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) If, N_c = 6, then the net ultimate bearing capacity of a surface footing in cohesive soil (ϕ = 0, unconfined compressive strength = 50 kN/m^2) is
(a) 300 kN/m^2 (b) 150 kN/m^2 (c) 250 kN/m^2 (d) 125 kN/m^2.

(ii) Terzaghi suggests that the parameters c_m and ϕ' for local shear failure, in terms of c and ϕ for general shear failure as
(a) $c_m = \frac{2}{3}c$ and $\phi_m = \tan^{-1}\left(\frac{2}{3}\tan\phi\right)$ (b) $c_m = \frac{1}{3}c$ and $\phi_m = \tan^{-1}\left(\frac{2}{3}\tan\phi\right)$
(c) $c_m = \frac{2}{3}c$ and $\phi_m = \tan^{-1}\left(\frac{1}{3}\tan\phi\right)$ (d) $c_m = \frac{1}{3}c$ and $\phi_m = \tan^{-1}\left(\frac{1}{3}\tan\phi\right)$.

(iii) Immediate settlement is given by
(a) $S_i = qB\frac{1-\mu^2}{E}I_f$ (b) $S_i = qE\frac{1-\mu^2}{B}I_f$ (c) $S_i = EB\frac{1-\mu^2}{q}I_f$ (d) $S_i = qB\frac{1-2\mu^2}{E}I_f$

(iv) As per IS: 2131, the weight and height of free fall of hammer, respectively in SPT test are
(a) 63.5 kg and 750 mm (b) 65.5 kg and 750 mm
(c) 63.5 kg and 650 mm (d) 65.5 kg and 650 mm.

(v) The sampler is used in SPT test is
(a) thin-walled sampler (b) open drive sampler
(c) split-barrel sampler (d) compressed air sampler.

(vi) The spacing of borehole for high-rise and industrial structures should be
(a) (10 – 20) m (b) (15 – 40) m (c) (30 – 60) m (d) greater than 60 m.

(vii) A static cone penetrometer test gives the following values at 8 m depth; q_c = 15 MPa and f_s = 60 kPa. The friction ratio.
(a) 0.3% (b) 0.4% (c) 0.2% (d) 0.5%.

(viii) The 'group efficiency' of a pile group
(a) is always less than 100%
(b) is always greater than 100%
(c) may be less than 100% or more than 100% depending upon the type of soil, only
(d) may be less than 100% or more than 100% depending upon the type of soil, method of installation, and pile spacing.

(ix) If the diameter of the pile is D, then the minimum spacing of friction pile in a group as per IS code is
(a) 2.5D (b) 3D (c) 3.5D (d) 2D.

(x) The anchor in an anchored bulkhead is under
(a) Compression (b) Shear (c) Tension (d) Torsion.

Group - B

2. (a) A square footing of 2 m × 2 m size has been founded at 1.2 m below the ground level in a cohesive soil having a bulk unit weight of 18 kN/m^3 and an unconfined compressive strength of 70 kN/m^2. Determine the ultimate and safe bearing capacity of the footing for a factor of safety of 2.5, by (i) Terzaghi's theory and (ii) Skempton's theory. [(CO1)(Evaluate/HOCQ)]

(b) Design a raft foundation, 14 m × 20 m in plan which is to be placed at 1.5 m below GL in the subsoil shown in the Fig.1. The net foundation pressure is 80 kN/m^2. Take depth correction factor as 1. Assume the footing to be rigid. The permissible settlement of the raft foundation is 125 mm. Use Skempton's equation. The minimum factor of safety against shear failure may be taken as 2.5. [Given: μ = 0.5, I_f = 1.2, λ = 0.7 and $E = 600c$]. [(CO1)(Evaluate/HOCQ),(CO2)(Evaluate/HOCQ)]

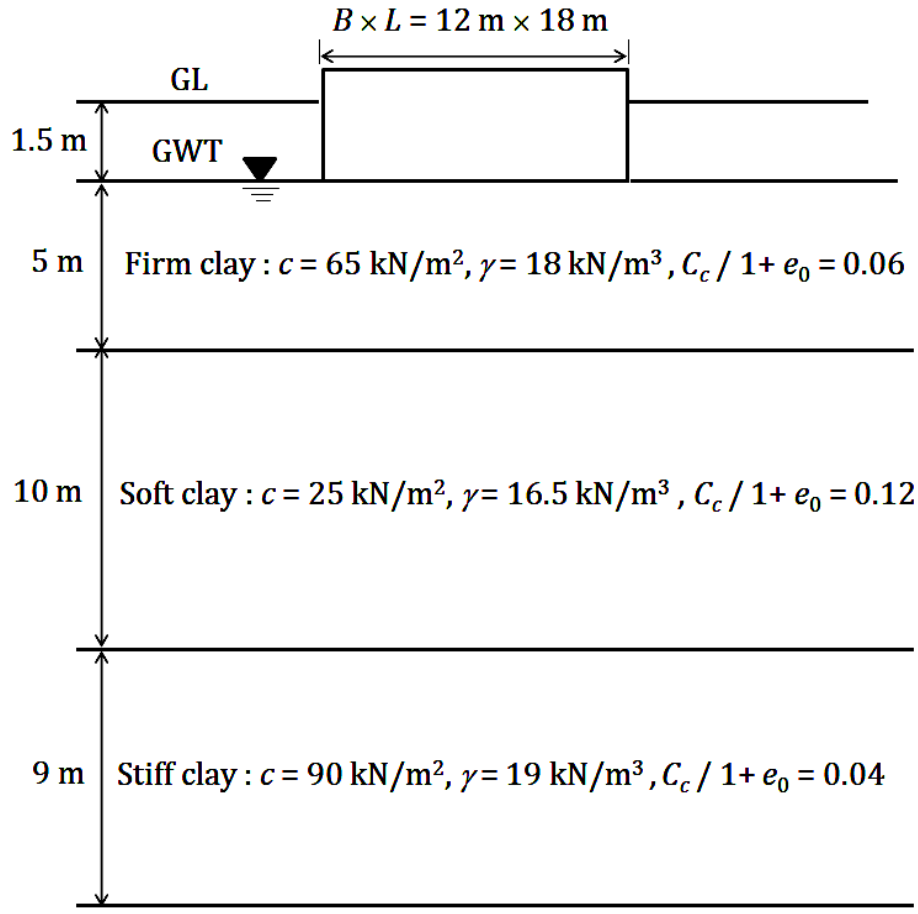

Fig.1

4 + 8 = 12

3. (a) A circular footing of 2 m diameter is founded at a depth of 1.5 m below ground level in a soil (c = 17 kN/m^2, ϕ = 30°, saturated unit weight = 18 kN/m^3). Determine the safe bearing capacity of the footing when the ground water table is located at a great depth. Also calculate the percent change in the safe bearing capacity of the footing if the water table rises to the ground level. Assume general shear failure. The factor of safety should be taken as 3.0. Use IS code method. [Given: for ϕ= 30°, N_c = 30.14, N_q = 18.40, N_γ = 22.40]. [(CO1)(Evaluate/HOCQ)]

(b) A 2.5 m square footing resting at 1.5 m below GL in a sand (unit weight = 18 kN/m^2) deposit. The net pressure at foundation level is 260 kN/m^2. The variation of cone penetration resistance, q_c with depth is shown in Fig.2. Determine the settlement of the using IS code method. Take depth correction factor as 0.7. [(CO2)(Evaluate/HOCQ)]

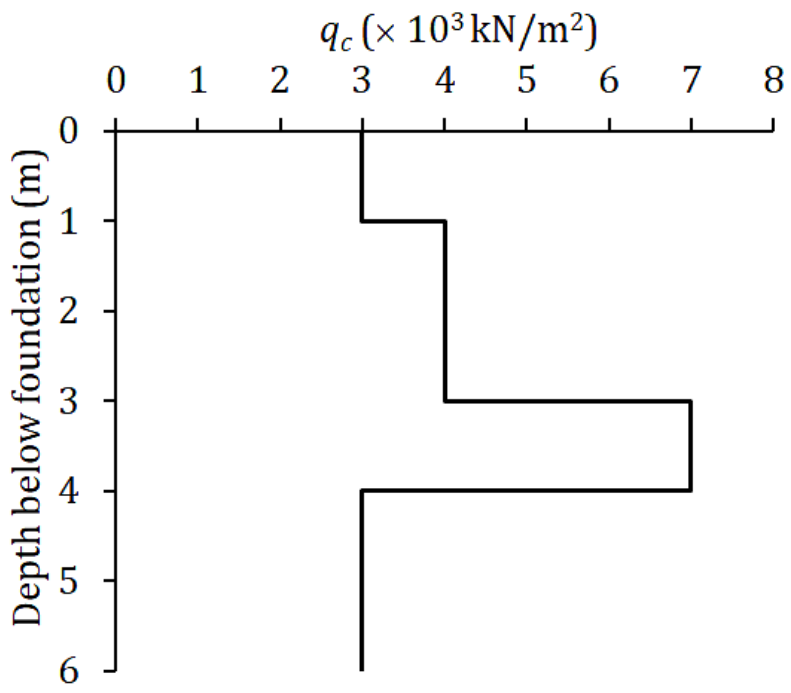

Fig.2

5 + 7 = 12

Group - C

4. (a) Determine the probable wall thickness of a sampling tube of 86 mm external diameter which is required for sampling in stiff to very stiff clay. [(CO3)(Evaluate/HOCQ)]
   (b) Describe Static Cone Penetration test. [(CO3)(Understand/IOCQ)]
   (c) The observed standard penetration test values in a deposit of fully submerged loose and dense sand were 31 and 42, respectively, at a depth of 7.3 m with hammer efficiency of 70%. The average unit weights of loose and dense sand are 16 and 17 kN/m^3, respectively. The other data given are: (i) drill rod length correction factor = 0.9 and (ii) 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. Write short notes on:
   (i) Seismic refraction method (ii) Percussion boring (iii) Field vane shear test.
   [(CO3)(Understand/IOCQ)]

(4 + 4 + 4) = 12

Group - D

6. (a) An RCC pile of 20 m overall length is driven into a deep stratum of medium stiff clay having an unconfined strength of 5 t/m^2. The diameter of the pile is 24 cm. Determine the safe load that can be carried by the pile with a factor of safety of 3.0. Take α as 0.75. [(CO4)(Evaluate/HOCQ)]
   (b) A 350 mm diameter concrete pile, 12 m long, was driven by a McKiernan and terry double acting hammer (total mass 2200 kg) falling through a height of 75 cm. The driving was done with a short dolly and cushion 2 m. The average penetration in the last five blows was 10 mm/blow. Calculate the safe pile load. Assume unit weight of concrete as 24 kN/m^3. [Given: Coeff. of restitution = 0.5 and hammer efficiency = 85%]. Take factor of safety as 2.5. Use modified Hiley's method. [(CO4)(Evaluate/HOCQ)]
   (c) A group of 16 piles with 4 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 30 cm and 10 m, respectively. The unconfined compressive strength of the clay is 56 kPa. If the piles were placed at 90 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 α as 0.8. [(CO5)(Evaluate/HOCQ)]

4 + 4 + 4 = 12

7. (a) The column of a footing founded at a depth of 1.5 m below GL and is supported by a number of driven piles (length = 14 m and diameter = 500 mm). The subsoil consists of three layers, the properties of which are given below:
   Layer I: Thickness = 8 m, c = 25 kN/m^2, $\phi = 0°$, γ = 17 kN/m^3
   Layer II: Thickness = 3 m, c = 40 kN/m^2, $\phi = 0°$, γ = 19 kN/m^3
   Layer III: Thickness = 15 m, c = 0 kN/m^2, $\phi = 30°$, γ = 18 kN/m^3
   Determine the safe load on each pile if the required factor of safety is 2.5. [Given: K_s = 1.0, N_q = 29, N_γ = 22.4, $\delta/\phi = 1$ and α = 0.85]. [(CO4)(Evaluate/HOCQ)]
   (b) A steel pipe pile of 61 cm outside diameter with a wall thickness of 2.5 cm is driven into loose sand (D_r = 30%) under submerged condition to a depth of 20 m. The submerged unit weight of the soil is 9 kN/m^3 and the angle of internal friction is 33°. The EI value of the pile is 4×10^2 MN-m^2. Compute the ground line deflection of the pile under a lateral load of 280 kN at GL when the head is fixed against rotation. Use Reese and Matlock method. [Given: A_y = 2.435, B_y = 1.623, A_s = -1.623, B_s = -1.75, A_m = 0, B_m = 1, coefficient of subgrade modulus = 5 MN/m^3]. [(CO4)(Evaluate/HOCQ)]
   (c) In a 25-pile group, the pile diameter is 45 cm and the centre to centre spacing of the pile is 1.5 m. If, c = 50 kN/m^2, determine whether the failure would occur with the pile acting individually, or as a group? Neglect bearing at the tip of the pile. All piles are 10 m long. Assume adhesion factor of 0.7 around each pile.
   [(CO5)(Evaluate/HOCQ)]

6 + 3 + 3 = 12

Group - E

8 Determine the theoretical depth of embedment and actual depth of embedment [D_{actual} = 1.4D_{theory}], for the cantilever sheet piling shown in Fig.3. The soil is cohesive in nature with unconfined compressive strength of 55 kN/m^2 and unit weight of 16 kN/m^3. [(CO6) (Evaluate/HOCQ)]

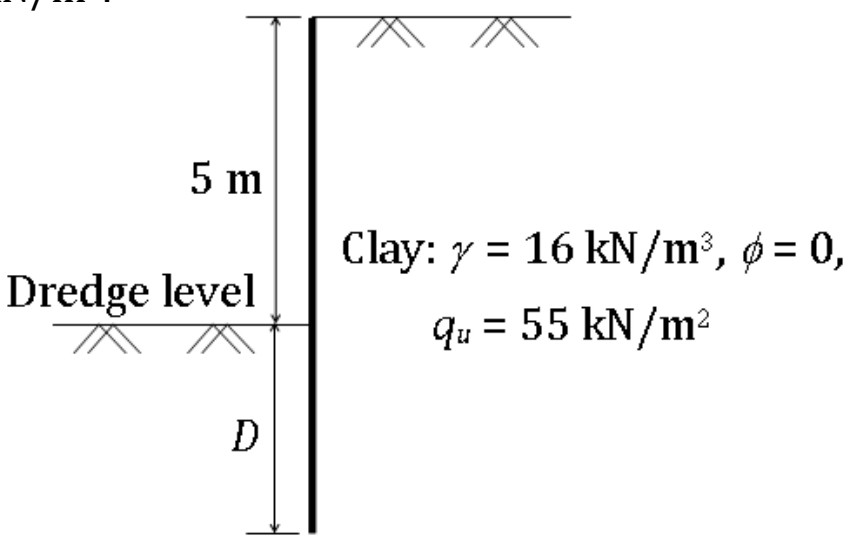

Fig.3

12

9 Determine the theoretical depth of embedment, actual depth of embedment [D_{actual} = 1.15D_{theory}] and the force in the tie rod for the anchored bulkhead (Fig. 4) by free earth support method. The backfill and the soil below the dredge line are sand, having the following properties: G = 2.75, e = 0.8 and ϕ = 30°. Assume the soil above the water table is dry. [(CO6) (Evaluate/HOCQ)]

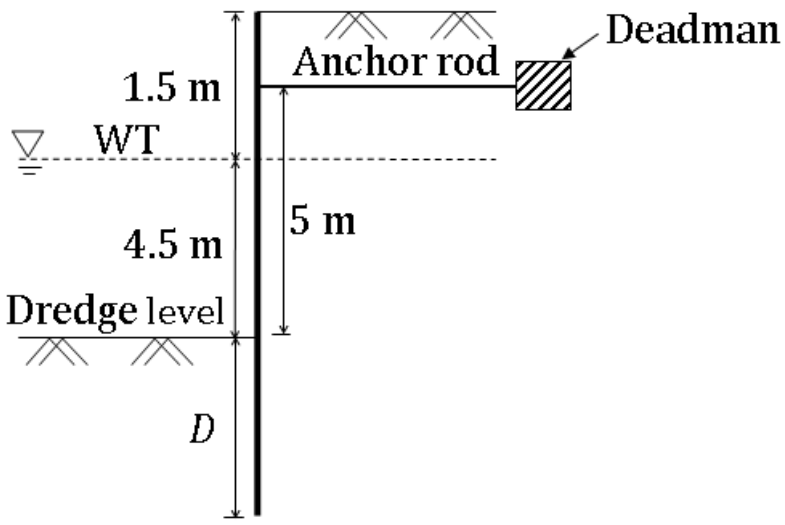

Fig.4

12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	0	16.67	83.33

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