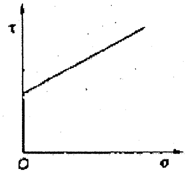
9 CHAPTER

Shear Strength

Q.1 Correct Mohr's failure envelope for saturated clay in consolidated drained test is

(a)



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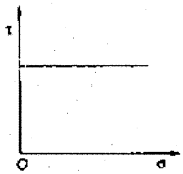

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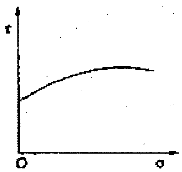

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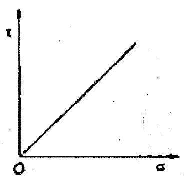


Q.2 Which one of the following statement provides the best argument that direct shear tests are not suited for determining shear strength parameters of a clay soil?

(a) Failure plane is not the weakest plane
(b) Pore pressures developed cannot be measured
(c) Satisfactory strain levels cannot be maintained
(d) Adequate consolidation cannot be ensured

Q.3 Consider the following statements related to triaxial test:

1. Failure occurs along predetemined plane
2. Intermediate and minor principal stresses are equal
3. Volume change can be measured
4. Field conditions can be simulated

Which of these statements are correct?

(a) 1, 2 and 3 (b) 1, 2 and 4
(c) 1, 3 and 4 (d) 2, 3 and 4

Q.4 Consider the following limitations:

1. Can be performed only on purely cohesionless soils.
2. Plane of failure is predetermined.
3. There is virtually no control on drainage.
4. Non-uniform distribution of stresses.
5. Principal stresses in the sample cannot be determined.

The limitations inherent in direct shear test include

(a) 1, 2 and 3 (b) 2, 3 and 4
(c) 3, 4 and 5 (d) 1, 2 and 5

Q.5 Consider the following statements:

The vane shear test is:

1. A direct test to determine shear strength parameter of saturated clays.
2. Mostly useful in cohesionless soils.
3. Use for determining undrained shear strength of normally consolidated sensitive clays.
4. To give on authentic value of 'f'

Which of these statement are correct?

(a) 1 and 4 (b) 2 and 4
(c) 1 and 3 (d) 2 and 3

Q.6 Which of the following is the appropriate field test for estimating the angle of shearing resistance ϕ of a sand deposit?

(a) Field vane shear test
(b) Plate load test
(c) Standard penetration test
(d) Electrical resistivity test

Q.7 Consider the following statements:

1. The parameter c, ϕ obtained using Coulomb's theory are empirical.
2. Mohr's envelope is a straight line.
3. The characteristic of soil are not used in the construction of Mohr's circle.
4. The strength of a soil is a function of effective stress.

Which of these statements are correct?

(a) 1, 2 and 3 (b) 1, 3 and 4
(c) 1, 2 and 4 (d) 2, 3 and 4

Q.8 Which one of the following shear test on a saturated clay soil gives a unique effective stress Mohr's circle?

(a) Drained triaxial test
(b) Unconsolidated undrained triaxial test
(c) Consolidation undrained triaxial test
(d) Consolidated drained triaxial test

Q.9 In an undrained shear test on a saturated soil sample, increase in pore water pressure, ΔU, due to increments in principal stresses, $\Delta\sigma_1$ and $\Delta\sigma_3$ is given by

(a) $B[\Delta\sigma_3 + A(\Delta\sigma_1 - \Delta\sigma_3)]$
(b) $A[\Delta\sigma_3 + B(\Delta\sigma_1 - \Delta\sigma_3)]$
(c) $B[\Delta\sigma_1 + A(\Delta\sigma_1 - \Delta\sigma_3)]$
(d) $A[\Delta\sigma_1 + B(\Delta\sigma_1 - \Delta\sigma_3)]$

Q.10 In a triaxial test, if a test is performed without allowing drainage during the initial application of cell pressure, but the same is allowed during the second stage of application of deviator load, the test may be termed as

(a) unconsolidated undrained test
(b) consolidated undrained test
(c) unconsolidated drained test
(d) consolidated drained test

Q.11 A vane shear test on a soil sample gives moment of total resistance as M. The shear stress at failure, 'S' being more or less uniform at top, bottom and surface of cylinder of soil, is given by (H = height of vane, D = Diameter of vane)

(a) $S = \dfrac{2M}{\pi D^2 H}$ (b) $S = \dfrac{M}{\pi D^2\left(\dfrac{H}{2}+D\right)}$

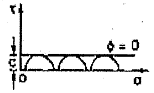
(c) $S = \dfrac{2M}{\pi D^2\left(H+\dfrac{D}{6}\right)}$ (d) $S = \dfrac{2M}{\pi DH}$

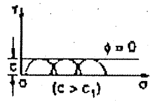
Q.12 Match List-I (Type of shear tests) with List-II (Mohr circle and its envelope) and select the correct answer using the codes given below the lists:

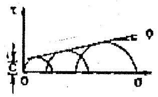
List-I

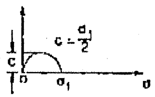
A. Undrained test on normally consolidated clays
B. Consolidated undrained test on normally consolidated clays
C. Drained tests on saturated cohesive soil (OCC)
D. Unconfined test on clays

List-II

1. 

2. 

3. 

4. 

Codes:

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

Q.13 Match List-I (Field problem) with List-II (Type of laboratory shear test) and select the correct answer using the codes given below the lists:

List-I

A. Stability of a clay foundation of an embankment, whose rate of construction is such that some consolidation occurs
B. Initial stability of a footing on saturated clay
C. Long-term stability of a slope in stiff, fissured clay
D. Foundation on soft marine clay deposits

List-II

1. Undrained triaxial test
2. Drained triaxial test
3. Consolidated undrained test
4. Quick vane shear test

Codes:

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

Q.14 Which of the following laboratory triaxial test parameters should one specify to be carried out in connection with the initial stability of footing on saturated clay?

1. C_{cu}, ϕ_{cu} – Consolidated undrained
2. C_u, ϕ'_u – Unconsolidated undrained
3. C_d, ϕ'_d – Drained

Select the correct answer using the codes given below:

(a) 1 alone (b) 2 alone
(c) 1 and 3 (d) 1, 2 and 3

Q.15 Consider the following statements associated with local shear failure of soils:

1. Failure is sudden with well-defined ultimate load.
2. This failure occurs in highly compressible soils.
3. Failure is preceded by large settlement.

Which of these statements are correct?

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

Q.16 Local shear failure in a c-ϕ soil occurs when

1. strain is between 10-20%
2. penetration index (N) is less than or equal to 5
3. angle of internal friction is more than 36°

Which of these statement/s is/are correct?

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

Q.17 The initial length and volume of the test specimen for the triaxial compression test are L and V, then the area, 'A' of the specimen at failure or during any stage of the test is

(a) $\dfrac{V+\Delta V}{L-\Delta L}$ (b) $\dfrac{V\pm\Delta V}{L+\Delta L}$

(c) $\dfrac{V-\Delta V}{L+\Delta L}$ (d) $\dfrac{V\pm\Delta V}{L-\Delta L}$

Q.18 Which of the following pairs are correctly matched?

1. Standard penetration test : Relative density
2. Vane-shear : Cohesion
3. Consolidation test : Bearing capacity

Codes

(a) 1, 2 and 3 (b) 1 alone
(c) 1 and 2 (d) 2 and 3

Q.19 Which one of the following plane is most likely to be the failure plane in sandy soils?

(a) Plane carrying maximum shear stress
(b) Plane carrying maximum normal stress
(c) Plane with maximum angle of obliquity
(d) Principal plane

Q.20 For checking the stability of the upstream slope of an earthen dam during rapid drawdown, the shear parameters are used from

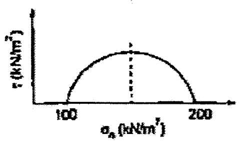
(a) unconsolidated undrained test
(b) consolidated undrained test with pore pressure measurement
(c) consolidated drained test
(d) unconsolidated undrained test with pore pressure measurement

Q.21 **Assertion (A):** With box-shear apparatus, quick and consolidated quick tests can be made only on clay samples.
Reason (R): The soils other than clays are so permeable that drainage takes place even under a very rapid application of load on the sample.
(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.22 **Assertion (A):** Mohr's circle passes through the origin in unconfined compression test.
Reason (R): The minor principal stress is zero.
(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

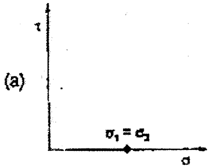
Q.23 In a triaxial shear test, a sample of c-ϕ soil failed along a failure plane making angle of 45° with the horizontal. The value of cohesion for the soil will be represented by
(a) $c = \frac{\sigma_1 + \sigma_3}{2}$ (b) $c = \frac{\sigma_1 - \sigma_3}{2}$
(c) $c = \sigma_1 + \sigma_3$ (d) None of these
where, σ_1 and σ_3 are major principle stress and confining stress respectively.

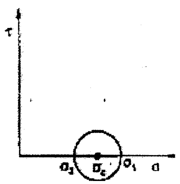
Q.24 The results of a consolidated drained triaxial shear test on a normally consolidated clay are shown in figure below:

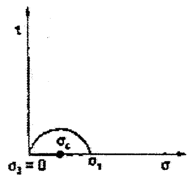


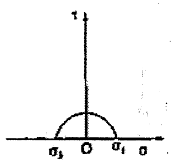
The angle of internal friction is
(a) $\sin^{-1}\left(\frac{1}{3}\right)$ (b) $\sin^{-1}\left(\frac{1}{2}\right)$
(c) $\sin^{-1}\left(\frac{2}{3}\right)$ (d) $\sin^{-1}\left(\frac{3}{2}\right)$

Q.25 When a soil sample is subjected to a uniformly distributed fluid pressure only, in a triaxial compression test, the Mohr's representation at the state of stress on sample is

(a)


(b)


(c)


(d)


Q.26 Using Mohr's diagram, the relation between major principal stress σ_1 and minor principal stress σ_3 and shear parameters c and ϕ is given by $\sigma_1 = \sigma_3 N_\phi + 2c\sqrt{N_\phi}$, where N_ϕ is
(a) $\frac{\sin\phi}{1+\sin\phi}$ (b) $\frac{\sin\phi}{1-\sin\phi}$
(c) $\frac{1-\sin\phi}{1+\sin\phi}$ (d) $\frac{1+\sin\phi}{1-\sin\phi}$

Q.27 A consolidated undrained triaxial compression test was performed on a saturated sand at a cell pressure of 80 kPa. The ultimate deviator stress was 270 kPa and the pore pressure at peak stress was −50 kPa. The effective angle of internal friction of soil will be
(a) 30.63° (b) 45°
(c) 63.43° (d) 0°

Q.28 A cylindrical sample of soil, having cohesion of 0.8 kg/cm² and angle of internal friction of 20°, is subjected to a cell pressure of 1.0 kg/cm². What is the maximum deviator stress at which the sample will fail?
(a) 4.32 kg/cm² (b) 3.32 kg/cm²
(c) 1 kg/cm² (d) 2.32 kg/cm²

Q.29 In a 6 m thick stratum of fine sand having submerged density of 11 kN/m³, quick sand condition occurred at a depth of 4.2 m of excavation. What is the depth of lowering of ground water table (in m) required for making an excavation 5 m deep?
[Take density of water as 10 kN/m³]
(a) 1.68 (b) 2.15
(c) 2.52 (d) 0.89

Q.30 A shear vane of 7.5 cm diameter and 11.0 cm length was used to measure the shear strength of soft clay. A torque of 600 kg-cm was required to shear the soil. The vane was then rotated rapidly to cause remoulding of the soil. If the torque required in the remoulded state was 200 kg-cm then sensitivity of the soil is
(a) 1 (b) 2
(c) 3 (d) 4

Q.31 In a triaxial test, a soil sample was consolidated under a cell pressure of 750 kN/m² and a back pressure of 400 kN/m². Thereafter with drainage not allowed, the cell pressure was raised to 900 kN/m², resulting in an increase in pore water pressure of 450 kN/m². The axial load was then increased to give a deviator stress of 600 kN/m² (while the cell pressure remained at 900 kN/m²) and pore water reading of 650 kN/m². The shear strength parameters A and B respectively, are
(a) 1 and 0.333 (b) 0.5 and 0.333
(c) 1 and 0.666 (d) 0.5 and 0.666

Q.32 During the Ist stage of triaxial test, when the cell pressure is increased from 0.10 N/mm² to 0.26 N/mm², the pore water pressure increases from 0.07 N/mm² to 0.15 N/mm². What is the value of the skempton's pore pressure parameter B?
(a) 0.5 (b) −0.5
(c) 2.0 (d) −2.0

Q.33 In a triaxial compression test, the major principal stress was 120 kPa and minor principal stress was 60 kPa at failure. The pore pressure at failure was observed to be 40 kPa. The tangent of the angle of shearing resistance of sandy soil that was tested was
(a) 1/2 (b) 3/4
(c) 1/3 (d) 2/3

Q.34 A vane 20 cm long and 10 cm in diameter was pressed into a soft marine clay at the bottom of a bore hole. Torque was applied gradually and failure occurred at 1000 kg cm. The cohesion of the clay in kg/cm² is:
(a) $\frac{1}{\pi} \times \frac{6}{7}$ (b) $\frac{1}{\pi} \times \frac{5}{7}$
(c) $\frac{1}{\pi} \times \frac{4}{7}$ (d) $\frac{1}{\pi} \times \frac{3}{7}$

Q.35 A braced cut, 5 m wide and 7.5 m deep is proposed in a cohesionless soil deposit having effective cohesion $c' = 0$ and effective friction angle, $\phi' = 36°$. The first row of struts is to be installed at a depth of 0.5 m below ground surface and spacing between the struts should be 1.5 m. If the horizontal spacing of struts is 3 m and unit weight of the deposit is 20 kN/m³, the maximum strut load will be

(a) 70.87 kN (b) 98.72 kN
(c) 113.90 kN (d) 151.86 kN

Q.36 If the effective stress strength parameters of a soil are $c' = 10$ kPa and $\phi' = 30°$, the shear strength on a plane within the saturated soil mass at a point where the total normal stress is 300 kPa and pore water pressure is 150 kPa will be:
(a) 90.5 kPa (b) 96.6 kPa
(c) 101.5 kPa (d) 105.5 kPa

Q.37 A clayey sample tested in an unconfined compression test fails at a normal stress of 100 kN/m² and the failure plane makes an angle of 45° with the horizontal. If the same sample is tested in triaxial test using lateral pressure of 30 kN/m², then deviator stress, shear stress on principal plane and cohesion, respectively, will be
(a) 70 kN/m², 70 kN/m², 100 kN/m²
(b) 70 kN/m², zero, 50 kN/m²
(c) 100 kN/m², 70 kN/m², zero
(d) 100 kN/m², zero, 50 kN/m²

Q.38 In triaxial test, the area of cross-section of soil at failure, if A_0 is the original area, ε_V is unit volume change and ε_L is axial strain, is

(a) $A_f = \dfrac{A_0}{1-\epsilon_L}$ (b) $A_f = \dfrac{A_0(1\pm\epsilon_V)}{1+\epsilon_L}$

(c) $A_f = \dfrac{A_0}{1+\epsilon_L}$ (d) $A_f = \dfrac{A_0(1\pm\epsilon_V)}{1-\epsilon_L}$

Q.39 For a saturated soil mass, Skempton's B parameter is
(a) nearly zero (b) nearly 0.5
(c) nearly 1 (d) very high

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Answers Shear Strength

1. (d)	2. (b)	3. (d)	4. (b)	5. (c)	6. (c)	7. (d)	8. (b)	9. (a)	10. (c)
11. (b)	12. (b)	13. (c)	14. (b)	15. (c)	16. (b)	17. (d)	18. (d)	19. (c)	20. (b)
21. (a)	22. (a)	23. (b)	24. (a)	25. (a)	26. (d)	27. (a)	28. (b)	29. (a)	30. (c)
31. (a)	32. (a)	33. (b)	34. (a)	35. (c)	36. (b)	37. (d)	38. (a)	39. (c)	

Explanations Shear Strength

1. (d)
In consolidated drained test, clay behaves like sand.

9. (a)
The total pore pressure change is given by,

$\Delta U = B\Delta\sigma_3 + \bar{A}\,\Delta\sigma_d$

$\Rightarrow \Delta U = B\Delta\sigma_3 + AB(\Delta\sigma_1 - \Delta\sigma_3)$

$\Rightarrow \Delta U = B(\Delta\sigma_3 + A(\Delta\sigma_1 - \Delta\sigma_3)$

11. (b)
Critical void ratio decreases with increase in confining pressure.
If any sand has

$e > e_{cr} \Rightarrow$ loose sand

$e < e_{cr} \Rightarrow$ dense sand

15 (c)
In local shear failure the plastic equilibrium develops only in part of the soil below the footing the failure surface doesn't reach the ground and only slight heaving occurs there would be no tilting of the footing. Arbitrary failure point is taken on the basis of settlement. This type of failure mostly occurs in loose or soft soils of high compressibility & excessive settlement

18. (d)
SPT test gives relative density of sands and gravels.

22. (a)
In unconfined compression test, minor principal stress, $\sigma_3 = 0$.

23. (b)

$$\sigma_1 = \sigma_3 \tan^2\alpha + 2c\tan\alpha$$

here, $\alpha = 45°$

$\therefore \quad \sigma_1 = \sigma_3 + 2c$

$\Rightarrow \quad c = \dfrac{\sigma_1 - \sigma_3}{2}$

24. (a)

$$\frac{\sigma_1}{\sigma_2} = \frac{1+\sin\phi}{1-\sin\phi}$$

$$\frac{200}{100} = \frac{1+\sin\phi}{1-\sin\phi}$$

$$2 - 2\sin\phi = 1 + \sin\phi$$

$\Rightarrow \quad \phi = \sin^{-1}\left(\dfrac{1}{3}\right)$

26. (d)

$$\sigma_1 = \sigma_3 N\phi + 2c\sqrt{N\phi}$$

This is expression for passive pressure.

$\therefore \quad k_p = \dfrac{1+\sin\phi}{1-\sin\phi}$

27. (a)
For saturated sand,

$C = 0, C' = 0$

$\sigma_3 = 80$ kN/m²

$\sigma_d = 270$ kN/m²

$u = -50$ kN/m²

$\sigma_1 = \sigma_3 + \sigma_d$

$= 80 + 270 = 350$ kN/m²

$\sigma_1' = \sigma_1 - u$

$= 350 - (-50) = 400$ kN/m²

$\sigma_3' = \sigma_3 - u = 80 - (-50) = 130$ kN/m²

$$\sin\phi' = \frac{\sigma_1' - \sigma_3'}{\sigma_1' + \sigma_3'}$$

When, ϕ' = effective angle internal friction of soil

$\therefore \quad \sin\phi' = \dfrac{400-130}{400+130} = \dfrac{270}{530}$

$\phi' = 30.63°$

28. (b)

$\sigma_3 = 1$ kg/cm²

$\alpha = 45° + \dfrac{\phi}{2} = 45° + \dfrac{20°}{2} = 55°$

$\sigma_1 = \sigma_3\tan^2\alpha + 2c\tan\alpha$

$= 1\cdot\tan^2 55° + 2\times 0.8 + \tan 55°$

$= 4.32$ kg/cm²

Deviator stress

$= \sigma_1 - \sigma_3 = (4.32 - 1)$ kg/cm²

$= 3.32$ kg/cm²

29. (a)
Given quick sand condition occurred at a depth of 4.2 m
Saturation density

$= 11 + 10 = 21$ kN/m³

So hydraulic head at 4.2 m depth is

$= \dfrac{4.2\times 21}{10} = 8.82$m

For excavation upto 5 m avoiding Quick Sand Condition
The hydraulic head

$= \dfrac{5\times 21}{10} = 10.5$ m

So, lowering of water table

$= 10.5 - 8.82 = 1.68$ m

30. (c)
Shear strength ∝ Torque

As $\quad \tau = \dfrac{T}{\pi d^2\left(\dfrac{H}{2}+\dfrac{d}{6}\right)}$

Sensitivity

$= \dfrac{\text{Shear strength in undisturbed condition}}{\text{Shear strength in disturbed condition}}$

$= \dfrac{\text{Torque in undisturbed condition}}{\text{Torque in disturbed condition}} = \dfrac{600}{200} = 3$

31. (a)

Back pressure is applied to saturate the soil. To ensure that application of back pressure does not result in an increase in effective stress in the sample, the cell pressure is also increased to the same level. Thus maintaining constant effective stress.

During application of pressure, pore water pressure is equal to bulk pressure.

$$B = \frac{\Delta u_1}{\Delta \sigma_1} = \frac{450-400}{900-750} = 0.333$$

$$\bar{A} = AB = \frac{\Delta u_2}{\Delta \sigma_2}$$

$$= \frac{650-450}{(900+600)-900} = 0.333$$

$$\therefore \quad A = \frac{AB}{B} = \frac{0.333}{0.333} = 1$$

32. (a)

$$B = \frac{\Delta U}{\Delta \sigma_3} = \frac{0.15-0.07}{0.26-0.1} = 0.5$$

33. (b)

$$\bar{\sigma}_1 = 120 - 40 = 80 \text{ kPa}$$

$$\bar{\sigma}_3 = 60 - 40 = 20 \text{ kPa}$$

$$\frac{\sigma_1}{\sigma_2} = \frac{1-\sin\phi}{1+\sin\phi}$$

$$\frac{90}{20} = \frac{1-\sin\phi}{1+\sin\phi}$$

$$\Rightarrow \quad \sin\phi = \frac{3}{5}$$

$$\therefore \quad \tan\phi = \frac{3}{4}$$

34. (a)

$$C_u = \frac{T}{\pi D^2\left[\frac{H}{2}+\frac{D}{6}\right]}$$

$$= \frac{1000}{\pi \times 10^2\left[\frac{20}{2}+\frac{10}{6}\right]}$$

$$= \frac{1}{\pi} \times \frac{1000}{100 \times 70} \times 6$$

$$= \frac{1}{\pi} \times \frac{6}{7} \text{ kg/cm}^2$$

36. (b)

$$\tau = c' + \sigma_n' \tan\phi'$$

$$\sigma_n' = \sigma_n - u$$

$$= 300 - 150 = 150 \text{ kPa}$$

$$\therefore \quad \tau = 10 + 150 \tan 30^\circ$$

$$= 96.6 \text{ kPa}$$

37. (d)

$$q_u = 2c \tan\left(45+\frac{\phi}{2}\right)$$

$$\theta_c = 45+\frac{\phi}{2} = 45^\circ$$

$$\therefore \quad c = \frac{q_u}{2} = 50 \text{ kN/m}^2$$

Now,

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

$$\Rightarrow \quad \sigma_1 = 30 + 100$$

$$= 130 \text{ kN/m}^2$$

$$\therefore \quad \sigma_d = \sigma_1 - \sigma_3$$

$$= 130 - 30 = 100 \text{ kN/m}^2$$

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