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 type of shear test in which the failure plane is predetermined is
(a) Triaxial test (b) Unconfined compression test
(c) Direct shear test (d) Vane shear test.

(ii) For a normally consolidated clay, Skempton's A-parameter at failure varies from
(a) - 0.5 to + 0 (b) + 0.0 to + 0.5
(c) 0.5 to + 1.0 (d) + 1.5 to + 2.0.

(iii) The degree of compaction of a soil is characterized by its
(a) Dry density (b) Saturated density
(c) Submerged density (d) All of the above.

(iv) Sheepsfoot roller is suitable for compacting
(a) Sandy soil (b) Clayey soil
(c) Rocky fill (d) All of the above.

(v) 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) $T_v = \frac{\pi}{4}\left(\frac{U\,\%}{100}\right)^2$
(c) $T_v = \frac{\pi}{5}\left(\frac{U\,\%}{100}\right)^2$ (d) $T_v = \pi\left(\frac{U\,\%}{100}\right)^2$.

(vi) Cohesion
(a) increases the active pressure and decreases the passive resistance.
(b) decreases both active pressure and passive resistance.
(c) increases both active pressure and passive resistance.
(d) decreases active pressure and increases passive resistance.

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

(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) The maximum angle β of an infinite slope in a pure cohesionless soil is
(a)$\beta = 2\phi$ (b) $\beta = \frac{\phi}{2}$ (c) $\beta = \frac{\phi}{3}$ (d) $\beta = \phi$.
where, ϕ is the angle of internal friction.

(x) In stability analysis, the term mobilized shear strength is referred to as
(a) shear strength (b) maximum shear stress
(c) applied shear stress (d) minimum shear stress.

Group–B

2. (a) A drained triaxial test on sand with $\sigma_{3f}^{'}$ = 151 kN/m². At failure, the ratio of effective major stress to effective minor stress was 4. Determine effective major principal stress, friction angle in terms of effective stress and the principal stress difference at failure. If the specimen was sheared undrained at the same total cell pressure of 151 kN/m² and the induced excess pore pressure at failure was 70 kN/m², then calculate $\sigma_{1f}^{'}$, $(\sigma_1 - \sigma_3)_f$, friction angle in terms of total stress. [(CO1)(Evaluate/HOCQ)]

   (b) Write short notes on (i) Dilatancy and (ii) Critical void ratio. [(CO1)(Understand/IOCQ)]

6 + (3 + 3) = 12

3. (a) A direct shear test was conducted on a specimen of dry sand with a normal stress of 140 kN/m². Failure occurred at a shear stress of 84 kN/m². The size of the specimen tested was 50 mm × 50 mm × 25 mm (height). Determine the angle of friction, $\phi^{'}$. For a normal stress of 84 kN/m², what shear force (in N) would be required to cause failure of the specimen? [(CO1)(Evaluate/HOCQ)]

   (b) The relationship between the relative density, D_r, and the angle of friction $\phi^{'}$, of a sand can be given as, $\phi^{'} = 25 + 0.18D_r$, where, $\phi^{'}$ is in degrees and D_r is in %. A drained triaxial test on the same sand was conducted with a chamber confining pressure of 103.6 kN/m². The relative density of compaction was 40%. Calculate the major principal stress at failure, the angle that the failure plane makes with the major principal plane and the normal and shear stresses (when the specimen failed) on a plane that makes an angle of 28° with the major principal plane. [(CO1)(Evaluate/HOCQ)]

   (c) Draw the stress path for the condition: $\Delta\sigma_h = \frac{1}{4}\Delta\sigma_v$, when the initial condition is hydrostatic compression, i.e., $\sigma_v = \sigma_h$. [(CO1)(Evaluate/HOCQ)]

4 + 4 + 4 = 12

Group - C

4. (a) The optimum moisture content of a soil is 17.2% and its maximum dry density is 1.57 gm/cc. The specific gravity of soil solids is 2.65. Determine the theoretical dry density at OMC corresponding to zero air voids. [(CO2)(Evaluate/HOCQ)]

   (b) During the construction of an embankment, the density attained by field compaction was investigated by the sand replacement method. A test pit was excavated in the newly compacted soil and was filled up by pouring sand. The following were the observations:
   Weight of soil excavated from the pit = 3000 gm
   Weight of sand required to fill the pit = 2412 gm
   Bulk density of sand = 1.52 gm/cc
   Moisture content of embankment soil = 16%.
   Determine the dry density of the compacted soil. [(CO2)(Evaluate/HOCQ)]

   (c) During a consolidation test, a sample of fully saturated clay, 2.0 cm thick is consolidated under a pressure increment of 200 kN/m². When equilibrium is reached, the sample thickness gets reduced to 1.65 cm. The pressure is then removed and the sample is allowed to expand and take water. The final thickness is observed as 1.92 cm and final water content is 35%. If G = 2.5, find void ratios before and after consolidation. Also determine m_v over the range of pressure applied. [(CO3)(Evaluate/HOCQ)]

2 + 4 + 6 = 12

5. (a) A moist soil sample compacted into a mould of 1000 cm³ capacity and weight 3.8 kg, weighs 5.2 kg with the mould. A representative sample of soil taken from it has an initial weight of 18.5 gm and oven dry weight of 16.5 gm. Determine (i) water content, (ii) wet density, (iii) dry density, (d) void ratio and (iv) degree of saturation of the sample. If the soil sample is so compressed as to have all air expelled, what will be the new volume and new dry density? Assume G = 2.65. [(CO2)(Evaluate/HOCQ)]

   (b) The void ratio of clay sample A decreased from 0.58 to 0.44 when pressure changes from 120 kg/m² to 180 kg/m². The void ratio of clay sample B decreased from 0.67 to 0.47 under the same increment of pressure. The thickness of sample A is 1.5 times that of sample B. The time required for 50% consolidation was three times longer for sample B than for sample A. Determine the ratio of coefficient of permeability of sample A to that of sample B. [(CO3)(Evaluate/HOCQ)]

6 + 6 = 12

Group - D

6. (a) A retaining wall has to retain a sand backfill (ϕ = 28°, e = 0.65, G = 2.68) upto a height of 6.5 m. A uniform surcharge of 40 kN/m^2 is placed over the backfill. The water table is at 2.3 m below ground surface. The soil above the water table has a degree of saturation of 17%. Determine the magnitude and point of application of the resultant active thrust above the toe of the wall. [(CO4)(Evaluate/HOCQ)]

   (b) For the cantilever wall shown in Fig. 1, check the stability of the wall with respect to overturning only. Take adhesion factor as 0.55. Assume angle of friction between base of the wall and the foundation soil as (2/3)ϕ_f, where, ϕ_f is the angle of friction of the foundation soil. The ultimate bearing capacity of the foundation soil is 600 kN/m^2. [(CO5)(Evaluate/HOCQ)]

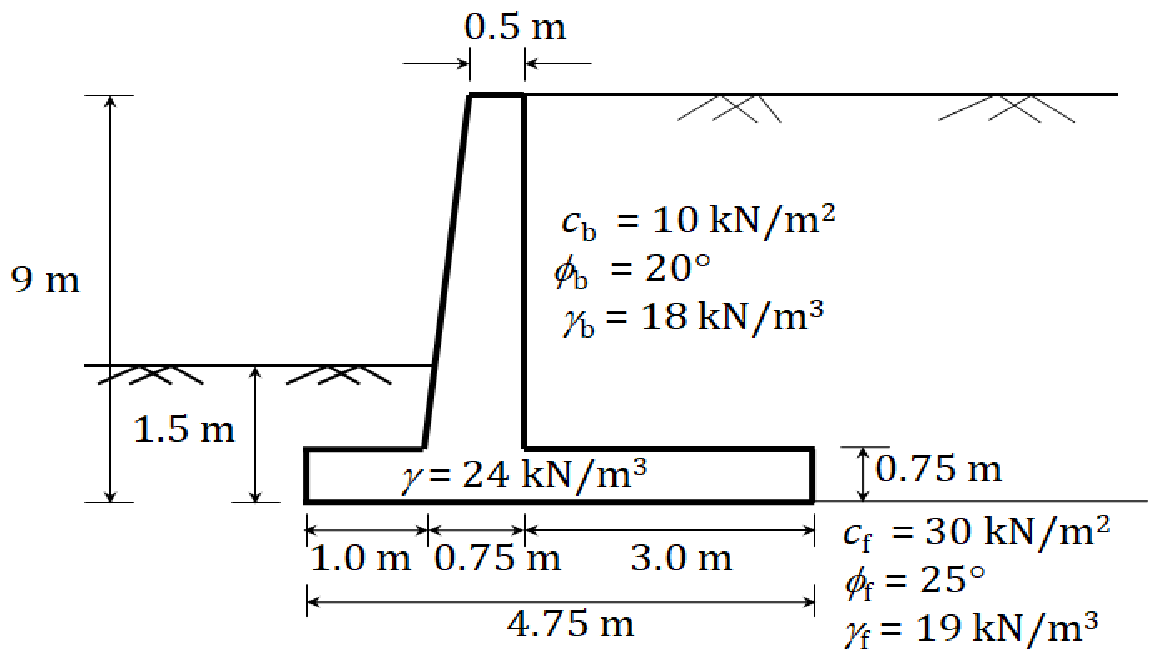

Fig. 1

6 + 6 = 12

7. (a) A rigid smooth retaining wall of height 7 m with vertical backface retains saturated clay as backfill. The saturated unit weight and undrained cohesion of the backfill are 16 kN/m^3 and 20 kPa, respectively. Determine the difference in the active lateral forces on the wall (in kN per meter length of wall), before and after the occurrence of tension cracks. [(CO4)(Evaluate/HOCQ)]

   (b) A trapezoidal masonry retaining wall 1.1 m wide at top and 3.4 m wide at its bottom is 4.5 m high. The vertical face is retaining soil (ϕ = 30°), the surface of which is inclined at an angle of 20° with the horizontal. Determine the maximum and minimum intensities of pressure at the base of the retaining wall. Unit weights of soil and masonry are 20 kN/m^3 and 24 kN/m^3 respectively. Assuming the coefficient of friction at the base of the wall as 0.45, determine the factor of safety against sliding. Also determine the factor of safety against overturning. Use Rankine's theory. [(CO5)(Evaluate/HOCQ)]

4 + 8 = 12

Group – E

8. (a) The shear strength parameters of a soil are: c' = 20 kN/m^2, ϕ' = 14°, c'_m = 16 kN/m^2 and ϕ'_m = 8°. Calculate the factor of safety with respect to (i) strength, (ii) cohesion and (iii) friction, (iv) F_ϕ when F_c = 1, (v) F_c when F_ϕ = 1 and (vi) true factor of safety. The average intergranular pressure on the failure surface is 100 kN/m^2. [(CO6)(Evaluate/HOCQ)]

   (b) Determine the critical height of an infinite slope made of clay (c' = 28 kN/m^2, ϕ' =15°, e = 0.50, G = 2.7) under the following conditions (i) when the soil is dry, (ii) when water seeps parallel to the surface of the slope, and (iii) when the slope is submerged. The slope is inclined at an angle of 20° with the horizontal. [(CO6)(Evaluate/HOCQ)]

6 + 6 = 12

9. (a) Why the slope stability problem is statically indeterminate? [(CO6)(Understand/IOCQ)]

   (b) A 6 m high embankment is required to be constructed with clay (c = 15 kN/m^2, ϕ = 0°, γ = 17.9 kN/m^3). 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 1). [(CO6)(Evaluate/HOCQ)]

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

Table 1: ***Values of S_n for slopes in cohesive soils (ϕ = 0) with different depth factors***

(c) A slope inclined at an angle of 40° is to be constructed with a soil [c' = 20 kN/m^2, ϕ' = 15°, γ = 18 kN/m^3]. Determine (i) the critical height of the slope and (ii) factor of safety with respect to the strength if the height of the slope is 10 m. [(CO6)(Evaluate/HOCQ)]

3 + 3 + 6 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	0	9.38	90.62

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.