FOUNDATION ENGINEERING
(CIVL 3141)

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) Dilatancy correction is applied to field SPT-*N* value when the soil strata is
(a) saturated clay (b) dry silt or fine sand
(c) saturated silt or fine sand (d) dry clay.

(ii) The geophysical method used in subsoil investigation is
(a) Plate load test method (b) Auger boring method
(c) Rotary drilling method (d) Seismic Refraction method.

(iii) In dense sand, the shallow foundation fails by
(a) Local shear failure (b) General shear failure
(c) Punching shear failure (d) Any one of the above.

(iv) The immediate settlement is given by
(a) $S_i = q_n E \frac{(1-\mu^2)}{B} I_f$ (b) $S_i = q_n B^2 \frac{(1-\mu^2)}{E^2} I_f$
(c) $S_i = q_n B \frac{(1-\mu^4)}{E} I_f$ (d) $S_i = q_n B \frac{(1-\mu^2)}{E} I_f$
where, the symbols have their usual meanings.

(v) A 1.2 m wide strip footing is located at a depth of 0.8 m in a cohesionless soil deposit for which the corrected *N*-value of SPT is 30. If, C_{D1} = 1.13333, then the net safe bearing pressure for settlement of 25 mm by modified Meyerhof's method after applying Bowles's correction is
(a) 622.5 kN/m^2 (b) 620.5 kN/m^2
(c) 618.5 kN/m^2 (d) 624.5 kN/m^2.

(vi) The cantilever sheet pile wall gains its stability from
(a) Active pressure above dredge level
(b) Passive resistance below dredge level
(c) Anchor
(d) Both active pressure and passive resistance.

(vii) In anchored sheet pile wall, the anchor is under
(a) Compression (b) Shear
(c) Tension (d) Both shear and compression.

(viii) The average unit skin friction for a pile embedded in clay with unconfined compressive strength of 40 kN/m^2 and adhesion factor of 0.85 is
(a) 34 kN/m^2 (b) 17 kN/m^2
(c) 24 kN/m^2 (d) 68 kN/m^2

(ix) For piles in sand and normally loaded clays the relative stiffness factor is given by
(a) $T = \sqrt[5]{\frac{EI}{\eta_h}}$ (b) $T = \sqrt[4]{\frac{EI}{\eta_h}}$
(c) $T = \sqrt[6]{\frac{EI}{\eta_h}}$ (d) $T = \sqrt[3]{\frac{EI}{\eta_h}}$
where, the symbols have their usual meanings.

(x) Indian standard code for pile foundation is
(a) IS: 2900 (b) IS: 2911
(c) IS: 3911 (d) IS: 2921.

Group – B

2. (a) A column footing of 5.0 m × 2.5 m is founded at a depth of 1.5 m below ground level in a soil (c = 15 kN/m^2, ϕ = 20°, saturated unit weight = 17.5 kN/m^3). Determine the safe bearing capacity of the footing with a factor of safety of 2.5, when the ground water table is located at (i) GL, (ii) 1 m below GL, (iii) 2 m below GL and (iv) 4 m below GL. Use IS code method. [Given: for ϕ = 10°, N_c = 8.35, N_q = 2.47, N_γ = 1.22; for ϕ = 15°, N_c = 10.98, N_q = 3.94, N_γ = 2.65]. Assume local shear failure. [(CO1) (Evaluate/HOCQ)]

(b) Determine the depth at which a circular footing of 1.8 m diameter be founded to provide a factor of safety of 3, if it has to carry a safe load of 1300 kN. The foundation soil has c = 10 kN/m^2, ϕ = 30°, and γ = 18 kN/m^3. Use Terzaghi's theory. [Given: for ϕ = 30°, N_c = 37.20, N_q = 22.50, N_γ = 19.70]. [(CO1) (Evaluate/HOCQ)]

8 + 4 = 12

3. (a) Calculate the net ultimate bearing capacity of a rectangular footing 2 m × 4 m in plan, founded at a depth of 1.5 m below the ground surface. The load on the footing acts at an angle of 20° to the vertical and is eccentric in the direction of width by 25 cm. The cohesion, friction angle and saturated unit weight of the soil are 15 kN/m^2, 25° and 18 kN/m^3, respectively. The ground water table is at a depth of 2 m below the ground surface. Use IS: 6403-1981 recommendations. [Given: for ϕ = 25°, N_c = 20.72, N_q = 10.66, N_γ = 10.88]. [(CO1) (Evaluate/HOCQ)]

(b) For the problem as shown in Fig.1, compute the consolidation settlement by Skempton and Bjerrum method. The compressible layer of depth 24 m is divided into four layers. The net pressure (q_n) transmitted by the foundation is

150 kN/m². [Given: λ = 0.7]. The depth correction factor is 0.95. Assume the footing to be rigid. [(CO2) (Evaluate/HOCQ)]

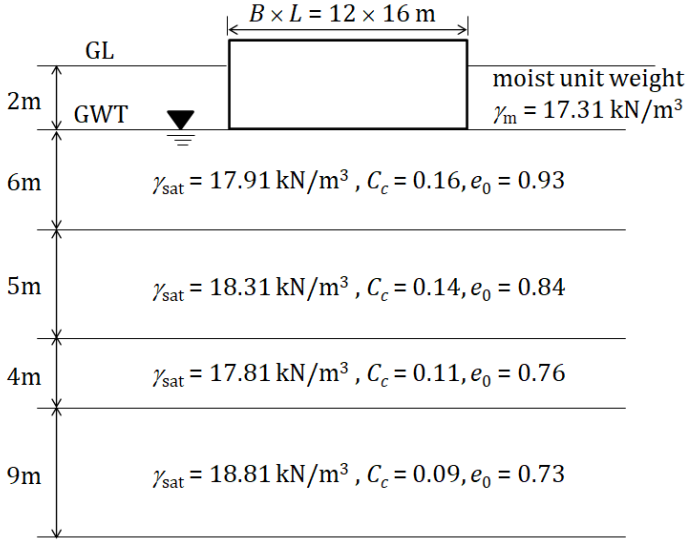

Fig.1

6 + 6 = 12

Group – C

4. (a) Determine the area ratio of a shelby tube type sampler of 60 mm outer diameter and 2.25 mm wall thickness. Do you recommend the sampler for obtaining undisturbed soil samples? Justify.
[(CO3) (Evaluate/HOCQ), (Understand/LOCQ)]

   (b) Explain static cone penetration test.
[(CO3)(Remember/LOCQ), (Understand/LOCQ)]

   (c) The observed standard penetration test values in a deposit of loose and dense sand were 30 and 45, respectively, at a depth of 6.5 m with hammer efficiency of 70%. The average unit weight of loose and dense sand is 16 and 17 kN/m³, respectively. The other data given are: (a) drill rod length correction factor = 0.9, and (b) borehole correction factor = 1.05. Determine N_{60} and $(N_1)_{60}$ at this depth and water table is well below this depth. The sampler was used with liner.
[(CO3) (Evaluate/HOCQ)]

2 + 4 + 6 = 12

5. (a) Describe the limitations of plate load test.
[(CO3)(Remember/LOCQ), (Understand/LOCQ)]

   (b) Describe percussion boring with the help of a neat sketch.
[(CO3)(Remember/LOCQ), (Understand/LOCQ)]

   (c) A 65 mm × 130 mm vane was pushed into a clay and rotated; the shearing occurred when the applied torque was 20 N-m. When the vane was further rotated to remould the clay, the torque dropped to 8.5 N-m. The plasticity index of the clay was 40%. Determine the sensitivity of the clay. What would be the maximum load that can be applied to a 50 mm diameter sample collecting at this depth? [(CO3) (Evaluate/HOCQ)]

3 + 4 + 5 = 12

Group – D

6. (a) Determine the allowable pile load capacity of the 50 cm diameter driven concrete pile (Fig. 2) for a factor of safety of 2.5. [Given: N_q = 120, N_γ = 109.41, α = 0.95, δ/ϕ = 1]. [(CO4) (Evaluate/HOCQ)]

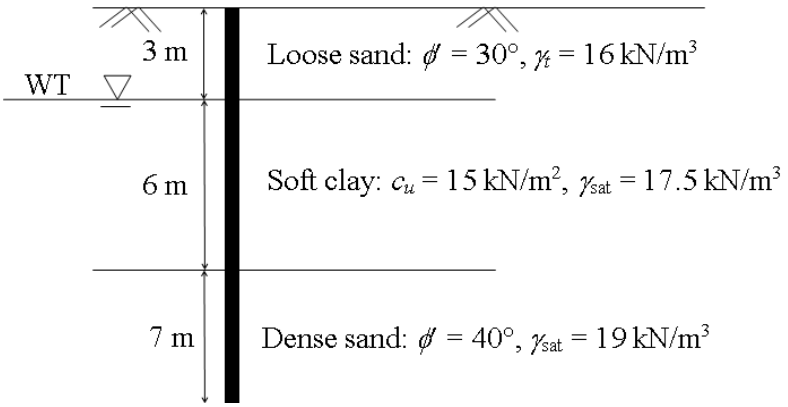

Fig. 2

(b) A group of 9 piles with 3 piles in a row were driven into a soft clay extending from ground level to a great depth. The diameter and the length of the piles were 40 cm and 10 m, respectively. The unconfined compressive strength of the clay is 50 kPa. If the piles were placed at 110 cm centre to centre, compute the allowable load on the pile group on the basis of shear strength failure criteria for a factor of safety of 2.5. Take adhesion factor as 0.85. [(CO5) (Evaluate/HOCQ)]

8 + 4 = 12

7. (a) A 40 cm × 40 cm reinforced concrete pile which is 20 m long is driven through loose materials and then into dense gravel to a final set of 5 mm/blow, using a 30 kN single-acting hammer with a stroke of 1.5 m. The arrangement is fitted with a helmet, plastic dolly and 50 mm packing on the top of the pile. The weight of the helmet and dolly is 4 kN. The other details are: weight of pile = 60 kN; weight of hammer = 30 kN; pile hammer efficiency = 0.80; coefficient of restitution = 0.40. Determine the safe pile capacity using (i) Hiley's formula and (ii) Engineering News formula. The sum of elastic compression C' of pile cap (c_1), pile material (c_2) and of soil (c_3), is $C' = c_1 + c_2 + c_3$ = 18 mm; $C = C'/2$. Use factor of safety of 2.0 for Hiley's formula. [(CO4) (Evaluate/HOCQ)]

(b) A 15 m long RCC pile (EI = 4.5 × 10^7 N-m²) is installed in a deposit of uniform sand. The pile head is subjected to a horizontal force of 50 kN. Determine the deflection of the pile head at the ground level under free and fixed head conditions. [Given: coefficient of subgrade modulus = 10 × 10^6 N/m³, A_y = 2.435, B_y = 1.623, A_s = -1.623, B_s = -1.750, A_m = 0, B_m = 1]. [(CO4) (Evaluate/HOCQ)]

(c) It is required to construct a pile foundation comprising of 25 piles arranged in 5 columns at distances of 120 cm c/c. The diameter and length of the piles are 40 cm and 9 m, respectively. The bottom of the pile cap is located at a depth of 2 m below ground level. The details of the soil layers are as given below with reference to ground level as datum. Water table is found at a depth of 4 m below ground level.

Depth (m) Soil properties

From To

0	2	Silt, saturated, γ = 16 kN/m^3
2	4	Clay, saturated, γ = 18 kN/m^3
4	12	Clay, saturated, γ = 18 kN/m^3, q_u = 120 kN/m^2, e_0 = 0.8, C_c = 0.23
12	14	Clay, γ= 17 kN/m^3, q_u = 90 kN/m^2, e_0 = 1.08, C_c = 0.34
14	17	Clay, γ= 20 kN/m^3, q_u = 180 kN/m^2, e_0 = 0.70, C_c = 0.20
17	-	Rocky strata

Compute the settlement of the pile group if the total load imposed on the foundation is 1000 kN. [(CO5) (Evaluate/HOCQ)]

4 + 4 + 4 = 12

Group – E

8. Determine the depth of embedment and the force in the tie rod for the anchored bulkhead (Fig.3) by applying directly a factor of safety of 1.5 to the passive pressure using free earth support method. The backfill and the soil below the dredge line is sand, having the following properties: G = 2.6, e = 1.0 and ϕ = 33°. Assume the soil above the water table is dry. [(CO6) (Evaluate/HOCQ)]

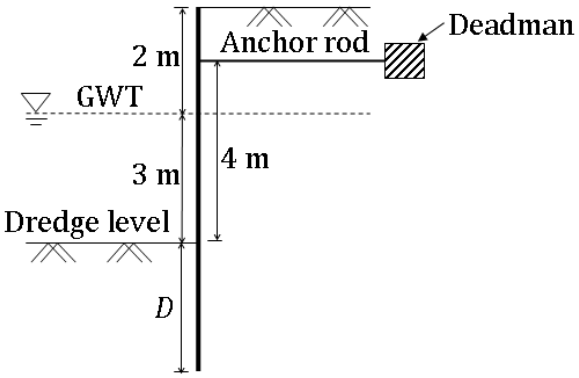

Fig.3

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9. Fig.4 shows a cantilever sheet pile wall penetrating a granular soil. Determine (i) Theoretical depth of embedment (D), (ii) The total length of sheet piles for a 30% increase in D and (iii) The minimum section modulus of the sheet piles if allowable bending stress is 190 MPa. [(CO6) (Evaluate/HOCQ)]

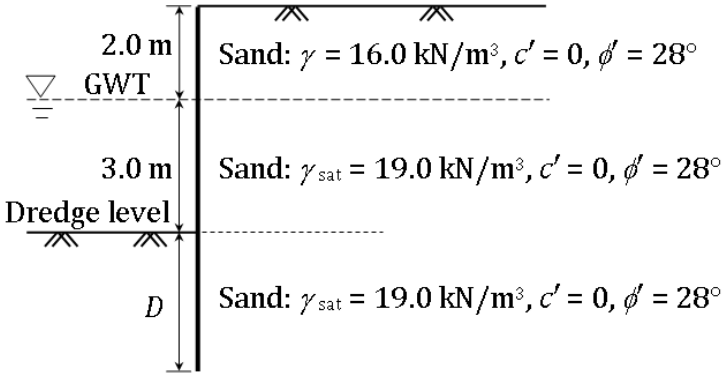

Fig.4

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Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	30%	43.33%	26.67%

Course Outcome (CO):

After the completion of the course students will be able to

- CO1 Compute bearing capacity of shallow foundation by different methods.
- CO2 Evaluate the settlement of shallow foundation by different methods.
- CO3 Understand different subsoil exploration methods and interpret field and laboratory test data to obtain design parameters for geotechnical analysis.
- CO4 Determine the load carrying capacity of pile foundation.
- CO5 Compute the efficiency and settlement of pile group.
- CO6 Analyze and design sheet pile structures.

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

Department & Section	Submission Link
CE & SEC A	https://classroom.google.com/w/MTIyOTQxNDQxNDA4/t/all
CE & SEC B	https://classroom.google.com/w/MjQwMzA5MzM2MTM1/t/all