Foundation Engineering PYQ In-Sem Solution

UNIT 1: SUBSURFACE INVESTIGATIONS FOR FOUNDATIONS

1. Explain the purpose of soil exploration (any 5)

Soil exploration is conducted to gather essential information about subsurface conditions for engineering projects. Its purposes include:

1. **Determining Soil Properties –** Identifies soil characteristics such as strength, compressibility, and permeability for foundation design.
2. **Assessing Groundwater Conditions –** Locates the water table and evaluates its impact on construction.
3. **Selecting Suitable Foundation Type –** Helps in choosing the appropriate foundation based on soil stability.
4. **Evaluating Soil Bearing Capacity –** Determines the load-bearing capacity of the soil to prevent structural failures.
5. **Identifying Potential Hazards –** Detects problematic soil conditions like expansive clay or loose sand that may affect construction.

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2. Describe Standard Penetration test.

The Standard Penetration Test (SPT) is a widely used in-situ test to determine soil properties. The procedure involves:

1. **Drilling a Borehole –** A borehole is advanced to the required depth.
2. **Lowering the Split Spoon Sampler –** A thick-walled sampler is placed at the bottom of the borehole.
3. **Driving the Sampler –** A 63.5 kg hammer is dropped from a height of 75 cm to drive the sampler into the soil.

4. **Recording Blow Counts –** The number of blows required to penetrate three 15 cm intervals is recorded. The sum of the last two intervals gives the N-value, indicating soil density.
5. **Interpreting Results –** The N-value helps in assessing soil strength and foundation suitability.

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3. The inner diameters of sampling tube and that of cutting edge are 72 mm and 70 mm respectively. Their outer diameters are 74 mm and 76 mm respectively. Determine the inside clearance, outside clearance and area ratio of sampler. Comment on suitability of sampler.

Given:

- Inner diameter of sampling tube (ds) = 72 mm
- Inner diameter of cutting edge (dc) = 70 mm
- Outer diameter of sampling tube (Ds) = 74 mm
- Outer diameter of cutting edge (Dc) = 76 mm

1. Inside Clearance (Ci)

$$Ci = \left(\frac{d_s - d_c}{d_c}\right) x100$$

$$Ci = \left(\frac{72-70}{70}\right) x100$$

$$Ci = 2.86\%$$

2. Outside Clearance (Co)

$$Co = \left(\frac{D_c - D_s}{D_s}\right) x100$$

$$Co = \left(\frac{76-74}{74}\right) x100$$

$$Co = 2.70\%$$

3. Area Ratio (Ar)

$$Ar = \left(\frac{{D_c}^2 - {d_c}^2}{{d_c}^2}\right) x100$$

$$Ar = \left(\frac{76^2 - 70^2}{70^2}\right) x100$$

$$Ar = 17.88\%$$

Comment on Suitability

- Inside Clearance (2.86%) – Falls within the acceptable range (1%–3%) for undisturbed sampling.
- Outside Clearance (2.70%) – Should ideally be less than inside clearance; this value is slightly high but still acceptable.
- Area Ratio (17.88%) – Below 20%, making it suitable for stiff formations but slightly high for soft sensitive clays.

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4. Discuss IS Criteria for depth of bore holes in subsurface investigations.

The depth of boreholes in subsurface investigations is determined based on guidelines provided in IS 1892:1979. The key criteria include:

1. Foundation Type Consideration:

- For shallow foundations, boreholes should extend at least 1.5 times the width of the foundation below the expected foundation level.
- For deep foundations (piles, wells, etc.), boreholes should extend at least 5 m below the anticipated pile tip or until a stable stratum is reached.

2. Soil and Rock Characteristics:

- Boreholes should penetrate all significant soil strata to determine their engineering properties.
- If bedrock is encountered, drilling should continue at least 3 m into the rock to confirm its stability.

3. Groundwater Table Consideration:

- Boreholes should extend below the lowest expected groundwater level to assess seasonal fluctuations and potential effects on foundation stability.

4. Structural Load Considerations:

- For high-rise buildings or heavy structures, boreholes should be deep enough to evaluate settlement and bearing capacity under expected loads.

5. Site-Specific Adjustments:

- In cases of soft clay, loose sand, or expansive soils, deeper boreholes may be required to assess potential risks like liquefaction or excessive settlement.

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5. Discuss pressure meter test with a neat sketch.

The Pressure meter Test (PMT) is an in-situ test used to determine soil strength and deformation characteristics. It involves inserting a cylindrical probe into a borehole and expanding it against the surrounding soil.

Procedure:

1. A borehole is drilled to the required depth.
2. A pressure meter probe is inserted into the borehole.
3. The probe is inflated using gas or water, applying pressure to the soil.
4. The pressure vs. volume change is recorded to assess soil stiffness and strength.
5. The test results help determine bearing capacity, settlement characteristics, and lateral load resistance.

Applications:

- Used for foundation design, especially for shallow and deep foundations.
- Helps in pile design by estimating lateral load resistance.
- Useful in tunnel and excavation stability analysis.

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6. Explain in detail 'Seismic refraction method'.

The Seismic Refraction Method is a geophysical technique used to determine subsurface soil and rock layers by analyzing the refraction of seismic waves.

Principle:

- Seismic waves travel at different velocities through different soil and rock layers.
- When waves encounter a boundary between two layers, they refract according to Snell's Law.
- By measuring the arrival times of refracted waves at different locations, the depth and type of subsurface layers can be determined.

Procedure:

1. A seismic source (hammer strike, explosion, or vibrator) generates waves.
2. Geophones are placed at known distances to record wave arrival times.
3. The time-distance graph is plotted to determine layer depths and velocities.
4. The subsurface profile is interpreted based on wave behavior.

Applications:

- Used in foundation investigations to detect bedrock depth.
- Helps in dam site selection by identifying weak zones.
- Applied in tunnel and excavation planning to assess rock stability.

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7. Write a note on purpose and planning of subsurface exploration.

Purpose: Subsurface exploration is conducted to determine soil properties, groundwater conditions, and the suitability of a site for construction. It helps in selecting appropriate foundation types, analyzing soil stability, and preventing structural failures.

Planning: Proper planning ensures cost-effective and efficient exploration. It involves understanding project requirements, selecting suitable drilling and sampling methods, determining borehole locations, and conducting laboratory tests on collected samples.

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8. Discuss SPT and what are the various corrections? What is the importance of the test?

The Standard Penetration Test (SPT) is a widely used in-situ soil testing method to assess soil strength and consistency. It involves driving a split spoon sampler into the ground using a hammer and recording the number of blows required for penetration.

Corrections: Various corrections are applied to SPT results to improve accuracy:

1. Overburden Stress Correction: Accounts for soil pressure above the test location.
2. Energy Transfer Correction: Adjusts for variations in hammer efficiency.
3. Borehole Diameter Correction: Considers the impact of borehole size on test results.
4. Sampler Size Correction: Adjusts for differences in sampler dimensions.

Importance: SPT helps in foundation design, soil classification, and assessing liquefaction potential during earthquakes.

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9. Explain percussion drilling with its advantages and disadvantages. ★

This method uses impact force to break rock or soil layers. A hammer delivers repeated blows to the drill bit, fracturing the material.

Advantages:

1. Simple operation and low cost.
2. Effective for soft soil and formations with boulders.
3. Requires minimal equipment.

Disadvantages:

1. High noise levels and strong vibrations.
2. Lower precision in complex formations.
3. Slower drilling speed compared to rotary methods.

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10. Explain with sketches electrical Resistivity method. ★

The electrical resistivity method is a geophysical technique used to investigate subsurface conditions by measuring the resistance of soil and rock to electrical current. Electrodes are placed in the ground, and a current is passed through them to determine variations in resistivity, which helps identify different geological formations, groundwater levels, and mineral deposits.

Procedure:

1. Four electrodes are inserted into the ground in a straight line.
2. Current is applied through the outer electrodes.
3. Voltage is measured between the inner electrodes.
4. Resistivity is calculated using Ohm's Law:

Applications:

- Determining groundwater table depth.
- Identifying bedrock or soil stratigraphy.
- Mapping clay aquitards and landfill thickness

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11. What is R.Q.D., How rating of rock quality is decided based on R.Q.D. ★

Rock Quality Designation (RQD) is a measure of the quality of rock core samples obtained from boreholes. It is expressed as a percentage and calculated by summing the lengths of intact rock pieces (greater than 100 mm) and dividing by the total core run length.

Core Log

A Core Log is a detailed record of rock samples obtained from boreholes during geological investigations. It includes information on rock type, fractures, weathering, and recovery percentage.

Rating Based on RQD:

- <25% – Very Poor (Highly Weathered Rock)
- 25-50% – Poor (Fractured Rock)
- 51-75% – Fair (Moderately Weathered Rock)
- 76-90% – Good (Hard Rock)
- 91-100% – Very Good (Fresh Rock)

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12. What is significant depth? How would you decide the depth of exploration?

Significant depth refers to the depth at which the stress increment due to superimposed loads can produce significant settlement or shear stresses in the soil. It is the depth beyond which additional soil exploration does not significantly impact foundation design.

Factors Affecting Depth of Exploration:

1. **Type of Structure:** Taller and heavier structures require deeper exploration.
2. **Soil Profile:** If soil layers vary significantly, deeper exploration is needed.
3. **Foundation Type:**
    - Shallow foundations: 1.5 times the width of the footing.
    - Deep foundations: 10–30 meters or more.
4. **Groundwater Conditions:** Boreholes should extend below the lowest expected groundwater level.
5. **Load Distribution:** The depth should be sufficient to ensure stability and prevent excessive settlement.

13. Explain N value correction and significance.

The **N-value** comes from the **Standard Penetration Test (SPT)**, which is a field test done during soil exploration.

This N-value tells us how dense or strong the soil is.

Higher N-value = stronger/dense soil
Lower N-value = weaker/loose soil

Why is Correction Needed for N-value?

The raw N-value we get from the test is not always accurate. It is affected by:

1. **Depth of the soil (overburden pressure)**
2. **Soil type (especially saturated fine sands and silts)**
3. **Type of equipment and energy used**

So, to make the result reliable and comparable across sites, we apply **corrections**.

Types of N-value Corrections

1) Overburden Pressure Correction (N_{cor}):

- Soil deeper in the ground is under more pressure, which affects resistance.
- Loose soil at a greater depth may show a high N-value just due to pressure.
- So, we correct the N-value to a standard overburden pressure using the formula:

  $N_{cor} = C_N \times N$

Where:

- N = recorded field value
- C_N = correction factor (based on depth and soil unit weight)

This correction is usually applied to sandy soils.

2) Dilatancy Correction (For Saturated Fine Sands and Silts):

- In saturated fine sands or silts, the N-value can become artificially high because of water resistance (pore pressure buildup).
- So, if corrected N-value (N_{cor}) > 15, we apply Dilatancy Correction:

  $N_{final} = 15 + 0.5 \times (N_{cor} - 15)$

This ensures that the result is not falsely high.

3) Energy Correction (If Non-standard Equipment is Used):

- In some cases, the hammer or method used may not follow standard procedure.
- Then we apply energy correction to standardize the N-value.

Significance of N-value Correction

1. Reliable Soil Strength Data:
   Corrected N-values reflect the true condition of soil strength and consistency.
2. Accurate Design of Foundations:
   If we don't correct the N-value, we might design a foundation that is too weak or too expensive.
3. Safety:
   Helps prevent foundation failure due to overestimation of soil strength.
4. Standardization:
   Corrected N-values can be used confidently in bearing capacity calculations and settlement analysis, and are acceptable in codes like IS 2131.

Type of Correction	When applied	Why Important
Overburden Correction	For sandy soils at different depths	Adjusts for depth pressure
Dilatancy Correction	For saturated silts and fine sands	Avoids overestimation due to pore water
Energy Correction	When non-standard tools used	Standardizes test results

UNIT 2: BEARING CAPACITY

1. Definitions of Bearing Capacity Terms

1. Ultimate Bearing Capacity : The maximum load per unit area that soil can carry without failure. It is the peak load the soil can bear.

$$q_u = Ultimate\ Bearing\ Capacity$$

2. Net Ultimate Bearing Capacity : It is the ultimate bearing capacity minus the overburden pressure (weight of soil above the footing level).

$$q_{nu} = q_u - \gamma D_f$$

Where:

- γ = unit weight of soil
- D_f = depth of foundation

3. Net Safe Bearing Capacity : It is the maximum pressure the soil can carry safely, considering a factor of safety (FOS).

$$q_{ns} = \frac{q_{nu}}{FOS}$$

4. Gross Safe Bearing Capacity : It is the total pressure (including overburden) the soil can take without failure, considering FOS.

$$q_{ng} = \frac{q_u}{FOS}$$

5. Allowable Soil Pressure : It is the pressure that can be safely applied to the soil, considering both shear failure and permissible settlement.

$$q_{allowable} = \min(q_{ns}, settlement\ criteria)$$

2. Discuss the modes of shear failure. ★

Shear failure in soil occurs when the applied load exceeds the soil's shear strength. The three primary modes of shear failure are:

1. General Shear Failure

- Occurs in dense sand or stiff clay.
- Sudden failure with well-defined failure surfaces.
- Significant bulging of soil around the footing.

2. Local Shear Failure

- Happens in medium-dense soils.
- Failure surfaces are not fully developed.
- Gradual settlement before failure.

3. Punching Shear Failure

- Occurs in loose or soft soils.
- No visible bulging or tilting.
- The footing sinks into the soil without clear failure surfaces.

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3. Plate load test was conducted on a square plate of size 0.3 mm in clay. The settlement observed was 4 mm. Determine the settlement of square footing of size 2 m under the same load intensity.

Given:

- Plate size = 0.3 m
- Settlement observed = 4 mm
- Footing size = 2 m

Settlement of footing is calculated using the empirical formula:

$$S_f = S_p \times \left(\frac{B_f}{B_p}\right)$$

where:

- S_f = Settlement of footing
- S_p = Settlement of plate
- B_f = Width of footing
- B_p = Width of plate

Substituting values:

$$S_f = 4 \times \left(\frac{2}{0.3}\right)$$

$$S_f = 26.67mm$$

Thus, the settlement of the square footing under the same load intensity is 26.67 mm

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4. Describe Meyerhof's bearing capacity theory ★ ★

Meyerhof's bearing capacity theory extends Terzaghi's approach by incorporating shape, depth, and inclination factors to improve accuracy for different foundation types.

Key Features:

1. Failure Mechanism:

- Assumes a log-spiral failure surface instead of Terzaghi's straight-line approach.
- Divides the failure zone into elastic wedge, radial shear zone, and mixed shear zone.

2. Bearing Capacity Equation:

$$q_u = cN_c + \gamma D_f N_q + 0.5\gamma B N_\gamma$$

where:

- q_u = Ultimate bearing capacity
- c = Cohesion of soil

- γ = Unit weight of soil
- D_f = Depth of foundation
- B = Width of foundation
- N_c, N_q, N_γ = Bearing capacity factors

3. Shape and Depth Factors:

- Introduces shape factors for rectangular, square, and circular footings.
- Includes depth correction factors to account for embedment effects.

4. Applications:

- Used for shallow and deep foundations.
- More accurate for non-strip footings compared to Terzaghi's method.

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5. Explain Terzaghi's bearing capacity equation for strip, rectangular and circular footing with meaning of all terms. ★ ★

Terzaghi's theory provides a fundamental approach to estimating soil bearing capacity for different footing shapes.

General Equation:

$$q_u = cN_c + \gamma D_f N_q + 0.5\gamma B N_\gamma$$

where:

- q_u = Ultimate bearing capacity
- c = Cohesion of soil
- γ = Unit weight of soil
- D_f = Depth of foundation
- B = Width of foundation
- N_c, N_q, N_γ = Bearing capacity factors

Modifications for Different Footings:

1. Strip Footing:

$$q_u = cN_c + \gamma D_f N_q + 0.5\gamma B N_\gamma$$

2. Square Footing:

$$q_u = 1.3cN_c + \gamma D_f N_q + 0.4\gamma B N_\gamma$$

3. Circular Footing:

$$q_u = 1.3cN_c + \gamma D_f N_q + 0.3\gamma B N_\gamma$$

Assumptions:

- Soil is homogeneous and isotropic.
- Load is vertical and symmetrical.
- Failure occurs in general shear mode.

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6. Explain the effect of water table on bearing capacity. ★★

The presence of a high-water table reduces soil strength and bearing capacity.

Effects:

1. Reduction in Effective Stress:
   - Water reduces soil cohesion and internal friction, lowering stability.
   - Effective unit weight γ' is used instead of γ.
2. Impact on Bearing Capacity Equation:
   - Terzaghi's equation includes water table correction factors:
     $q_u = cN_c + \gamma D_f N_q R_2 + 0.5\gamma B N_\gamma R_1$
     where R_1 and R_2 are water table correction factors.
3. Three Cases of Water Table Influence:
   - Case 1: Water table below foundation depth → No effect.
   - Case 2: Water table at foundation level → Reduced bearing capacity.
   - Case 3: Water table above foundation level → Significant reduction in capacity.

Mitigation Strategies:

- Lower foundation depth to avoid water table interference.

- Use drainage systems to control groundwater effects.
- Increase foundation size to distribute load over a larger area.

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7. Write a note on plate load test. Also explain limitations of plate load test. ★

The Plate Load Test is a field test used to determine the ultimate bearing capacity of soil and estimate settlement under a given load. It is particularly useful for designing shallow foundations.

Procedure:

1. A rigid steel plate (usually 30 cm to 75 cm in size) is placed at the desired foundation depth.
2. Load is applied gradually using a hydraulic jack.
3. Settlement is recorded using dial gauges.
4. A load-settlement curve is plotted to determine bearing capacity.

Limitations:

- **Limited Depth Influence:** The test only assesses soil behavior up to twice the plate width, which may not represent deeper soil layers
- **Short Duration:** It does not account for long-term settlement, especially in cohesive soils
- **Scale Effect:** Results may not accurately reflect full-scale foundation behavior, particularly in dense sands
- **Groundwater Influence:** The presence of high-water tables can affect test accuracy

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8. A 30 cm square bearing plate settles by 8 mm in the plate load test on cohesionless soil, when the intensity of loading is 180 kN/m2. Estimate the settlement of shallow foundation of 1.6 m square under the same intensity of loading.

Given:

- Plate size (Bp) = 300 mm

- Settlement (Sp) = 8 mm = 8 mm
- Foundation size (Bf)= 1600 mm
- μ = Poisson's ratio (For cohesionless soils, assumed 0.5)
- Soil = cohesionless

To estimate the settlement of the shallow foundation, we use Terzaghi's plate load test correlation:

$$S_f = S_p \times \left(\frac{B_f}{B_p}\right)^{1-\mu}$$

$$S_f = 8 \times \left(\frac{1600}{300}\right)^{1-0.5}$$

$$S_f = 18.5\ mm$$

Settlement of foundation = 18.5 mm