SOIL MECHANICS - II
(CIVL 2202)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) The stress responsible for the mobilization of shearing strength of a soil is
(a) Effective normal stress (b) Neutral stress
(c) Total normal stress (d) Shear stress

(ii) The flow value N_ϕ is given by
(a) $\tan^2\left(45° - \frac{\phi}{2}\right)$ (b) $\tan^2\left(45° + \frac{\phi}{2}\right)$
(c) $\tan\left(45° + \frac{\phi}{2}\right)$ (d) $\tan\left(45° - \frac{\phi}{2}\right)$

(iii) As per IS code, in light compaction test, the weight of hammer and height of fall, respectively are
(a) 2.6 kg and 350 mm (b) 1.6 kg and 310 mm
(c) 3.6 kg and 210 mm (d) 2.6 kg and 310 mm

(iv) If the average degree of consolidation U is less than 60%, the time factor T is given by
(a) $T_v = \frac{\pi}{2}\left(\frac{U\ \%}{100}\right)^2$ (b) $T_v = \frac{\pi}{4}\left(\frac{U\ \%}{100}\right)^3$
(c) $T_v = \frac{\pi}{4}\left(\frac{U\ \%}{100}\right)^2$ (d) $T_v = \frac{\pi}{2}\left(\frac{U\ \%}{100}\right)^4$

(v) The empirical relationship established by Skempton between the compression index, C_c and liquid limit, w_L for remoulded clays is given by
(a) $C_c = 0.005(w_L - 10)$ (b) $C_c = 0.009(w_L - 10)$
(c) $C_c = 0.007(w_L - 20)$ (d) $C_c = 0.007(w_L - 10)$

(vi) If the Poisson's ratio of a soil is μ , then according to the theory of elasticity, the coefficient of earth pressure at rest, K_0 is given by
(a) $K_0 = \frac{\mu}{1-0.5\mu}$ (b) $K_0 = \frac{0.5\mu}{1-\mu}$
(c) $K_0 = \frac{\mu}{1-\mu}$ (d) $K_0 = \frac{2\mu}{1-\mu}$

(vii) Uniform Surcharge
(a) Increases both the passive resistance and the active earth pressure
(b) Increases the passive resistance while it decreases the active earth pressure
(c) Increases the active earth pressure while it decreases the passive resistance
(d) Decreases both the passive resistance and the active earth pressure

(viii) For a gravity wall the maximum eccentricity of the base reaction for 'no tension' condition to be satisfied is
(a) One sixth of the base width (b) One fourth of the base width
(c) One fifth of the base width (d) One third of the base width

(ix) Taylor's stability number is given by
(a) $S_n = \frac{\gamma H}{c_m}$ (b) $S_n = \frac{c_m}{\gamma H}$ (c) $S_n = \frac{c_m H}{\gamma}$ (d) $S_n = \frac{\gamma c_m}{H}$
where, the symbols have their usual meanings.

(x) The maximum angle β of an infinite slope of a purely cohesionless soil (with friction angle, ϕ) is
(a) $\beta = \frac{\phi}{2}$ (b) $\beta = \frac{\phi}{3}$ (c) $\beta = \phi$ (d) $\beta = 1.5\phi$

Group–B

2. (a) A drained triaxial test on sand with $\sigma_{3f}^{'}$ = 138 kN/m^2. At failure, the ratio of effective major stress to effective minor stress was 3.0. Determine the effective major principal stress, principal stress difference at failure and the friction angle in terms of effective stress. If the specimen was sheared undrained at the same total cell pressure of 138 kN/m^2 and the induced excess pore pressure at failure was 55 kN/m^2, then evaluate $\sigma_{1f}^{'}$, $(\sigma_1 - \sigma_3)_f$ and friction angle in terms of total stress. [(CO1)(Evaluate/HOCQ)]

(b) The following data were obtained in a direct shear test conducted on a remoulded sample of sand at the time of failure: Normal load = 272 N; shear load = 160 N. The cross-sectional area of the sample is 36 cm^2. Determine (i) the angle of internal friction, (ii) the magnitude and direction of major and minor principal stresses in the zone of failure and (iii) the magnitude of the deviator stress if a sample of the same sand with the same void ratio as that in the direct shear test was tested in a triaxial apparatus with a confining pressure of 62 kN/m^2. Use graphical method. [(CO1)(Evaluate/HOCQ)]

6 + 6 = 12

3. (a) The stresses at failure on the failure plane in a cohesionless soil mass were: Shear stress = 14.5 kN/m^2; normal stress = 25 kN/m^2. Determine the resultant stress on the failure plane, the angle of internal friction of the soil and the angle of inclination of failure plane to the major principal plane. [(CO1)(Evaluate/HOCQ)]

(b) A soil has an unconfined strength of 100 kN/m^2. In a triaxial compression test, a specimen of the same soil when subjected to a chamber pressure of 50 kN/m^2 failed at an additional stress of 160 kN/m^2. Determine (i) the shear strength parameters of the soil and (ii) the angle made by the failure plane with the horizontal in the triaxial test. [(CO1)(Evaluate/HOCQ)]

(c) A laboratory vane shear test was performed in an undisturbed sample of soft clay. The diameter and the height of the vane were 6.3 mm and 11.3 mm, respectively. The sample failed under an applied torque of 130 gm-cm. The sample was then completely disturbed by rotating the vane rapidly. The remoulded soil failed under a torque of 80 gm-cm. Determine the undrained shear strength of the soil in the undisturbed and remoulded states and compute its sensitivity. If a field vane shear test is performed on that soil, with a vane of 11.3 cm height and 7.5 cm diameter, determine the torques required to fail the soil in the undisturbed and remoulded states. [(CO1)(Evaluate/HOCQ)]

3 + 4 + 5 = 12

Group - C

4. (a) It is required to construct an embankment by compacting a soil from nearby borrow areas. The OMC and MDD of this soil were 22.5% and 1.66 gm/cc, respectively. However, the natural moisture content and bulk density of the soil were 15% and 1.78 gm/cc, respectively. Determine the quantity of soil to be excavated and the quantity of water to be added to it, for every 100 m^3 of the finished embankment. [(CO2)(Evaluate/HOCQ)]

(b) In a laboratory consolidation test, a 2.5 cm thick sample of clay reached 60% consolidation in 17 mins. under double drainage condition. Determine the time (in days) required for 60% consolidation of a layer of this soil in the field under the following conditions: (i) when a 3 m thick layer of the given soil is sandwitched between two sand layers and (ii) when a 5 m thick clay layer of the soil is overlain by a sand layer and underlain by a deep layer of intact shale. [(CO3)(Evaluate/HOCQ)]

(c) A 6 m thick clay layer is drained at both top and bottom. The coefficient of consolidation of the soil is 5×10^{-4} cm^2/sec. Determine the time (in days) required for 50% consolidation of the layer due to an external load.

[(CO3)(Evaluate/HOCQ)]

6 + 4 + 2 = 12

5. (a) It is required to construct an embankment having a total volume of 75000 cu. m. The required soil is to be collected from borrow pits. It was found that the existing soil has a moisture content of 15%, void ratio of 0.63 and specific gravity of soil solids of 2.68. Laboratory tests indicate that OMC and MDD of the soil are 20% and 1.72 gm/cc, respectively. The soil is to be carried from the borrow pits to the construction site by trucks having average net carrying capacity of 5500 kg. Determine the total number of trips the trucks have to make for constructing the entire embankment and the quantity of water that has to be added to the borrowed soil before compaction. [(CO2)(Evaluate/HOCQ)]

(b) In a laboratory consolidation test, the void ratio of the sample reduced from 0.85 to 0.75 as the pressure was increased from 1 to 3 kg/cm^2. If the coefficient of permeability of the soil is 5.5×10^{-4} cm/sec, determine coefficient of volume change and coefficient of consolidation. [(CO3)(Evaluate/HOCQ)]

8 + 4 = 12

Group - D

6. (a) For the retaining wall shown in the Fig.1, determine the magnitude and point of application of the resultant active thrust above the toe of the wall. [(CO4)(Evaluate/HOCQ)]

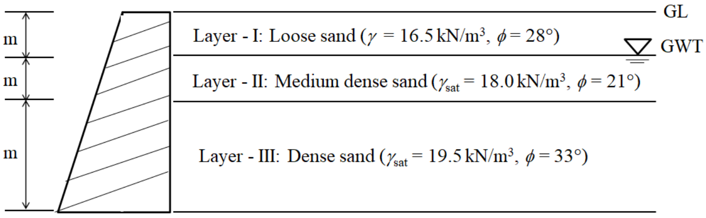

Fig.1

(b) A retaining wall 7 m high with a smooth vertical back supports a saturated clay soil with a horizontal surface. The properties of the backfill are: c =12 kN/m², ϕ = 28°, γ = 18 kN/m³. Determine (i) the depth of tension cracks, (ii) the critical depth of a vertical cut, (iii) the total active thrust against the wall and its point of application, if cracks are formed in the tension zone, (iv) what will be the depth of tension cracks, if any, if the backfill carries a uniform surcharge of 22 kN/m² over the backfill surface? and (v) what will be the magnitude of the resultant active thrust above the toe of the wall after placing the surcharge? [(CO4)(Evaluate/HOCQ)]

6 + 6 = 12

7. (a) For the cantilever wall shown in Fig.2, check the stability of the wall with respect to overturning, sliding and bearing capacity. Take adhesion factor as 0.30. Assume angle of friction between base of the wall and the foundation soil as $(2/3)\phi_f$, where, ϕ_f is the angle of friction of the foundation soil. The ultimate bearing capacity of the foundation soil is 650 kN/m². [(CO5)(Evaluate/HOCQ)]

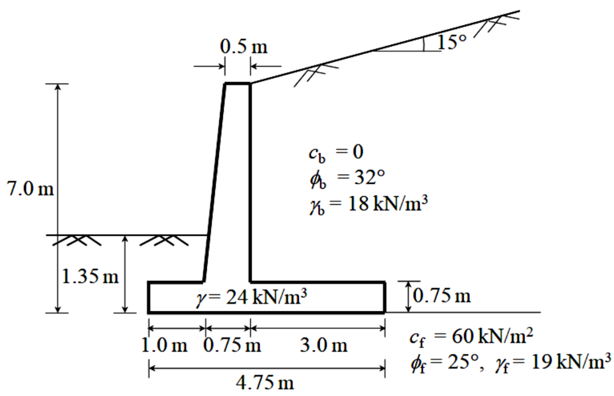

Fig.2

(b) A 6 m high vertical wall retains a granular backfill where the ground level is inclined at 10° to the horizontal. The bulk unit weight of the fill is 18 kN/m and the friction angle is 28°. Assuming the backfill is in the active state and the wall is smooth, determine the magnitude of the resultant thrust on the wall by Coulomb's theory. [(CO4)(Evaluate/HOCQ)]

9 + 3 = 12

Group – E

8. (a) Evaluate the short term stability for the dam shown in Fig.3. The embankment consists of a saturated soil for which the angle of shearing resistance ϕ_u = 0, and the undrained cohesion, c_u = 75 kN/m². The calculation is to be carried out for the reservoir depth of 18 m and for the case where the reservoir has been completely emptied. [(CO6)(Evaluate/HOCQ)]

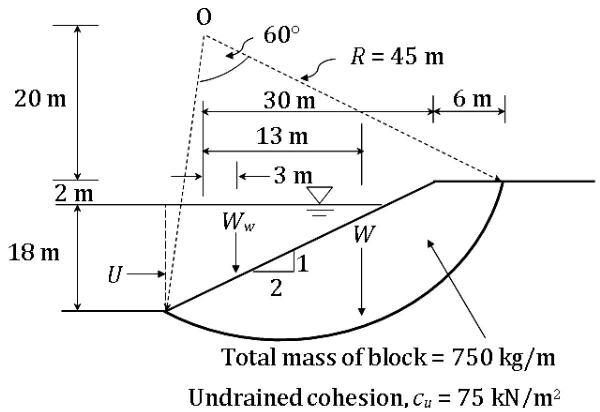

Fig.3

(b) A 15 m high earth dam is to be built from a soil (c = 25 kN/m², ϕ= 23°, γ_{sat} = 19 kN/m³). Determine the steepest angle at which the upstream slope of the dam may be inclined to the horizontal, for a factor of safety of 1.3. Use Taylor's stability number (Table 1). [(CO6)(Evaluate/HOCQ)]

Table 1: Taylor's stability number

β \ ϕ	0°	5°	10°	15°	20°	25°
90°	0.261	0.239	0.218	0.199	0.182	0.166
75°	0.219	0.195	0.173	0.152	0.134	0.117
60°	0.191	0.162	0.138	0.116	0.097	0.079
45°	0.170	0.136	0.108	0.083	0.062	0.044
30°	0.156	0.110	0.075	0.046	0.0625	0.009
15°	0.145	0.068	0.023	-	-	-

6 + 6 = 12

9. (a) A 6 m high embankment is required to be constructed with clay (c = 20 kN/m², ϕ = 0, γ = 19.5 kN/m³). Hard rocky stratum is found to exist at 3 m below the ground level. Determine the critical maximum side slope angle for the embankment. Use Taylor's stability number (Table 2). [(CO6)(Evaluate/HOCQ)]

Table 2: Values of S_n for slopes in cohesive soils (ϕ = 0) with different depth factors

Slope angle	Stability number, S_n				
	Depth factor, D_f				
	1.0	1.5	2.0	3.0	∞
90°	0.261	-	-	-	-
75°	0.219	-	-	-	-
60°	0.191	-	-	-	-
53°	0.181	0.181	0.181	0.181	0.181
45°	0.164	0.174	0.177	0.180	0.181
30°	0.133	0.164	0.172	0.178	0.181
22.5°	0.113	0.153	0.166	0.175	0.181
15°	0.083	0.128	0.150	0.167	0.181
7.5°	0.054	0.080	0.107	0.140	0.181

(b) A slope has to be made from a granular soil [γ_{sat} = 19 kN/m^3, ϕ' = 32°, e = 0.75, G = 2.71]. If a factor of safety of 2.0 is needed against slope failure, determine the safe angle of the slope when (i) the slope is dry or submerged without seepage, (ii) the seepage occurs at and parallel to the surface of the slope, (iii) If seepage occurs parallel to the slope with water table at a depth of 2.5 m, what is the factor of safety available on a slip plane parallel to the ground surface at a depth of 4 m assuming the slope angle as that obtained in case (i) ? The degree of saturation above water table is 15%. [(CO6)(Evaluate/HOCQ)]

(c) Determine by Culmann's method the critical height of an embankment having a slope angle of 30° and the constructed soil having $c' = 25$ kN/m^2, $\phi' = 15°$, and effective unit weight = 18 kN/m^3. Also evaluate the allowable height of the embankment if $F_c = F_\phi = 1.5$. [(CO6)(Evaluate/HOCQ)]

4 + 4 + 4 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	0	0	100

Course Outcome (CO):

After the completion of the course students will be able to

CO1 Apply the concept of shear strength to analyze different geotechnical problems and determine the shear strength parameters from lab and field tests.

CO2 Assess the compaction characteristics of soil for solving geotechnical problems.

CO3 Estimate the consolidation settlement using relevant parameters for a soil.

CO4 Calculate earth pressure on rigid retaining walls on the basis of classical earth pressure theories.

CO5 Analyze and design rigid retaining walls (cantilever types) from geotechnical engineering consideration.

CO6 Compute safety of dams and embankments on the basis of various methods of slope stability analysis.

*LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question