SOIL MECHANICS - II
(CIVL 2202)

Time Allotted : 2½ hrs **Full Marks : 60**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 4 (four) from Group B to E, taking one from each group.

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

Group – A

1. Answer any twelve: **12 × 1 = 12**

Choose the correct alternative for the following

(i) A dry sand specimen was tested in a triaxial machine with the cell pressure of 50 kPa. If the deviator stress at failure was 100 kPa, the angle of shearing resistance is
(a) 30° (b) 15° (c) 45° (d) 60°

(ii) With an increase in the liquid limit, compression index
(a) decreases (b) increases
(c) remains constant (d) may increase or decrease.

(iii) Wall friction
(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.

(iv) Consolidation time of a soil sample
(a) increases with an increase in permeability
(b) increases with a decrease in unit weight of soil
(c) increases with a decrease in unit weight of water
(d) increases with a decrease in permeability

(v) Pneumatic tyred rollers are useful for compacting
(a) Cohesive soils (b) Cohesionless soils
(c) Both (a) and (b) (d) Rocky fill

(vi) The active earth pressure caused by a cohesionless backfill on a smooth vertical retaining wall may be reduced by
(a) Compacting the backfill (b) Proving a surcharge load on the backfill
(c) Saturating the backfill with water (d) None of the above.

(vii) One of the assumptions in Rankine's theory is
(a) The wall is vertical and rough (b) The wall is vertical and smooth
(c) The wall is inclined and smooth (d) The wall is inclined and rough

(viii) If a uniform surcharge of 120 kN/m² is placed on the backfill with $\phi' = 30°$, the active pressure intensity is
(a) 12 kN/m² (b) 30 kN/m²
(c) 40 kN/m² (d) 120 kN/m²

(ix) The factor of safety of an infinite slope in a sand deposit is 1.732. If the angle of shearing resistance is 30°, the safe slope angle is
(a) 19.5° (b) 75.4° (c) 18.4° (d) 71.6°

(x) An excavation is made with a vertical face in a clay soil which has c_u = 50 kN/m², γ_t = 18 kN/m³. If S_n = 0.261, then the maximum depth of excavation, so that it is stable is
(a) 10.2 m (b) 10.4 m (c) 10.6 m (d) 10.8 m

Fill in the blanks with the correct word

(xi) The higher the compactive effort, the _____ the optimum moisture content upto a certain limit.

(xii) Coulomb's equation for shear strength can be represented as _____.

(xiii) The shear strength for a saturated clay from unconfined compression test is _____ of the unconfined compression strength.

(xiv) The inclination of the failure plane behind a vertical wall in the passive pressure case is inclined to the horizontal at _____.

(xv) For a gravity wall the maximum eccentricity of the base reaction for 'no tension' condition to be satisfied is _____ of the base width.

Group - B

2. (a) The stresses at failure on the failure plane in a cohesionless soil mass were: Shear stress = 14 kN/m^2; normal stress = 20 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 cylindrical sample of soil having a cohesion of 60 kN/m^2 and an angle of internal friction of 15° is subjected to a cell pressure of 120 kN/m^2. Determine the maximum deviator stress at which the sample will fail and the angle made by the failure plane with the horizontal. *[(CO1) (Evaluate/HOCQ)]*

(c) A saturated specimen of cohesionless sand was tested under undrained conditions in a triaxial compression tests apparatus and the sample failed at a deviator stress of 500 kN/m^2 and the plane of failure made an angle of 53° with the horizontal. Determine the magnitudes of the principal stresses. Also evaluate the deviator stress and the major principal stress at failure for another identical specimen of sand if it is tested under a cell pressure of 275 kN/m^2. *[(CO1) (Evaluate/HOCQ)]*

3 + 4 + 5 = 12

3. (a) An unconfined compression test was performed on an undisturbed sample of normally consolidated clay, having a diameter of 3.75 cm and 7.5 cm high. Failure occurred under a vertical compressive load of 133 kg. The axial deformation recorded at failure was 0.9 cm. A remoulded sample of the same soil failed under a compressive load of 86 kg, and the corresponding axial compression was 1.15 cm. Determine the cohesion of the soil in the undisturbed and remoulded state, the sensitivity of the soil and hence classify it accordingly. *[(CO1)(Evaluate/HOCQ)]*

(b) A saturated normally consolidated clay sample is subjected to a CU triaxial compression test under a backpressure of 45 kPa. The cell pressure during consolidation is 206 kPa. When the sample is fully consolidated, the drainage valve is closed and the additional vertical stress is increased from 0 to 125 kPa when the sample failed. During this period of shearing, the pore water pressure increased by 70 kPa. Determine the effective friction angle and Skempton's A-parameter at failure. *[(CO1)(Evaluate/HOCQ)]*

6 + 6 = 12

Group - C

4. (a) A compacted fill is to be constructed using the borrow area located nearby. The in-situ properties of soil are as follows: $e_n = 0.68$, $w_n = 10\%$. The specific gravity of solids for soils is 2.65. The compacted volume of the embankment will be 50,000 m^3, its unit weight is 20 kN/m^3 at a placement water content of 20%. Soil from the borrow area is to be excavated and transported to the site in trucks of 10 m^3 capacity. During excavation and dumping of soil in the trucks, the soil increases in volume by 8%. At the site, the required additional amount of water is added to the soil and compacted to the desired extent by pneumatic rubber-tyred rollers. The cost of excavation, transportation and compaction is Rs. 400/- per truck. Water charges per truck is Rs. 165/-. Determine the total cost of construction of the compacted fill. *[(CO2)(Evaluate/HOCQ)]*

(b) A 7 m thick saturated clay stratum is sandwitched between a pervious stratum at the top and impervious stratum at the bottom. It has a compression index of 0.38 and coefficient of permeability of 4.5 × 10^{-4} cm/sec. It has an initial void ratio of 1.6 when the initial effective overburden pressure at the mid-height of the layer is 90 kN/m^2. Determine (i) void ratio when pressure increases to 222 kN/m^2, (ii) settlement of the soil stratum due to the above increase of pressure and (iii) time (in hours) required for 45% consolidation. *[(CO3)(Evaluate/HOCQ)]*

6 + 6 = 12

5. (a) It is required to construct an embankment by compacting a soil from nearby borrow area. The OMC and MDD of this soil were 25% and 1.5 gm/cc, respectively. However, the natural moisture content and bulk density of the soil were 9% and 1.7 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 70% consolidation in 20 mins. under double drainage condition. Determine the time (in days) required for 70% 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 6 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)]*

6 + 6 = 12

Group – D

6. (a) A vertical wall 12.5 m high supports a backfill with horizontal surface as shown in Fig. 1. Determine the total active earth pressure and its point of action above the base of the wall.

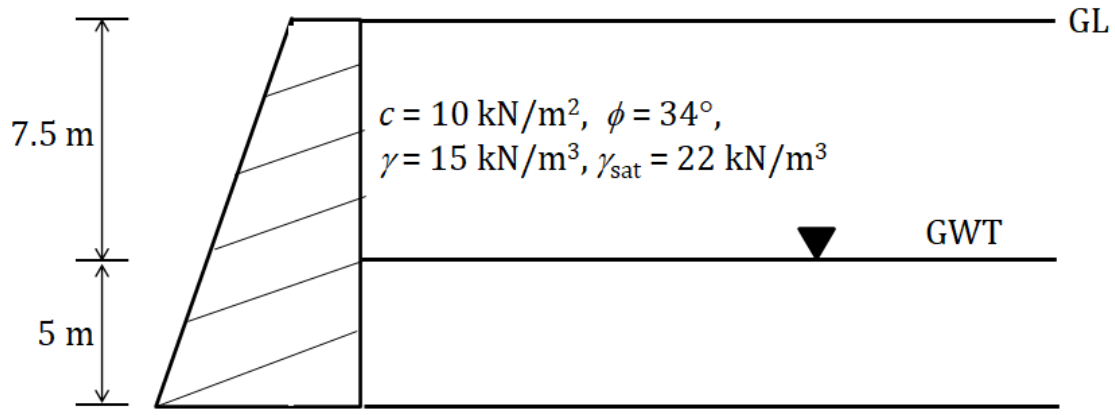

Fig. 1

[(CO4)(Evaluate/HOCQ)]

(b) For the cantilever wall shown in Fig. 2, evaluate 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 $(2/3)\phi_f$, where, ϕ_f is the angle of friction of the foundation soil. The ultimate bearing capacity of the foundation soil is 700 kN/m^2.

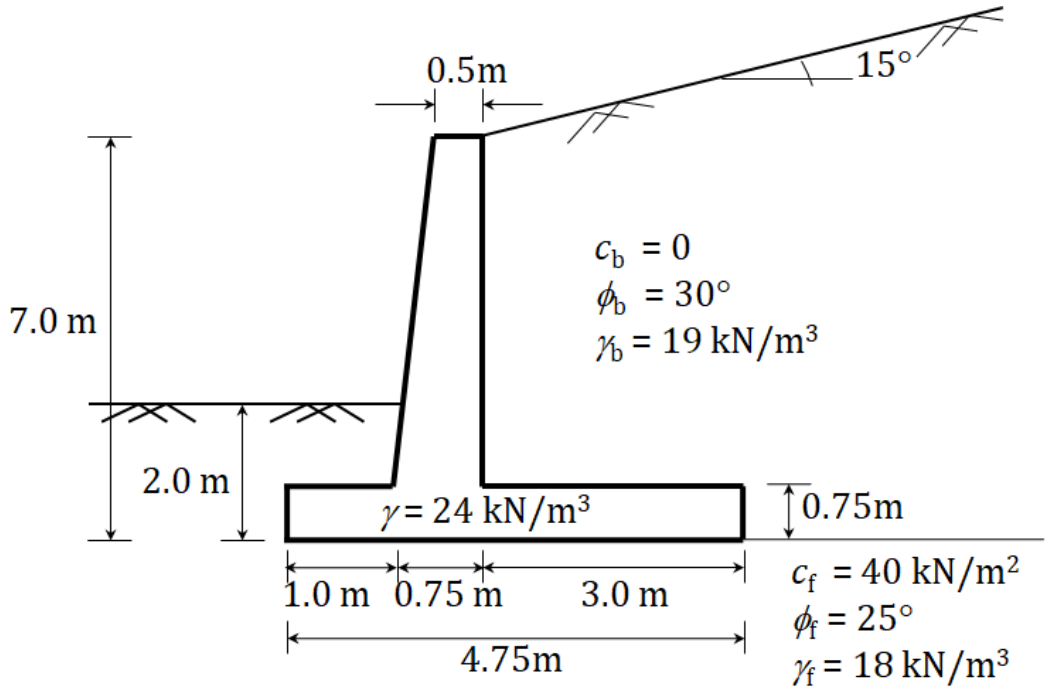

Fig. 2

[(CO5)(Evaluate/HOCQ)]

6 + 6 = 12

7. (a) A vertical wall 8 m high supports a cohesive backfill ($\phi = 0$) with horizontal surface as shown in Fig. 3. If tension cracks develop, determine the total active earth pressure and its point of action above the base of the wall.

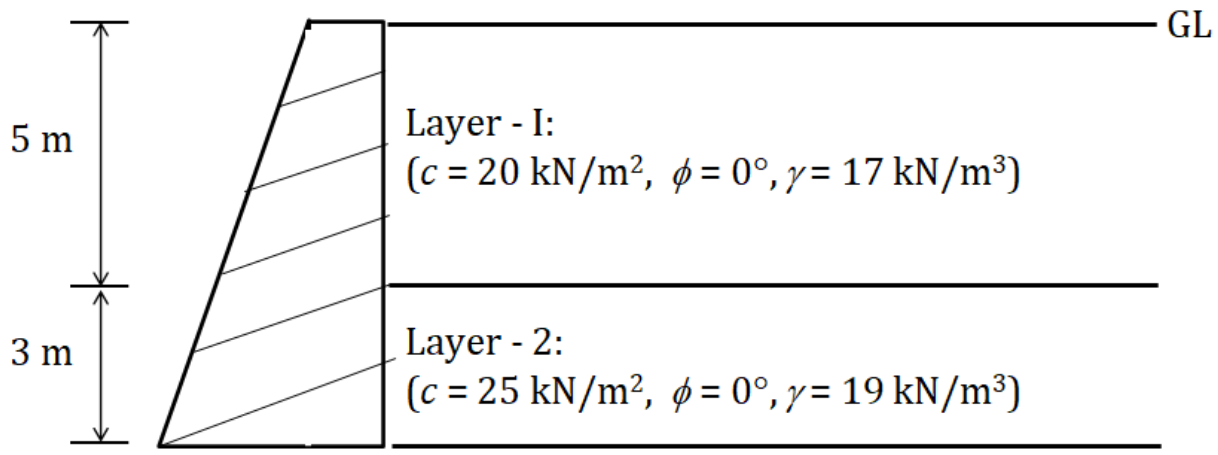

Fig. 3

[(CO4)(Evaluate/HOCQ)]

(b) The retaining wall (Fig. 4) is designed to retain a 5 m high sandy backfill that has a friction angle of 34° and a unit weight of 17 kN/m^3. The base of the wall rests on the existing ground that consists of clayey sand having an effective cohesion and friction angle of 10 kPa and 26°, respectively. The unit weights of clayey sand and concrete are 18 kN/m^3 and 23 kN/m^3, respectively. Determine the factor of safety of the retaining wall with respect to sliding and overturning. Also determine the contact pressure beneath the toe of the wall. [Given: $\delta = (2/3)\phi$ and adhesion factor = 2/3].

[(CO5)(Evaluate/HOCQ)]

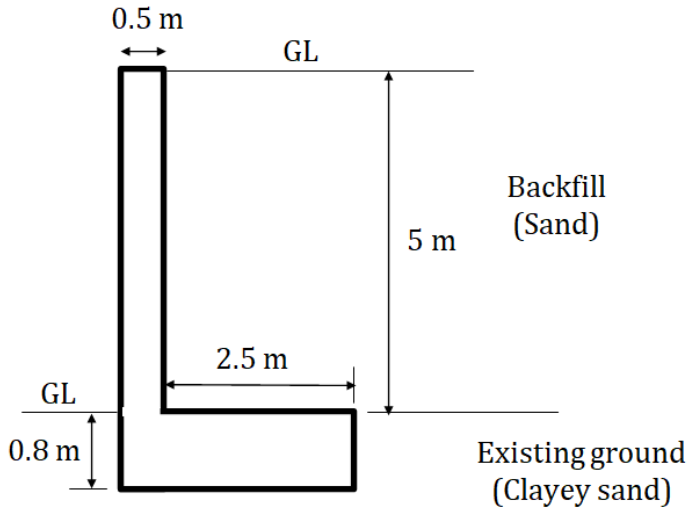

Fig. 4

6 + 6 = 12

Group - E

8. (a) An infinite slope in a sandy soil is inclined at 16° to the horizontal. The properties of the soil are: c' = 0, ϕ' = 34°, γ = 17 kN/m^3, γ_{sat} = 21 kN/m^3. A hard layer exists 5 m below and parallel to the surface. Determine the factor of safety against slip when (i) the slope is dry, (ii) the slope is completely submerged with seepage parallel to the surface, and (iii) the water table level is parallel to the ground surface at 1.5 m depth, seepage being parallel. *[(CO6)(Evaluate/HOCQ)]*

(b) Determine the factor of safety with respect to cohesion of a clay (c = 18 kN/m^2, ϕ = 10° and γ = 19 kN/m^3) slope laid at 1 in 2 to a height of 10 m. Also estimate the critical height of the slope in this soil. Use Taylor's stability number (Table 1). *[(CO6)(Evaluate/HOCQ)]*

(c) A cutting is to be made in a soil deposit for a depth of 18 m in a homogeneous soil with the following properties: γ = 19 kN/m^3, c' = 25 kN/m^2, ϕ_u = 20°. Determine (i) the steepest slope angle that can be provided if a true factor of safety of 1.44 is needed against slope failure and (ii) the factor of safety with respect to cohesion for this slope. Use Taylor's stability number (Table 1). *[(CO6)(Evaluate/HOCQ)]*

4 + 4 + 4 = 12

9. (a) Determine the slope angle where a 9 m high fill is to be constructed having a factor of safety of 1.6. The soil has c = 20 kN/m^2, ϕ = 21° and γ = 19 kN/m^3. Determine the initial depth up to which the trench can be excavated without any lateral support. Use Taylor's stability number (Table 1). *[(CO6)(Evaluate/HOCQ)]*

(b) A cohesive infinite soil slope has 2.5 m soil overburden above the underlying stiff stratum. The slope is inclined at 20° to the horizontal and there is no water table within the overburden soil. The soil properties are: γ_m = 19 kN/m^3, c' = 35 kN/m^2, ϕ' = 15°. Determine (i) Safety factor against sliding, (ii) Maximum shear stress developed within the overburden soil, (iii) Shear strength along the potential failure plane and (iv) Critical height of overburden that would have caused sliding. *[(CO6)(Evaluate/HOCQ)]*

6 + 6 = 12

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	-	-	-

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 engineeringconsideration.
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.*