FOUNDATION ENGINEERING
(CIVL 3202)

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 equivalent diameter of stone column for an equilateral triangular pattern and a square pattern are respectively,
(a) 1.05*S* and 1.17*S* (b) 1.05*S* and 1.13*S*
(c) 1.13*S* and 1.05*S* (d) 1.07*S* and 1.13*S*
where, *S* is the spacing between the stone columns.

(v) The net ultimate bearing capacity for continuous footing as per Teng's method is given by,
(a) $q_{nd} = 0.16\left[5N^2BR_w + 3\left(100 + N^2\right)D_f R'_w\right]$ (b) $q_{nd} = 0.16\left[3N^2BR_w + 5\left(100 + N^2\right)D_f R'_w\right]$
(c) $q_{nd} = 0.16\left[3D_f R'_w + 5\left(100 + N^2\right)N^2BR_w\right]$ (d) $q_{nd} = 0.16\left[3N^2BR_w + 5\left(100 + N^2\right)D_f R'_w\right]$
where, the symbols have their usual meanings.

(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) The primary function of geogrid is
(a) separation (b) filtration
(c) drainage (d) reinforcement.

(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 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. [(CO1)(Evaluate/HOCQ)]

(b) A 15 m long RCC pile ($EI = 4.5 \times 10^7$ N-m^2) 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/m^3, $A_y = 2.435$, $B_y = 1.623$, $A_s = -1.623$, $B_s = -1.750$, $A_m = 0$, $B_m = 1$]. [(CO1)(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) From	To	Soil properties
0	2	Silt, saturated, $\gamma = 16$ kN/m^3
2	4	Clay, saturated, $\gamma = 18$ kN/m^3
4	12	Clay, saturated, $\gamma = 18$ kN/m^3, $q_u = 120$ kN/m^2, $e_0 = 0.8$, $C_c = 0.23$
12	14	Clay, $\gamma = 17$ 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. [(CO2) (Evaluate/HOCQ)]

4 + 4 + 4 = 12

3. (a) Determine the allowable pile load capacity of the 50 cm diameter driven concrete pile (Fig. 1) for a factor of safety of 2.5. [Given: N_q = 120, N_γ = 109.41, α = 0.95, δ/ϕ = 1]. [(CO1) (Evaluate/HOCQ)]

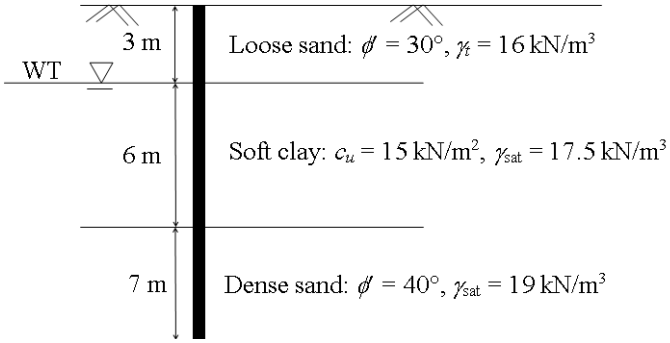

Fig. 1

(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.

[(CO2)(Evaluate/HOCQ)]

8 + 4 = 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/m^3, 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 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. [(CO5)(Evaluate/HOCQ)]

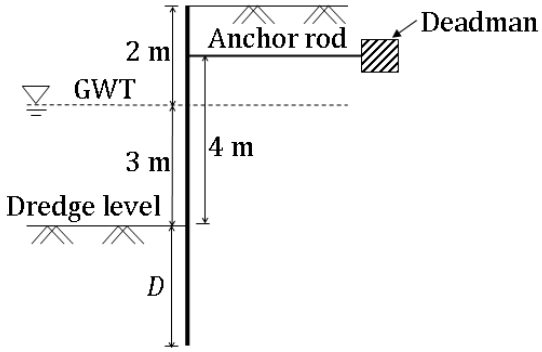

Fig. 2

(b) A footing of size 3 m × 3 m is to be constructed at a site at a depth of 1.5 m below ground surface. The water table is at the base of the foundation. The average static cone penetration resistance of the cohesive soil obtained at the site is 30 kg/cm^2. Determine the safe bearing pressure for a settlement of 40 mm. [(CO4)(Evaluate/HOCQ)]

10 + 2 = 12

7. (a) Fig.3 shows a cantilever sheet pile wall penetrating a granular soil. Determine (i) Theoretical depth of embedment (D). [(CO5)(Evaluate/HOCQ)]

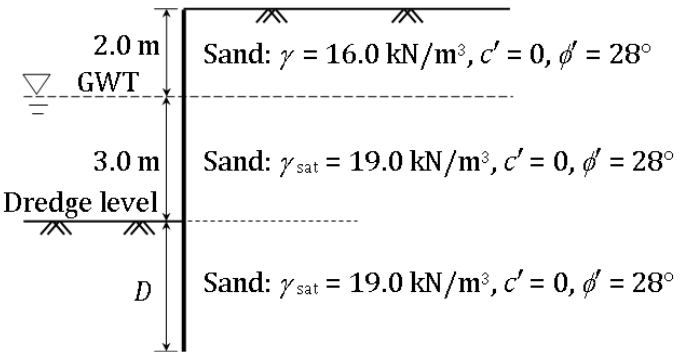

Fig. 3

(b) Two plate load tests were conducted at the level of prototype foundation in cohesionless soil. The following data are given:

Size of plate	Load applied (kN)	Settlement recorded (mm)
0.3 m × 0.3 m	30	25
0.6 m × 0.6 m	90	25

If a square footing has to carry a load of 800 kN, determine the required size of the footing for same settlement of 25 mm. [(CO4)(Evaluate/HOCQ)]

8 + 4 = 12

Group – E

8. (a) Define ground improvement. What are the different types of ground improvement methods? [(CO6)(Understand/LOCQ)]

   (b) Explain vibrocompaction with the help of a neat sketch. [(CO6)(Understand/LOCQ)]

   (c) Describe the separation and moisture barrier functions of geosynthetics. [(CO6)(Understand/LOCQ)]

   4 + 4 + 4 = 12

9. (a) Distinguish between principles of ground improvement in cohesive and cohesionless soils. [(CO6)(Understand/LOCQ)]

   (b) Explain different types of nails used in soil nailing. [(CO6)(Understand/LOCQ)]

   (c) Describe different types of drains (with neat sketches) used in preconsolidation method. [(CO6) (Understand/LOCQ)]

   4 + 4 + 4 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	34	0	66

Course Outcome (CO):

After the completion of the course students will be able to

CO1 Determine the load carrying capacity of pile foundation.
CO2 Compute the efficiency and settlement of pile group.
CO3 Understand different subsoil exploration methods and interpret field and laboratory testdata to obtain design parameters for geotechnical analysis.
CO4 Correlate bearing capacity of shallow foundation from field test data.
CO5 Analyze and design sheet pile structure on the basis of earth pressure theories.
CO6 Understand and apply various types of ground improvement methods for solving complexgeotechnical problems.

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