

**FOUNDATION ENGINEERING**  
**ENCE 302**

Year/Part: III/I

| Teaching Schedule |   |   |       | Examination Scheme |                |       |                  |                | Total |       |
|-------------------|---|---|-------|--------------------|----------------|-------|------------------|----------------|-------|-------|
| L                 | T | P | Total | Theory             |                |       | Practical        |                |       |       |
|                   |   |   |       | Assessment Marks   | Final          |       | Assessment Marks | Final          |       |       |
|                   |   |   |       |                    | Duration (Hrs) | Marks |                  | Duration (Hrs) |       | Marks |
| 3                 | 2 | 1 | 6     | 40                 | 3              | 60    | 25               | 0              | 0     | 125   |

**Depth Codes**

|                     |                  |                     |                             |
|---------------------|------------------|---------------------|-----------------------------|
| D-Definition        | E-Explanation    | DES-Describe        | DIS-Discussion              |
| DV-Derivation       | DM-Demonstration | I-Illustration      | REV-Review / Recap          |
| NUM-Numerical       | DEG-Design       | EXP-Experiment      | S-State                     |
|                     | MP- Mini Project | PS- Problem Solving | ACT-Activity-based Learning |
| QA- Question Answer | Q- Quiz          | ST- Surprise Test   | MT-Mid Term Test            |

| Unit     | Topic/ Sub topic  | Depth Code                         | Description of Depth   | Actual plan |          |           | Week       |
|----------|---|------------------------------------|--|-------------|----------|-----------|------------|
|          |   |                                    |  | L           | T        | P         |            |
| <b>1</b> | <b>Geotechnical Investigation</b>   |                                    |  | <b>8</b>    | <b>4</b> | <b>15</b> | <b>1-3</b> |
| 1.1      | Geotechnical investigation; Objective and scope   | D<br>E<br>S                        | Site Investigation-Introduction<br>Importance of investigation<br>Objective and scope  | 0.5         |          |           |            |
| 1.2      | Stages and extent of site exploration   | E<br>DIS<br><br>E, I               | Different stages (Preliminary, detailed, during construction, Performance monitoring) of exploration<br>Extent of exploration (Spacing and depth) with illustrative example of different physical infrastructures i.e., Building, Bridges, Embankment, Highway, Railway and Airport etc.   | 1           |          |           |            |
| 1.3      | Methods of site exploration: Accessible, inaccessible and indirect methods  | E, I,<br>DM,<br>DIS                | Accessible: Methods (Pit/trench), suitability, advantages and disadvantages<br>Inaccessible: Methods/procedure/equipment (Drilling/boring: Auger, wash, percussion, rotary), suitability, advantages and disadvantages<br>Indirect methods: Suitability, advantages and disadvantages  | 1.5         | 1        | 4         |            |
| 1.4      | Soil sampling (Disturbed and undisturbed) and samplers  | E,<br>REV,<br>I, DM,<br>DIS<br>NUM | Disturbed and undisturbed soil sample<br>Their use on determination of soil properties (recap/review on soil testing)<br>Soil samplers: Requirement of soil samplers<br>Types of samplers: Procedure, suitability and key features.<br>Numerical examples (Sampler requirements)   | 1           | 1        | 9         |            |
| 1.5      | Field tests (Standard penetration test, static cone penetration test, dynamic cone penetration test, pressure meter tests and dilatometer test) | E,<br>DM,<br>DIS,<br>NUM           | Standard penetration test (SPT): Equipment, Field procedure and observation, suitability, advantages and limitations<br>Factors affecting SPT, corrections (dilatancy, overburden, energy etc.) and applications of SPT value<br>Cone penetration test (CPT): Equipment, Field procedure and observation, suitability, advantages and disadvantages<br>Applications and limitation of penetration values<br>Dynamic cone penetration test (DCPT): Equipment, Field procedure and observation, suitability, | 1.5         |          | 2         |            |

| Unit | Topic/ Sub topic                          | Depth Code        | Description of Depth  | Actual plan |   |   | Week |
|------|---|-------------------|---|-------------|---|---|------|
|      |   |                   |   | L           | T | P |      |
|      |   |                   | advantages and disadvantages<br>Pressure meter tests (PMT): Equipment, Field procedure and observation, usages, suitability, advantages and disadvantages<br>Dilatometer tests (DMT): Equipment, Field procedure and observation, usages, suitability, advantages and disadvantages<br>Numerical example on SPT |             |   |   |      |
| 1.6  | Groundwater observation and borehole logs | DES<br>DEM<br>DIS | Different methods of groundwater observations, its importance in geotechnical analysis<br>Typical borehole logs, its importance and key features  | 0.5         |   |   |      |
| 1.7  | Geophysical tests and their application   | D<br>I            | Geophysical tests: Seismic, electrical, MASW, GPR and their applications  | 1           |   |   |      |
| 1.8  | Evaluation of liquefaction potential (LP) | D<br>DEM<br>NUM   | Liquefaction-definition<br>Factors affecting liquefaction (Parameters required for liquefaction evaluation)<br>Methods of LP evaluation<br>Numerical example on evaluation of LP  | 1           | 2 |   |      |
|      | Evaluation                                | Q/A<br>Q<br>ST    | Question after each sub-topic<br>Quiz after completion of the unit  |             |   |   |      |

| Unit     | Topic/ Sub topic                      | Depth Code      | Description of Depth   | Actual plan |          |          | Week       |
|----------|---------------------------------------|-----------------|--|-------------|----------|----------|------------|
|          |                                       |                 |  | L           | T        | P        |            |
| <b>2</b> | <b>Slope Stability Analysis</b>       |                 |  | <b>4</b>    | <b>4</b> | <b>0</b> | <b>3-4</b> |
| 2.1      | Types of slopes and possible failures | DES,<br>REV     | Finite and infinite slopes, actuating forces, and failure modes (rotational, translational, compound, wedge etc.)  | 1           |          |          |            |
| 2.2      | Analysis of infinite slopes           | D<br>DV,<br>NUM | Introduction to Limit equilibrium approach; slope stability analysis of infinite slope; Cohesionless soil(Dry, seepage and submerged condition); cohesive soil (dry, seepage and submerged condition); Comparison between cohesionless and cohesive soil , Definitions of FOS. | 1           | 1        |          |            |
| 2.3      | Analysis of finite slopes             | DES,<br>NUM     | ( $\phi_u=0$ including Submerged slope and tensile crack effect, friction circle method, method of slices) and location of most critical slip circle   | 1.5         | 2        |          |            |
| 2.4      | Use of stability charts               | DES,<br>NUM     | Use of Taylor stability chart  | 0.5         | 1        |          |            |
|          | Evaluation                            | Q/A<br>Q<br>ST  | Question after each sub-topic<br>Quiz after completion of the unit   |             |          |          |            |

| Unit     | Topic/ Sub topic                              | Depth Code | Description of Depth  | Actual plan |          |          | Week       |
|----------|---|------------|---|-------------|----------|----------|------------|
|          |   |            |   | L           | T        | P        |            |
| <b>3</b> | <b>Earth Pressure Theories</b>                |            |   | <b>5</b>    | <b>3</b> | <b>0</b> | <b>5-6</b> |
| 3.1      | Earth pressure and slope retaining structures | E<br>DIS   | Introduction (Compare Lateral Pressure in fluids and grains)<br>Common Slope retaining structures (Abutment walls, Sheet pile walls, Braced walls, Basement walls etc.) | 0.5         |          |          |            |

| Unit | Topic/ Sub topic                          | Depth Code     | Description of Depth  | Actual plan |   |   | Week |
|------|---|----------------|---|-------------|---|---|------|
|      |   |                |   | L           | T | P |      |
| 3.2  | Wall movement and types of earth pressure | E              | Relationship between wall movement and Earth Pressure; Earth Pressure at rest (Elastic theory and empirical approaches; Active earth Pressure and Passive Earth Pressure based on theory of plastic equilibrium.  | 0.5         |   |   |      |
| 3.3  | Rankine earth pressure theory             | DV<br>NUM      | Active and Passive Earth Pressure for Cohesionless backfill (Horizontal and Inclined), orientation of failure planes, its modification for cohesive Backfill; Approach to apply Rankine's Theory for non-vertical face of wall.<br>Numerical Problems         | 2           | 2 |   |      |
| 3.4  | Coulomb earth pressure theory             | DV<br>E<br>NUM | Columb's theory for cohesionless backfill for active and passive cases based on theory of limiting equilibrium.<br>Forces acting in case of cohesive backfill.<br>Numerical problem.  | 1           | 1 |   |      |
| 3.5  | Culmann's graphical solution              | E<br>DM        | Culmann's graphical construction for active and passive cases.<br>Demonstration taking the case of vertical back of wall and horizontal backfill and comparing the result of earth pressure force and orientation of the failure plane with Rankine's theory. | 1           |   |   |      |
|      | Evaluation                                | UT             | Unit test after completion of the unit.   |             |   |   |      |

| Unit     | Topic/Subtopic  | Depth Code                   | Description of Depth  | Actual plan |          |          | Week       |
|----------|---|------------------------------|---|-------------|----------|----------|------------|
|          |   |                              |   | L           | T        | P        |            |
| <b>4</b> | <b>Bearing Capacity Theories</b>                      |                              |   | <b>4</b>    | <b>3</b> | <b>0</b> | <b>7-8</b> |
| 4.1      | Basic terminologies and their relationships           | D<br>DES                     | Basic terminologies: Foundation width, depth, ultimate bearing capacity, net ultimate bearing capacity, safe bearing capacity, bearing pressure, allowable bearing capacity   | 0.5         |          |          |            |
| 4.2      | Types of shear failure                                | D, E                         | General, local and punching shear failure   | 0.5         |          |          |            |
| 4.3      | History and development of bearing capacity theories  | D<br>DV<br>DES               | Poker, Bell's, Prandtl bearing capacity theories  | 0.5         |          |          |            |
| 4.4      | Terzaghi's bearing capacity theory                    | D<br>DES<br>DV<br>DIS<br>NUM | Assumptions and derivation of bearing capacity for strip foundation.<br>Bearing capacity factors<br>General, local, and punching shear failure<br>Determination of bearing capacity for general and local shear failure<br>Numerical examples | 1.5         | 1        |          |            |
| 4.5      | Corrections on Terzaghi's bearing capacity equation   | DV<br>DIS<br>NUM             | Shape and water table correction factors<br>Discussion on the importance of correction and<br>Evaluation of bearing capacity using different corrections  | 0.5         | 1.5      |          |            |
| 4.6      | Skempton, Meyerhof, Brinch Hansen and Vesic's methods | DV<br>DIS<br>NUM             | Concept and development of the bearing capacity formula, with different corrections applied<br>Skempton method and its applicability in clayey soil   | 0.5         | 0.5      |          |            |
|          | Evaluation  | Q/A<br>Q<br>ST               | Question after each sub-topic<br>Quiz after completion of the unit<br>Surprise test   |             |          |          |            |

| Unit     | Topic/Subtopic  | Depth Code               | Description of Depth  | Actual plan |          |   | Week        |
|----------|---|--------------------------|---|-------------|----------|---|-------------|
|          |   |                          |   | L           | T        | P |             |
| <b>5</b> | <b>Analysis of Shallow Foundation</b>                           |                          |   | <b>7</b>    | <b>5</b> |   | <b>9-10</b> |
| 5.1      | Shallow foundation and its types                                | D<br>DES                 | List of different types of shallow foundation and their applications  | 0.5         |          |   |             |
| 5.2      | Settlement of foundation, its types and effects                 | D<br>DES<br>DV           | Type of settlements<br>Evaluation of settlement<br>Permissible settlement   | 1           |          |   |             |
| 5.3      | Allowable bearing capacity of strip and isolated footings       | DV<br>NUM                | Determination of safe bearing pressure<br>Allowable bearing capacity<br>Numerical examples  | 1           | 1        |   |             |
| 5.4      | Bearing capacity from in-situ tests and laboratory test results | DES<br>DEM<br>DEV<br>NUM | Plate load test<br>Bearing capacity from the plate load test<br>Bearing capacity from SPT (Teng )<br>Numerical examples               | 1           | 2        |   |             |
| 5.5      | Safe bearing pressure   | DEV<br>NUM               | Settlement criteria: Teng, Meyerhof, Bowles, IS<br>Numerical examples   | 0.5         | 1        |   |             |
| 5.6      | Raft foundation and its types                                   | D<br>DES                 | Definition of raft foundation<br>Types of raft foundation and their suitability   | 0.5         |          |   |             |
| 5.7      | Bearing capacity of raft foundation                             | DES<br>DEV               | Bearing capacity for bearing capacity theories<br>From insitu tests<br>Floating/fully/partially compensated foundation                | 0.5         |          |   |             |
| 5.8      | Stress distribution and settlement of raft foundation           | DV<br>NUM                | Stress distribution and settlement of raft foundation<br>Numerical examples   | 1           | 1        |   |             |
| 5.9      | Foundation on stratified soil                                   |                          | Foundation on stratified soil<br>Soft layer over hard layer<br>Hard layer over soft layer<br>Soft layer sandwiched between hard layer | 1           |          |   |             |
|          | Evaluation  | MT                       | Mid-Term Test 1   |             |          |   |             |

| Unit     | Topic/ Sub topic   | Depth Code            | Description of Depth   | Actual plan |          |   | Week         |
|----------|--|-----------------------|--|-------------|----------|---|--------------|
|          |  |                       |  | L           | T        | P |              |
| <b>6</b> | <b>Analysis of Deep Foundation</b>   |                       |  | <b>6</b>    | <b>5</b> |   | <b>11-12</b> |
| 6.1      | Deep foundations: Pile, pier and caisson and their classification  | D<br>DES              | Introduction to deep foundation<br>Types of pile, pier and caisson<br>Uses of pile and factors affecting selection of pile type<br>Load Transfer mechanism on pile   | 0.5         |          |   |              |
| 6.2      | Load carrying capacity of single pile (Static, in-situ tests, dynamic and pile load test) and group action of pile | D<br>DV<br>DIS<br>NUM | Dynamic Pile Load formula (Engineering NEWS and Modified Hiley formula)<br>Pile Capacity from Static pile load formula (for cohesive and cohesionless soil)<br>Pile capacity from SPT number for driven and bored piles<br>Load test on pile<br>Allowable load on single and group of pile from load test on pile<br>Introduction to group action of pile and definition of group efficiency (Feld rule and Converse-Labarre Formula)<br>Minimum spacing criteria (IS 2911)<br>Ultimate pile load capacity of group of pile for cohesive (Block failure and individual pile failure) | 1.5         | 2.5      |   |              |

| Unit | Topic/ Sub topic                                      | Depth Code        | Description of Depth   | Actual plan |     |   | Week |
|------|---|-------------------|--|-------------|-----|---|------|
|      |   |                   |  | L           | T   | P |      |
|      |   |                   | Numerical examples   |             |     |   |      |
| 6.3  | Settlement of pile foundation                         | DES<br>DEV<br>NUM | Settlement of pile foundation in group for cohesive and cohesionless soil (Vessic Semi-empirical Formula)  | 0.5         | 1   |   |      |
| 6.4  | Lateral and uplift capacity of pile                   | DES<br>DEV<br>NUM | Introduction of Modulus of subgrade reaction (Winkler's Hypothesis)<br>Introduction of p-y curve for the solution of laterally loaded piles<br>Broom (1964) for the calculation of capacity<br>Uplift capacity of single pile and pile group in clay<br>Numerical examples | 0.5         | 1   |   |      |
| 6.5  | Construction and quality assurance of pile foundation | DIS<br>DES        | Construction of displacement piles (Hammer Driving, Jetting and partial Auguring) (description only)<br>Construction of Non-Displacement pile (Boring Method)- Dry Method, Casing Method and Slurry Method and their suitability (Description Only)                        | 0.5         |     |   |      |
| 6.6  | Negative skin friction                                | D<br>DV<br>NUM    | Definition<br>Causes of (Necessary conditions for developing) Negative skin friction<br>Mitigative measures to avoid Negative Skin Friction<br>Calculation of Negative Skin Friction for single and group of piles<br>Numerical including negative skin friction           | 0.5         | 0.5 |   |      |
| 6.7  | Analysis of pier foundation                           | DES<br>DV<br>NUM  | Design Consideration of Pier<br>Bearing Capacity equation for the base in cohesive soil<br>Bearing Capacity equation for the base in granular soil<br>Numerical examples   | 0.5         |     |   |      |
| 6.8  | Components of well (Caisson) foundation               | D<br>DES          | 1. Introduction and necessity of well foundation<br>2. Sketch showing all components of well foundation and their brief description  | 0.5         |     |   |      |
| 6.9  | Lateral stability of well foundation                  | DES<br>DV<br>NUM  | 1. Forces acting on well Foundation<br>2. Lateral Stability analysis Based on Bulkhead concept for Light and Heavy well<br>3. Numericals related to lateral stability of well  | 0.5         |     |   |      |
| 6.10 | Sinking of well, problems and remedial measures       | DES<br>DIS        | 1. Procedure of sinking of well<br>2. Types of Dredger used<br>3. Problems During sinking of well<br>4. Remedial measures for the problems during sinking  | 0.5         |     |   |      |
|      | Evaluation  | Q<br>Q/A<br>ST    | Question after each sub-topic<br>Quiz after completion of the unit<br>Surprise test  |             |     |   |      |

| Unit     | Topic/ Sub topic                               | Depth Code | Description of Depth   | Actual plan |          |   | Week      |
|----------|--|------------|--|-------------|----------|---|-----------|
|          |  |            |  | L           | T        | P |           |
| <b>7</b> | <b>Analysis of Foundation in Rock</b>          |            |  | <b>3</b>    | <b>1</b> |   | <b>13</b> |
| 7.1      | Basis for design of foundation on rock         | DES<br>DV  | Intact and rock mass properties<br>Mode of foundation failure in rock  | 2           | 1        |   |           |
| 7.2      | Foundations on weathered and un-weathered rock | NUM<br>DIS | Soil, intermediate geomaterial and rock<br>Bearing capacity and settlement: Bells solution, IS 12070, IRC78 (Shallow and pile) |             |          |   |           |
| 7.3      | Bearing capacity and settlement of foundation  |            | Numerical Examples   |             |          |   |           |

| Unit | Topic/ Sub topic          | Depth Code      | Description of Depth  | Actual plan |   |   | Week |
|------|---------------------------|-----------------|---|-------------|---|---|------|
|      |                           |                 |   | L           | T | P |      |
| 7.4  | Treatment of rock defects | D<br>DES<br>DIS | Grouting<br>Bolt and anchor<br>Shotcrete<br>Drainage management | 1           |   |   |      |
|      | Evaluation                | Q/A             | Question answer   |             |   |   |      |

| Unit     | Topic/ Sub topic   | Depth Code            | Description of Depth   | Actual plan |          |   | Week         |
|----------|--|-----------------------|--|-------------|----------|---|--------------|
|          |  |                       |  | L           | T        | P |              |
| <b>8</b> | <b>Retaining Structures: Rigid and Flexible</b>                        |                       |  | <b>8</b>    | <b>5</b> |   | <b>14-15</b> |
| 8.1      | Types of rigid and flexible retaining structures and their application | D<br>E<br>DIS         | Gravity walls, semi-gravity walls, cantilever retaining walls, counterfort retaining walls, buttressed walls, concrete or masonry crib walls<br>sheet pile walls, soldier pile and lagging walls, diaphragm (slurry) walls, mechanically stabilized earth (MSE) walls, gabion walls, reinforced soil slopes (RSS), soil nailing, secant and tangent pile walls | 1           |          |   |              |
| 8.2      | Proportioning and stability analysis of rigid retaining wall           | D<br>DES<br>DV<br>NUM | Proportioning of Gravity wall, cantilever wall and buttress wall.<br>Stability Analysis of Rigid Retaining wall<br>Numerical examples  | 2           | 2        |   |              |
| 8.3      | Theory of arching  | D<br>DV               | Arching in Soils, Terzaghi's Trap door experiment  | 1           |          |   |              |
| 8.4      | Flexible retaining structures (Type and function)                      | D<br>DES              | Function of Sheet Pile Walls, Soldier Pile and Lagging Walls, Diaphragm (Slurry) Walls, Mechanically Stabilized Earth (MSE) Walls, Gabion Walls, Reinforced Soil Slopes (RSS), Soil Nailing, Secant and Tangent Pile Walls   | 0.5         |          |   |              |
| 8.5      | Analysis of sheet piles  | E<br>DV<br>NUM        | Cantilever sheet pile in cohesionless soil<br>Cantilever sheet pile in cohesive soil<br>Anchored wall Free Earth Support<br>Anchored wall Fixed Earth support  | 2           | 2        |   |              |
| 8.6      | Analysis of braced excavation  | E<br>DV<br>NUM        | Deep cut in Sand<br>Deep cut in Saturated, soft to medium clays<br>Apparent Pressure diagram for calculating loads in strut of braced cuts   | 0.5         | 1        |   |              |
| 8.7      | Analysis of reinforced or mechanically stabilized earth wall           | DES<br>DV             | Example of Retaining wall with the backfill reinforced with metal strips and Geogrid (Procedure only)  | 1           |          |   |              |
|          | Evaluation   | MT                    | Mid-term -2  |             |          |   |              |

### References:

1. Das, B. M. (2020). Principles of Geotechnical Engineering. Cengage Learning.
2. Arora, K. R. (2019). Soil Mechanics and Foundation Engineering (Geotechnical Engineering). India: Standard Publishers.
3. Murthy, V. (2003). Geotechnical Engineering: Principles and Practices of Soil Mechanics and Foundation Engineering. Switzerland: Taylor & Francis.
4. Bowles, J. E. (1978). Engineering properties of soils and their measurement (Latest Edition). United Kingdom: McGraw-Hill.

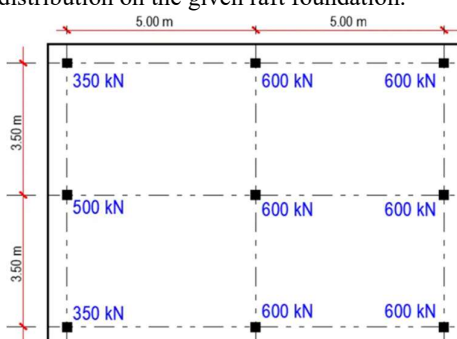
## Model Question

# FOUNDATION ENGINEERING

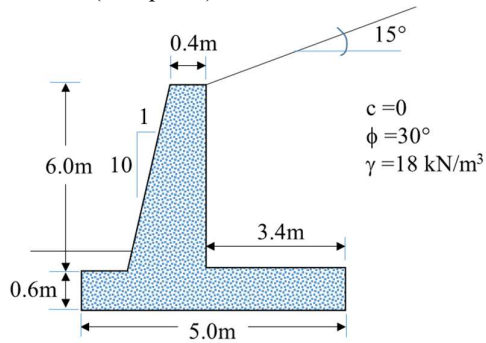
## ENCE 302

**Year/Part: III/II**

*Attempt all questions*

| QN   | Questions  | Marks       | Unit |
|--|--|-------------|------|
| 1  | <ul style="list-style-type: none"> <li>a. Describe detailed site investigations</li> <li>b. What are the requirements of samplers for undisturbed sample? Explain</li> <li>c. Determine the liquefaction potential of a soil layer located at a depth of 6 m below the ground surface. The field SPT value is 24. The unit weight of soil above the water table is 17 kN/m<sup>3</sup>, and below the water table is 20 kN/m<sup>3</sup>. The percentage of fines is 15%. The groundwater table is located at a depth of 3 m. The peak ground acceleration is 0.35 g, and the earthquake magnitude is 7.5.</li> </ul>  | 2<br>2<br>4 | 1    |
| 2  | A circular failure surface with the coordinates of three points indicated in parentheses. The circle has a radius of 30.5 m and a center at (0, 30.5). The circle intercepts the slope surface at (0, 0) and (27.45, 17.2). The soil in the slope has a cohesion of 38.3 kN/m <sup>2</sup> , a friction angle of 10°, and a total unit weight of 19.6 kN/m <sup>3</sup> . Compute the factor of safety by the Fellenius method.  | 6           | 2    |
| 3  | <ul style="list-style-type: none"> <li>a. Explain the effect of wall movement on lateral earth pressure in soils.</li> <li>b. Derive the equation for the active lateral earth pressure for the inclined backfill</li> <li>c. Calculate the total active thrust on a vertical wall 5 m high retaining a sand of unit weight 17 kN/m<sup>3</sup> for which <math>\phi' = 35^\circ</math>; the surface of the sand is horizontal and the water table is below the bottom of the wall. Also, determine the thrust on the wall if the water table rises to a level 2 m below the surface of the sand. The saturated unit weight of the sand is 20 kN/m<sup>3</sup>.</li> </ul> | 2<br>2<br>4 | 3    |
| 4  | <ul style="list-style-type: none"> <li>a. Discuss different types of shear failure</li> <li>b. A square footing 2.5 m × 2.5 m is placed at a depth of 1.5 m in a sandy soil with <math>\phi = 30^\circ</math>, <math>\gamma = 18</math> kN/m<sup>3</sup>. Compute the safe bearing capacity using Terzaghi's theory when water table is at 0.5 m below ground level. Take <math>N_q=22.5</math>, <math>N_\gamma=19.7</math>, <math>\gamma_{sat}=20</math> kN/m<sup>3</sup>, FoS= 3, for general shear failure.</li> </ul>  | 2<br>4      | 4    |
| 5  | <ul style="list-style-type: none"> <li>a. Settlement, types and determination</li> <li>b. Determine the allowable bearing capacity 4 (a) using Teng formula if the corrected SPT value is 18.</li> <li>c. Determine the stress distribution on the given raft foundation.</li> </ul>   | 2<br>2<br>4 | 5    |
|  <p>The diagram shows a rectangular raft foundation with a total width of 10.00 m (two 5.00 m sections) and a total height of 7.00 m (two 3.50 m sections). The foundation is divided into a 3x2 grid of rectangular areas by dashed lines. The loads are as follows:         <ul style="list-style-type: none"> <li>Top row: 350 kN (left), 600 kN (middle), 600 kN (right)</li> <li>Middle row: 500 kN (left), 600 kN (middle), 600 kN (right)</li> <li>Bottom row: 350 kN (left), 600 kN (middle), 600 kN (right)</li> </ul> </p> |  |             |      |
| 6  | <ul style="list-style-type: none"> <li>a. Describe the component of well foundation</li> <li>b. Determining the load carrying capacity of a 15m long pile of 600mm diameter driven in the sandy soil (<math>N_q=25</math>, <math>\gamma=18</math> kN/m<sup>3</sup> and <math>\phi=30^\circ</math>). Also calculate the capacity of the foundation with 9 piles arranged in 3B spacing.</li> <li>c. Discuss on the load carrying capacity of Pier foundation</li> </ul>   | 2<br>6<br>2 | 6    |

- 7 a. What are the factor affecting the bearing capacity of shallow foundation in rock? 2 7  
 b. Discuss the IRC recommendation on the load carrying capacity of pile in rock 2  
 8 a. Describe arching phenomena 2 8  
 b. Carryout the stability analysis of the given retaining wall and recommend appropriate solutions (if required) 4



- c. A fixed earth support anchored sheet pile has to retain 5m soil ( $\gamma=18\text{kN/m}^3$  and  $\phi=30^\circ$ ). The sheet pile is anchored at 1 m from the top surface. Calculate the depth of embedment and tension in anchor rod. Assume necessary data if required. 4

*Note: Number of questions and distribution of marks are indicative only.*