m. The coefficient of compressibility of sand is 1/3rd of the coefficient of compressibility of clay and permeability of sand is 5000 times that of clay. Assuming the same void ratio, the ratio of consolidation time for the clay to that of sand is
(a) 10,000 (b) 15,000
(c) 5,000 (d) 30,000

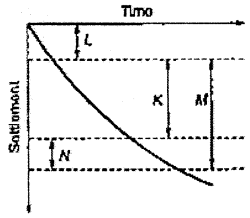
Q.20 A compressible layer having total settlement of 15 cm under a given load. It settles by 3 cm at the end of two months after the application of load. How many months will be required to reach a settlement of 7.5 cm.
(a) 60 days (b) 375 days
(c) 540 days (d) 150 days

Q.21 The void ratio (e) v/s pressure (σ) curve for a soil is shown in the figure. The coefficient of compressibility (in m²/kN) of the soil is



(a) 3.33×10^{-4} (b) 4.00×10^{-4}
(c) 5.00×10^{-4} (d) 6.67×10^{-4}

Q.22 Match List-I (Type of settlement) with List-II (Notation on diagram) and select the correct answer using the codes given below the lists:



List-I	List-II
A. Immediate settlement	1. K
B. Primary consolidation	2. L
C. Secondary consolidation	3. M
D. Time-dependent settlement	4. N

Codes:

	A	B	C	D
(a)	1	2	4	3
(b)	2	1	4	3
(c)	2	1	3	4
(d)	1	2	3	4

Q.23 1 m thick compressible clay layer has initial void ratio of 0.6. If change in void ratio of 0.2 has been observed when construction gets completed, then the total settlement is (in mm)
(a) 100 (b) 90
(c) 125 (d) 150

Q.24 A clay layer, 8 m thick, is subjected to a pressure of 70 kN/m². If the layer has a double drainage and undergoes 50% consolidation ($T_v = 0.196$) in one year, the coefficient of consolidation is (in m²/year)
(a) 2.16 (b) 3.136
(c) 4.182 (d) 0.196

Q.25 Average pore water pressure in a fully saturated clay specimen, which was subjected to a pressure of 20 N/cm² initially, was measured to be 7 N/cm² after a period of time. Degree of consolidation reached at that time is
(a) 35% (b) 70%
(c) 45% (d) 65%

Q.26 Skempton's formula for determination of compression index C_C for remoulded soil is
(a) $C_C = 0.003\,(w_L - 10)$
(b) $C_C = 0.005\,(w_L - 10)$
(c) $C_C = 0.007\,(w_L - 10)$
(d) $C_C = 0.009\,(w_L - 10)$
(w_L = liquid limit)

Q.27 The present overburden pressure on an over consolidated clay deposit is 30 kN/m². It is known that the deposit was earlier subjected to an overburden pressure of 90 kN/m². The over consolidation ratio of clay deposit is
(a) 3 (b) 0.33
(c) 3.5 (d) 0.28

Q.28 For normally consolidated clays, compression index can be determined from the empirical formula C_c =
(a) $0.0009\,(LL - 10)$
(b) $0.009\,(LL - 10)$
(c) $0.009\,(LL - 20)$
(d) $0.009\,(LL - 15)$

Q.29 Compression modulus (E_c) is related to the modulus of volume change (m_v), as

(a) $E_c = \frac{1}{m_v}$ (b) $E_c = \frac{1}{\sqrt{m_v}}$

(c) $E_c = ln\, m_v$ (d) $E_c = \log_{10} m_v$

Q.30 During the consolidation process of a saturated clay
(a) a gradual decrease in neutral pressure and a gradual increase in effective pressure occurs, and the sum total of the two remains constant
(b) a gradual increase in neutral pressure and a gradual decrease in effective pressure occurs, and the sum total of the two remains constant
(c) both the neutral pressure as well as the effective pressure decrease
(d) both the neutral pressure as well as the effective pressure increase

Q.31 So long as the degree of consolidation (U) does not exceed 60%, its value after a time t, is determined by the equation

(a) $U = \frac{2}{d}\sqrt{\frac{C_v}{\pi t}}$ (b) $U = \frac{2}{d}\sqrt{\frac{C_v t}{\pi}}$

(c) $U = 2d\sqrt{\frac{C_v}{\pi t}}$ (d) $U = 2d\sqrt{\frac{C_v t}{\pi}}$

Q.32 Which of the following statement/s is correct?
(a) Isotropic consolidation of clay can be obtained in the triaxial apparatus under equal all-round pressure.
(b) If the present effective stress is the maximum to which the clay has ever been subjected, it is called normally consolidated clay.
(c) If the effective stress in the past was more than present effective stress, it is called over-consolidated clay
(d) All of the above

Q.33 Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I

A. Elastic settlement
B. Primary consolidation
C. Secondary consolidation
D. Creep

List-II

1. Constant effective stress with change in volume of soil
2. Dissipation of excess pore water pressure
3. Occurs within a short period
4. Compression and rearrangement of particles

Codes:

	A	B	C	D
(a)	3	2	1	4
(b)	4	3	1	2
(c)	3	2	4	1
(d)	4	3	2	1

Q.34 Study the following statements:

1. Coefficient of compressibility of an over-consolidated clay is less than that of a normally consolidated clay
2. Coefficient of compressibility is different for different types of soils and also for a soil under different states of consolidation
3. The ultimate consolidation settlement of a structure resting on a soil decreases with the increase in the initial void ratio

Which of these statements is/are correct?

(a) Only 2 (b) Only 3
(c) Both 1 and 2 (d) 1, 2 and 3

Q.35 The total settlement of a compressible soil stratum 2 m deep and having a coefficient of volume compressibility of 0.02 cm^2/kg under a pressure increment of 2 kg/cm^2 will be

(a) 2 cm (b) 4 cm
(c) 8 cm (d) 10 cm

Q.36 A fully saturated clay specimen is placed in a consolidometer and subjected to a loading of 200 kN/m^2. After some time it was found that the average pore pressure in the specimen was 70 kN/m^2. The percentage of consolidation reached by then was

(a) 70 (b) 65
(c) 35 (d) 29

Q.37 Assertion (A): Consolidation time increases with increasing compressibility or decreasing permeability.

Reason (R): Higher compressibility shows presence of more water voids and lower permeability shows more water voids but are connected properly.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

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Answers Compressibility and Consolidation

1. (c)	2. (b)	3. (b)	4. (c)	5. (c)	6. (b)	7. (d)	8. (d)	9. (b)	10. (c)
11. (d)	12. (0.848)		13. (c)	14. (65)	15. (d)	16. (b)	17. (a)	18. (b)	19. (b)
20. (b)	21. (d)	22. (b)	23. (c)	24. (b)	25. (d)	26. (c)	27. (a)	28. (b)	29. (a)
30. (a)	31. (b)	32. (d)	33. (c)	34. (d)	35. (c)	36. (b)	37. (c)		

Explanations Compressibility and Consolidation

3. (b)

Time required will depend on:

(i) Rate of application of load
(ii) Coefficient of permeability
(iii) Drainage facility available
(iv) Length of drainage path

$$t \propto \frac{1}{C_v}\frac{a_v}{k}$$

$$C_v = \frac{k}{\gamma_w m_v} = \frac{k}{\gamma_w \frac{a_v}{1+e_0}}$$

$$C_v \propto \frac{k}{a_v} \qquad \text{i.e., } t \propto \frac{a_v}{k}$$

$$\frac{t_1}{t_2} = \frac{a_{v_1}}{a_{v_2}} \times \frac{k_2}{k_1} = \frac{1}{3} \times \frac{1}{5000}$$

$$\frac{t_2}{t_1} = 15000$$

12. (0.848)

$$T_v = \frac{\pi}{4} \times V^2 \qquad (\text{If } U \le 60\%)$$

$$T_v = 1.781 - 0.9332 \log (100 - U) \qquad (\text{If } U > 60\%)$$

$$T_v = 1.781 - 0.9332 \log (100 - 90) = 0.848$$

13. (c)

Sand drains accelerate only primary consolidation.

17. (a)

$$C_c = \frac{\Delta e}{\log\left(\frac{\sigma_2}{\sigma_1}\right)}$$

$$0.28 = \frac{\Delta e}{\log\left(\frac{250}{180}\right)}$$

$$\Rightarrow \quad \Delta e = 0.04$$

18. (b)

$$m_v = \frac{a_v}{1+e_0} = \frac{\Delta e}{\Delta\sigma(1+e_0)} = 1.83 \times 10^{-4}\ m^2/kN$$

$$C_v = \frac{k}{\gamma_w \times m_v} = 1.67 \times 10^{-3}\ m^2/s$$

$$T_v = \frac{C_v t}{h^2} = \frac{\pi}{4} \times 60^2 = 0.283$$

$$0.283 = \frac{1.67 \times 10^{-3} \times t}{4^2}$$

$$\Rightarrow \quad t = 45.19\ \text{min}$$

19. (b)

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

20. (b)

$$U_1 = \frac{\Delta H}{H} \times 100 = \frac{3}{15} \times 100 = 20\%$$

$$U_2 = \frac{7.5}{15} \times 10 = 50\%$$

$$T_v = \frac{\pi}{4} \times U^2 \Rightarrow T_v \propto U^2$$

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

$$T_v \propto t$$

$$\therefore \quad t \propto U^2$$

$$\frac{t_1}{t_2} = \frac{U_1^2}{U_2^2}$$

$$\frac{60}{t_2} = \frac{0.2^2}{0.5^2}$$

$$\Rightarrow \quad t_2 = 375\ \text{days}$$

21. (d)

Coefficient of compressibility,

$$a_v = -\frac{\Delta e}{\Delta\sigma}$$

$$\therefore \quad a_v = -\left(\frac{0.7 - 0.8}{300 - 150}\right)$$

$$\Rightarrow \quad a_v = \frac{0.1}{150} = 6.67 \times 10^{-4}\ m^2/kN$$

23. (c)

$H = 1\,m$

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

$\Rightarrow \quad \Delta H = \frac{0.2}{1+0.6} \times 1$

$= 0.125\,m = 125\,mm$

24. (b)

$d = \frac{H}{2} = \frac{8}{2} = 4m$

(For double drainage)

$T_v = \frac{\pi}{4}U^2 = \frac{\pi}{4}(0.5)^2$

$= 0.196$ for 50% consolidation

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

$0.196 = \frac{C_v \cdot 1}{(4)^2}$

$\Rightarrow \quad C_v = 3.136\,m^2/year$

25. (d)

After time t, pore water pressure = 7 N/cm^2

$\therefore$ Load transferred to the soil = 20 – 7 = 13 N/cm^2

Consolidation will be complete, when load transferred to the soil = 20 N/cm^2

(As we know, settlement is directly proportional to stress applied)

$\therefore$ Degree of consolidation reached at time

$= \frac{h}{H} = \frac{13}{20} = 0.65$ or 65%.

27. (a)

Over consolidation ratio, OCR

$= \frac{\text{Past overburden pressure}}{\text{Present overburden pressure}} = \frac{90}{30} = 3$

31. (b)

$T_v = \frac{\pi}{4}U^2$ for $U \le 60\%$

$T_v = \frac{C_v t}{d^2} = \frac{\pi}{4}U^2$

$\Rightarrow \quad U = \frac{2}{d}\sqrt{\frac{C_v t}{\pi}}$

33. (c)

Elastic or immediate settlement occurs as soon as the load is placed on the soil the settlement is small but relatively quick. Primary consolidation occurs due to dissipation of excess pore water pressure. The secondary consolidation is due to the rearrangement of soil particles and occurs at constant effective stress.

35. (c)

$S_c = H_0 m_v \Delta\bar{\sigma}$

$= 2 \times 0.02 \times 2\,m$

$= 8\,cm$

36. (b)

Percentage consolidation

$= \frac{\text{Load applied} - \text{Pore pressure}}{\text{Load applied}} \times 100$

$= \frac{200-70}{200} \times 100 = 65\%$

37. (c)

Low permeability means water voids but are not connected in a proper fashion.

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