FOUNDATION ENGINEERING
(CIVL 3141)

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) Local shear failure is associated with soils having
(a) high compressibility (b) high pore pressure
(c) low porosity (d) low compressibility.

(ii) Two footings, one circular and the other square, are founded in pure clay. The diameter of the circular footing is the same as the side of the square footing. The ratio of their net ultimate bearing capacities is
(a) 1 (b) 2
(c) $\frac{1}{2}$ (d) $\frac{1}{3}$.

(iii) If the gross bearing capacity of a 1.5 m wide strip footing located at a depth of 1 m in clay is 400 kN/m^2, its net bearing capacity for γ = 20 kN/m^3 is
(a) 370 kN/m^2 (b) 350 kN/m^2
(c) 380 kN/m^2 (d) 360 kN/m^2.

(iv) As per IS code, the ratio of total settlement of a rigid foundation to the total settlement at the centre of a flexible foundation is
(a) 0.7 (b) 0.8
(c) 0.9 (d) 0.6.

(v) In-situ vane shear strength is used to measure shear strength of
(a) very soft and sensitive clays (b) stiff and fissured clays
(c) sandy soils (d) all of the above.

(vi) As per IS code, the apex angle and base area of the cone in Static Cone Penetration Test (SCPT) are, respectively
(a) 60° and 15 cm^2 (b) 60° and 10 cm^2
(c) 30° and 10 cm^2 (d) 30° and 15 cm^2.

(vii) For an undisturbed sample, the area ratio of the sampler should be
(a) zero (b) 10 % or less
(c) 10 % to 20 % (d) more than 20 %.

(viii) The negative skin friction on a pile develops when
(a) the soil in which it is driven is sandy soil (b) the soil surrounding it settles more than the pile
(c) the ground water table rises (d) the soil near the tip is clay.

(ix) Dynamic formulae are best suited for
(a) Fine-grained soil (b) Coarse-grained soil
(c) Cohesive soil (d) All of the above.

(x) The passive resistance is reduced by a factor of safety in
(a) free earth support method of analysis (b) fixed earth support method of analysis
(c) analysis of cantilever sheet piles (d) all of the above methods of analysis.

Fill in the blanks with the correct word

(xi) Size effects in plate load tests are more important in the case of _____ soils .

(xii) The observed *N* value of a SPT is 21, the *N* value after correcting for dilatancy is_____.

(xiii) The maximum permissible differential settlement for isolated foundation on clay as per IS code is _____.

(xiv) Terzaghi suggests that the parameters *c*′ for local shear failure, in terms of *c* for general shear is _____*c*.

(xv) The minimum centre to centre distance between the piles of a pile group in clayey soil should be equal to _____ times the pile diameter.

Group - B

2. (a) Determine the net ultimate bearing capacity of a rectangular footing 2 m × 3 m in plan, founded at a depth of 0.8 m below the ground surface. The load on the footing acts at an angle of 13° to the vertical and is eccentric in the direction of width by 20 cm. The cohesion, friction angle and saturated unit weight of the soil are 16 kN/m^2, 25° and 18 kN/m^3, respectively. The ground water table is at a depth of 1.5 m below the ground surface. Use IS: 6403-1981 recommendations. [Given: for $\phi = 25°$, $N_c = 20.72$, $N_q = 10.66$, $N_\gamma = 10.88$]. *[(CO1)(Evaluate/HOCQ)]*

(b) A plate load test on a uniform deposit of sand (unit weight = 18 kN/m^3) was conducted and the pressure vs. settlement data is given in Table 1. The size of the plate was 750 mm × 750 mm and that of the pit 3.75 m × 3.75 m × 1.5 m. A square footing of size 2.5 m × 2.5 m is to be founded at 1.5 m depth in this soil. Assuming the factor of safety against shear failure as 3 and the maximum permissible settlement as 25 mm, determine the allowable bearing pressure. Design the footing for a load of 2000 kN. The water table is at a great depth. Use Terzaghi's theory. [Given: $N_q = 50$, $N_\gamma = 67$]. *[(CO1, CO2)(Evaluate/HOCQ)]*

Table 1: Pressure vs. settlement data from Plate Load Test

Pressure (kN/m^2)	Settlement (mm)
100	2
200	4.5
300	7
350	10
400	12
450	16
500	20
550	27
600	40

6 + 6 = 12

3. (a) A circular footing of 1.5 m diameter is founded at a depth of 0.9 m below ground level in a soil (c = 20 kN/m^2, $\phi = 28°$, γ_{sat} = 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. The factor of safety should be taken as 2.5. Use Terzaghi's theory. [Given: for $\phi = 28°$, $N_c = 32.5$, $N_q = 18.8$, $N_\gamma = 15.7$]. *[(CO1)(Evaluate/HOCQ)]*

(b) A footing 4 m × 2 m in plan transmits a pressure of 467 kN/m^2 on a cohesive soil having modulus of elasticity as 4×10^4 kN/m^2 and Poisson's ratio as 0.4. Determine the immediate settlement of the footing at the centre assuming it to be (i) flexible and (ii) rigid. [Given: I_f = 1.53 and 1.20 for flexible and rigid footings, respectively]. Take depth correction factor as 1.0. *[(CO2)(Evaluate/HOCQ)]*

8 + 4 = 12

Group - C

4. (a) Summarize the principal objectives of the site investigation. *[(CO3)(Understand/IOCQ)]*
(b) Demonstrate undisturbed sample. *[(CO3)(Understand/IOCQ)]*
(c) Describe split-spoon sampler. *[(CO3)(Remember/LOCQ)]*

4 + 4 + 4 = 12

5. (a) The observed standard penetration test values in a deposit of loose and dense sand were 25 and 40, respectively, at a depth of 8 m with hammer efficiency of 80%. The average unit weight of loose and dense sand is 16 and 17.5 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)]*

(b) Explain wash boring stating its advantages and disadvantages. *[(CO3)(Understand/IOCQ)]*

6 + 6 = 12

Group - D

6. (a) A precast concrete pile (45 cm × 45 cm) is driven by a single-acting steam hammer. Estimate the allowable load using (i) Engineering News Record formula and (ii) Modified Hiley formula with factor of safety of 4. Use the following data: Maximum rated energy = 3000 kN-cm, Weight of hammer = 35 kN, Length of pile = 25 m, Efficiency of hammer = 0.8, Coefficient of restitution = 0.5, Weight of pile cap = 3 kN, No. of blows for last 25.4 mm = 6, Unit weight of concrete = 24 kN/m^3. *[(CO4)(Evaluate/HOCQ)]*

(b) A group of 16 piles, each having a diameter of 35 cm and 10 m long are arranged in 4 rows at spacing of 1.2 m c/c. The capacity of each pile is 400 kN. Determine the group capacity of the piles. *[(CO5)(Evaluate/HOCQ]*

8 + 4 = 12

7. (a) A concrete pile of 40 cm diameter is driven to a depth of 30 m through a layered system of dry sandy soil. The following data are available:
(i) Top layer - I: Thickness = 8 m, γ_d = 15 kN/m^3, $\phi = 30°$.
(ii) Layer - II: Thickness = 9 m, γ_d = 16 kN/m^3, $\phi = 35°$.

(iii) Layer - III: Extends to a great depth, $\gamma_d = 17$ kN/m^3, $\phi = 40°$.
Calculate the safe load on the pile with factor of safety of 2.5. [Given: $N_q = 100$, $N_\gamma = 109.41$ and $\delta/\phi = 1$].

[(CO4)(Evaluate/HOCQ]

(b) A group of 25 piles with 5 piles in a row were driven into 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 50 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. *[(CO4, CO5)(Evaluate/HOCQ]*

8 + 4 = 12

Group - E

8. Fig. 1 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 165 MPa. *[(CO6)(Evaluate/HOCQ)]*

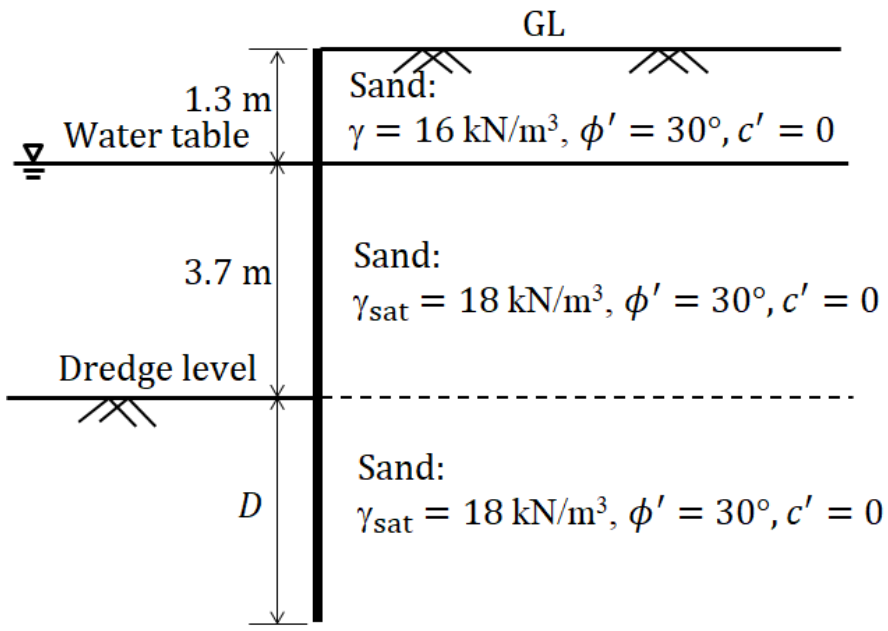

Fig. 1

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9. Determine the theoretical depth (D_{theory}) of embedment, actual depth (D_{actual}) of embedment [$D_{actual} = 1.4D_{theory}$], and the force in the anchor rod for the anchored bulkhead (Fig. 2) by free earth support method. The backfill is sand having $\phi = 30°$ and the soil below the dredge line is clay, having $c = 20$ kN/m^2. For both the soil, assume $G = 2.6$, and $e = 1.0$ and the soil above the water table is dry. *[(CO6)(Evaluate/HOCQ)]*

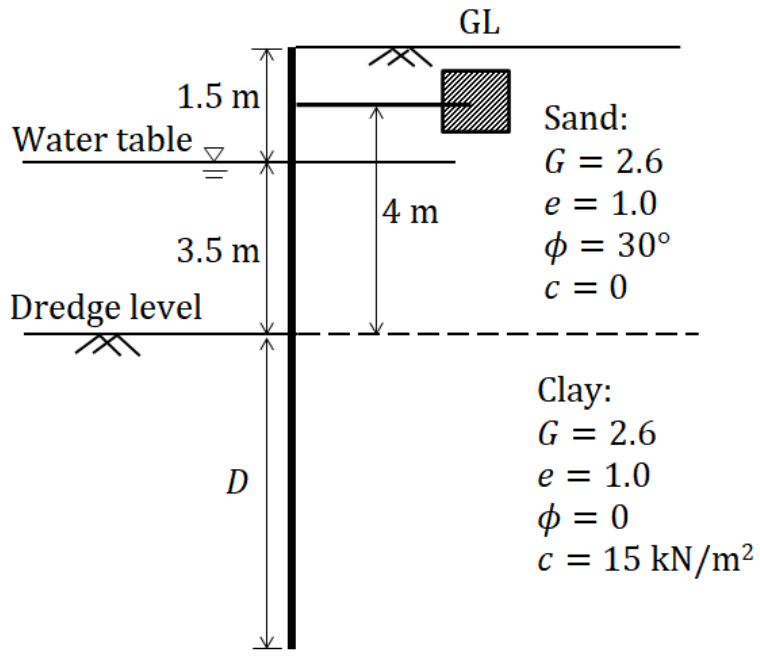

Fig. 2

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Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	4.17	14.58	81.25

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.*