GEO TECHNICAL ENGINEERING

DIPLOMA WALLAH

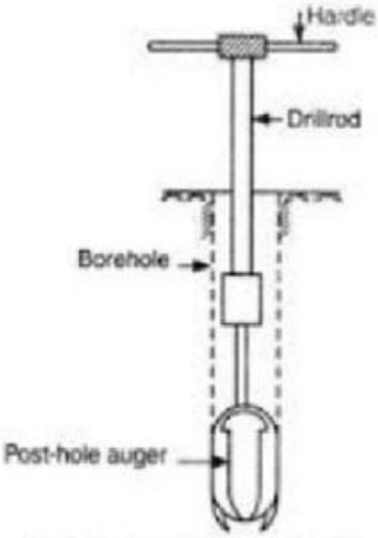
CIVIL

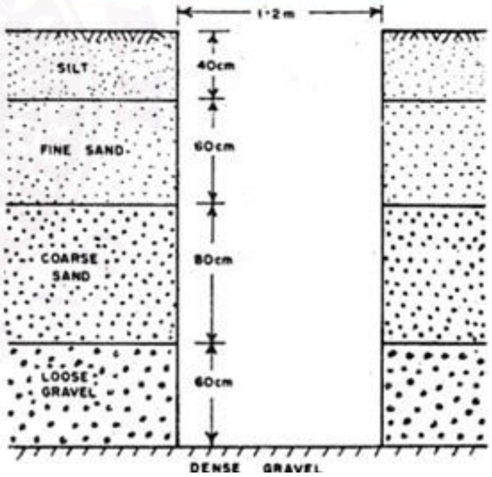
Jharkhand University Of Technology (JUT)

Unit - V Site Investigation and Bearing Capacity of Soil

5.1 Site Investigation and Sub-soil Exploration

5.1.1 Necessity of Site Investigation & Sub-soil Exploration


Hardle
Drillrod
Borehole
Post-hole auger


1·2m
SILT
40cm
FINE SAND
60cm
COARSE SAND
80cm
LOOSE GRAVEL
60cm
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Definition:
Site investigation (also called sub-soil exploration) is the process of investigating the ground conditions (soil and rock layers, groundwater, stratification, strength and deformation properties) at a proposed construction site, in order to obtain reliable information required for design and construction of foundations and other geotechnical works.

Why it's necessary:

- Provides vital information about soil/rock strata, groundwater level, depth to competent bearing layer, weak zones, fill materials, etc, which are critical for safe and economic foundation design.
- Helps determine suitable foundation type (shallow or deep), evaluate bearing capacity, estimate settlement, assess lateral soil pressures, slope stability, ground improvement needs.
- Prevents surprises during construction (such as unexpected weak layers, high water table, rock heads) which can lead to increased costs, delays or risk of failure.
- Helps in efficient and rational design: the cost of investigation is small relative to cost of foundation/failure mitigation.
- Meets code/standard requirements and reduces risk for owners/contractors/investors.

Key points to include in exam answer:

- Distinguish between *preliminary investigation* (to assess general site conditions) and *detailed investigation* (to obtain engineering parameters).
- Mention that exploration covers soil classification, sampling, in-situ testing, ground water assessment, geophysical surveys if needed.
- Emphasise that without adequate investigation, design is based on assumptions and carries higher risk.

5.1.2 Types of Exploration


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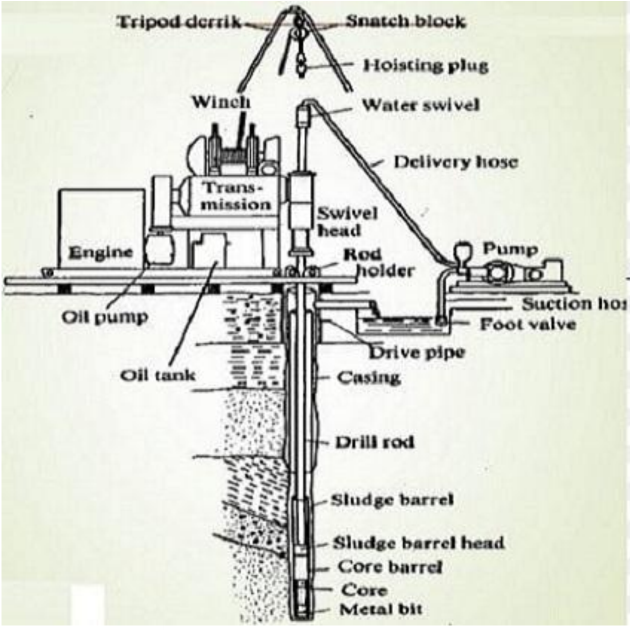
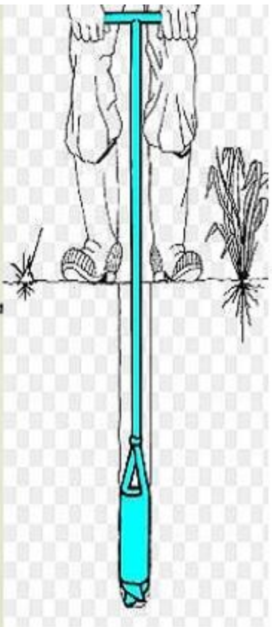
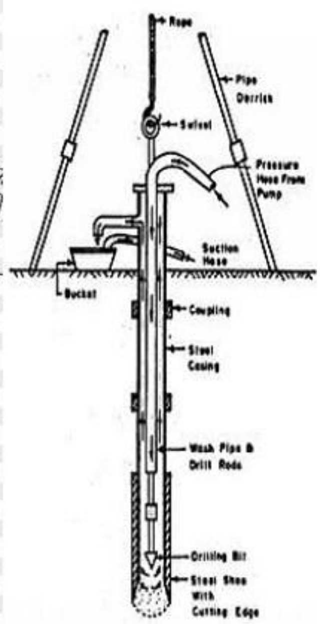
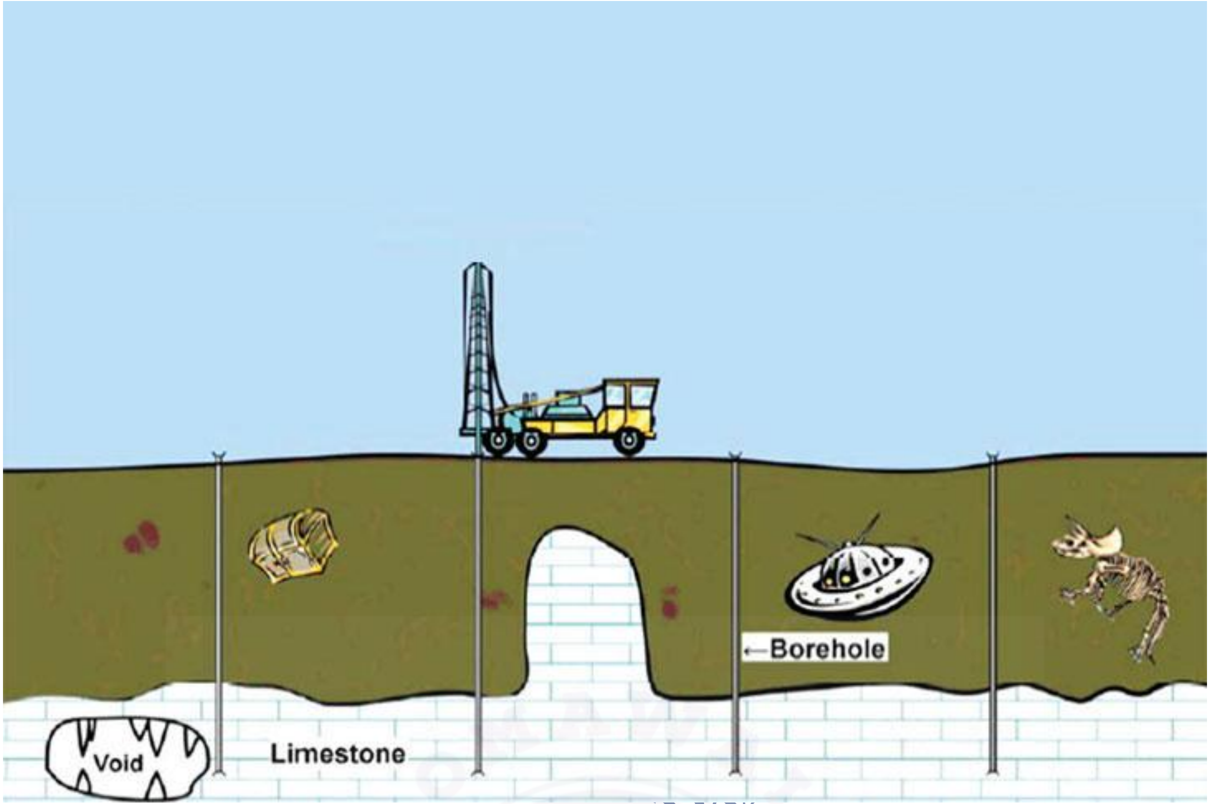
Perserverance Rd.,
Hereford
TPA1
1/2/07


Tripod derrik
Snatch block
Hoisting plug
Winch
Water swivel
Delivery hose
Trans-
mission
Swivel
head
Engine
Rod
holder
Pump
Suction hos
Foot valve
Oil pump
Drive pipe
Oil tank
Casing
Drill rod
Sludge barrel
Sludge barrel head
Core barrel
Core
Metal bit




Rope
Pipe
Derrick
Pressure
Hose From
Pump
Suction
Hose
Bucket
Coupling
Steel
Casing
Wash Pipe &
Drill Rods
Drilling Bit
Steel Shoe
With
Cutting Edge



Principal types of exploration methods:

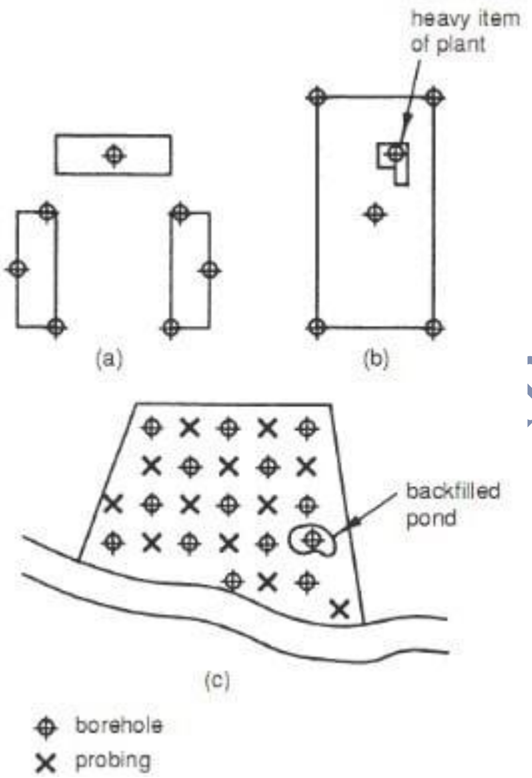
1. **Open excavations / Test pits / Trial pits:**
   - Shallow excavations excavated to expose soil and rock profile directly, allow visual inspection, sample collection, groundwater observation.
   - Typically used for shallow foundations and where soil conditions are relatively simple.
   - Advantages: direct observation, simpler, lower cost for shallow depth. Disadvantages: limited depth, safety concerns in deep or water logged soils.
2. **Boreholes / Drilling (Auger, Wash, Rotary, Percussion):**
   - Vertical borings drilled into the ground to specified depth. Soil and/or rock samples recovered (disturbed or undisturbed) and logged. Ground water encountered. In-situ tests (SPT, CPT) may be included.
   - Suitable for deeper exploration, complex strata, larger/heavy structures.
3. **Subsurface Soundings / In-Situ Tests / Geophysical Methods:**
   - Methods such as Standard Penetration Test (SPT), Cone Penetration Test (CPT), geophysical surveys (seismic refraction, resistivity) that give continuous profiles or soil resistance data.

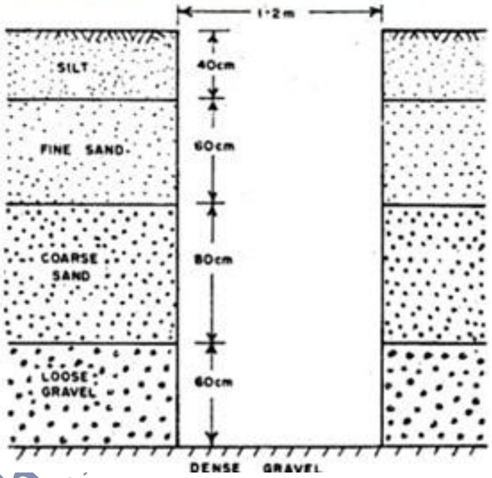
- Often used to supplement borehole data and improve spatial coverage.
  Choosing methods:

- Choice depends on depth of interest, soil/rock type, site complexity, cost, accessibility.
- Often a combination of methods is used to achieve adequate coverage (e.g., test pits for shallow zones + boreholes for deep).

Exam answer tip:
List each method, describe when it is used, key advantages/disadvantages. Mention that in practice the selection is tailored to site conditions and project requirements.

5.1.3 Criteria for Deciding Location & Number of Test Pits / Bores

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Minimum depth of boring (ASCE, 1972)

- Determine the net increase of stress, Δσ, under the foundation (as shown in Figure)
- Estimate the variation of the vertical effective stress, σ'_v, with depth
- Determine the depth $D = D_1$, at which stress increase $\Delta\sigma = q/10$, where q = estimated net stress on the foundation
- Determine the depth $D = D_2$, at which $\Delta\sigma/\sigma'_v = 0.05$.
- Unless bedrock is encountered, the smaller of the two depths, D_1 and D_2 will be the approximate minimum depth of boring required.

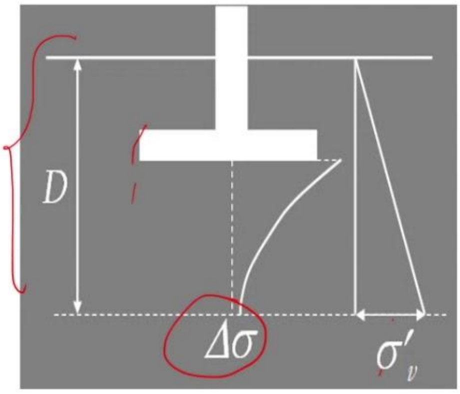

TABLE 2.1
MINIMUM NUMBER AND MINIMUM DEPTHS OF BOREHOLES FOR BUILDINGS[a,b,c,d,e]

NO. OF STORIES	BUILT AREA (m^2)	NO. OF BOREHOLES	MINIMUM DEPTH[f] OF TWO THIRDS OF THE BOREHOLES (m)	MINIMUM DEPTH[f] OF ONE THIRD OF THE BOREHOLES (m)
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	600 – 5000	3 – 10[g]	5	8
	> 5000	Special investigation		
3 - 4	< 600	3	6 - 8	9 - 12
	600 – 5000	3 – 10[g]		
	> 5000	Special investigation		
5 or higher	Special investigation			

Key criteria to determine how many exploration points and where to locate them:

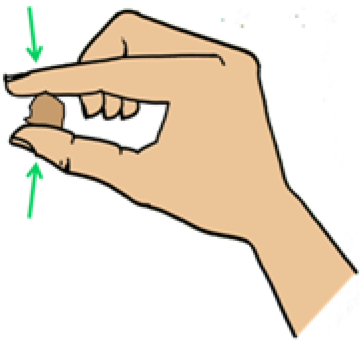
- **Variability of subsurface conditions:** If soil/rock conditions vary significantly across site (variations in fill layers, rock heads, groundwater), more boreholes are required.
- **Size and nature of structure:** Large or heavy structures (tall building, industrial plant, dam) demand more detailed investigation (greater number and depth of boreholes) compared to small structures.
- **Depth of interest / Foundation depth:** The exploration should extend to a depth sufficient to capture the bearing layer or zone of influence of the

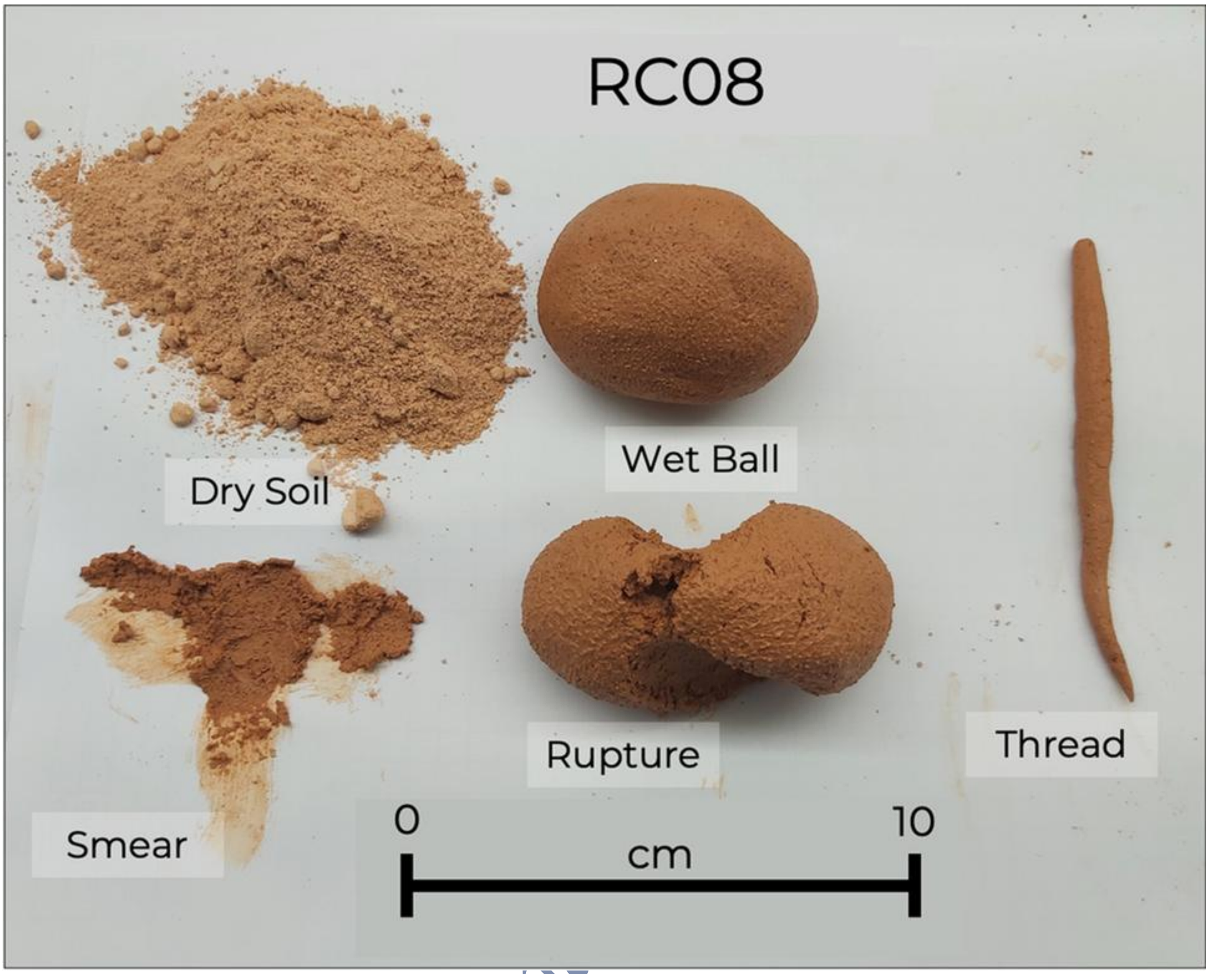
structural load—often 1–2 times the width of the footing or to competent layer.

- **Location of critical zones:** Boreholes should be placed under footings, load bearing zones, near property limits, near changes in load or foundation type, near boundaries or potential weak zones (e.g., near slopes or previous fill).
- **Groundwater and hazards:** Areas near ground water, soft soils, rock discontinuities may need closer spacing.
- **Accessibility, cost and safety:** Practical factors such as drilling rig access, safety (existing services), cost, traffic disruptions also influence layout.
  Guidance (not rigid):
- For relatively uniform site, borehole spacing might be one per footing or one every certain area (depends on standard/practice).
- Depth must exceed potential failure surface under footing.
- Exploration programme should aim for representative coverage rather than minimal number.

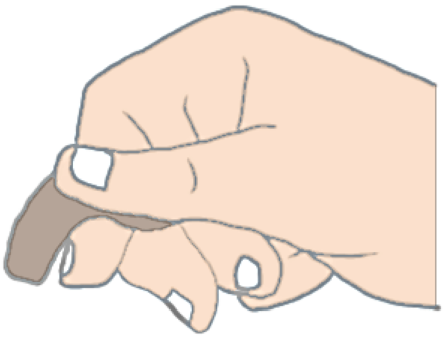
Exam writing advice:
You may write that number and location of pits/bores must ensure representative subsurface information, and justify with points above. You might state typical guideline (e.g., "exploration to depth ≈ 1.5 B (footing width) or until competent strata") though exact numbers depend on local practice.

5.1.4 Field Identification of Soil: Dry Strength Test, Dilatancy Test and Toughness Test




RC08
Dry Soil
Wet Ball
Thread
Smear
Rupture
0
10
cm

Take a small handful of soil, add enough water to be able to squeeze it into a ball



Gently press the ball of soil over the forefinger with the thumb, and extrude it in length to form a hanging ribbon

Purpose:
These quick field tests help the field engineer classify fine-grained soils (silts, clays) and assess their behaviour (plasticity, strength, dilatancy) before detailed laboratory testing. They inform judgement on site whether soil is clay, silt or sand and potential issues.

Tests & how to conduct them:

1. **Dry Strength Test:**
   - A small lump of air-dried soil is pressed between thumb and forefinger or lightly crushed.
   - Based on how easily it crumbles, it is categorised (for example: *very weak/crumbles easily* → likely fine sand or silt; *medium strength* → silt with some clay; *high strength / cannot be crumbled* → clay with high plasticity).
   - Helps indicate soil plasticity and clay content.
2. **Dilatancy (Shaking) Test:**
   - A moistened soil pat (just at saturation or slightly above) is swiftly shaken/horizontally rubbed in hand or between hands.

  - If water quickly appears on surface ("glossy wet surface"), the soil shows dilatant behaviour (common in dense granular soils or silts). If no water film appears, soil likely clay. If water appears slowly the soil may be mixture.
  - This test distinguishes soils that will dilate (granular/silty) from those that do not (clays). {[turn0search4]}

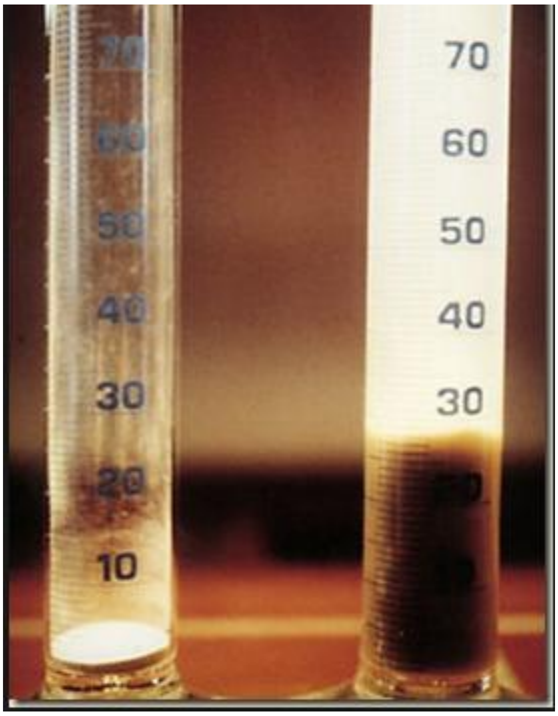
3. **Toughness Test / Thread Test / Ribbon Test:**
  - A soil sample is worked with water in hand until plastic consistency then rolled into a thin thread or ribbon between thumb and forefinger. The length and ease before it breaks gives an indication of 'toughness' (resistance to deformation) and thereby plasticity. A ribbon longer than e.g., 100 mm hints high plasticity clay.
  - Helps classify fine soils in terms of plasticity and strength (tough, medium, soft).

Importance in field work:

- These tests are low cost, quick, require no specialized equipment.
- They allow the engineer to make preliminary decisions (e.g., whether soil appears problematic, needs further testing or improvement) on site.
- They also assist in logging borehole/test pit records accurately (identifying soil types and behaviour).

Exam tip:
List each test, describe procedure concisely, state what results indicate (e.g., clay vs silt vs sand). Provide reason for relevance (e.g., fast water film in dilatancy means dilating silt).

5.1.5 Determination of Free Swell Index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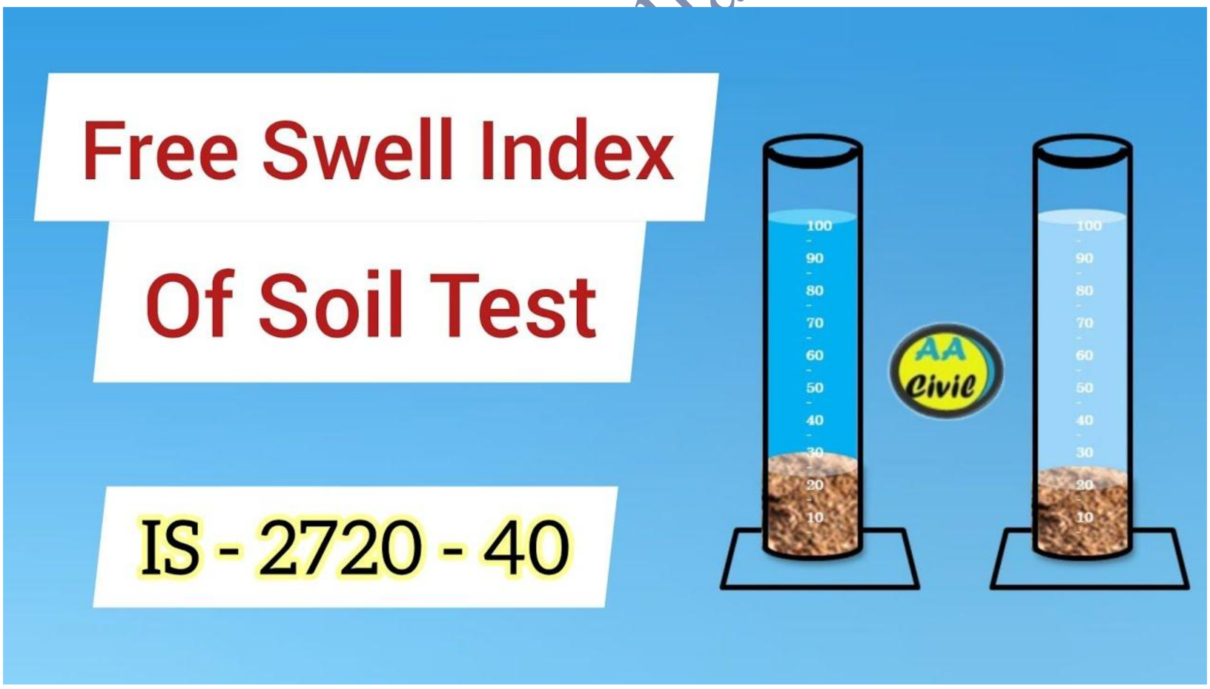
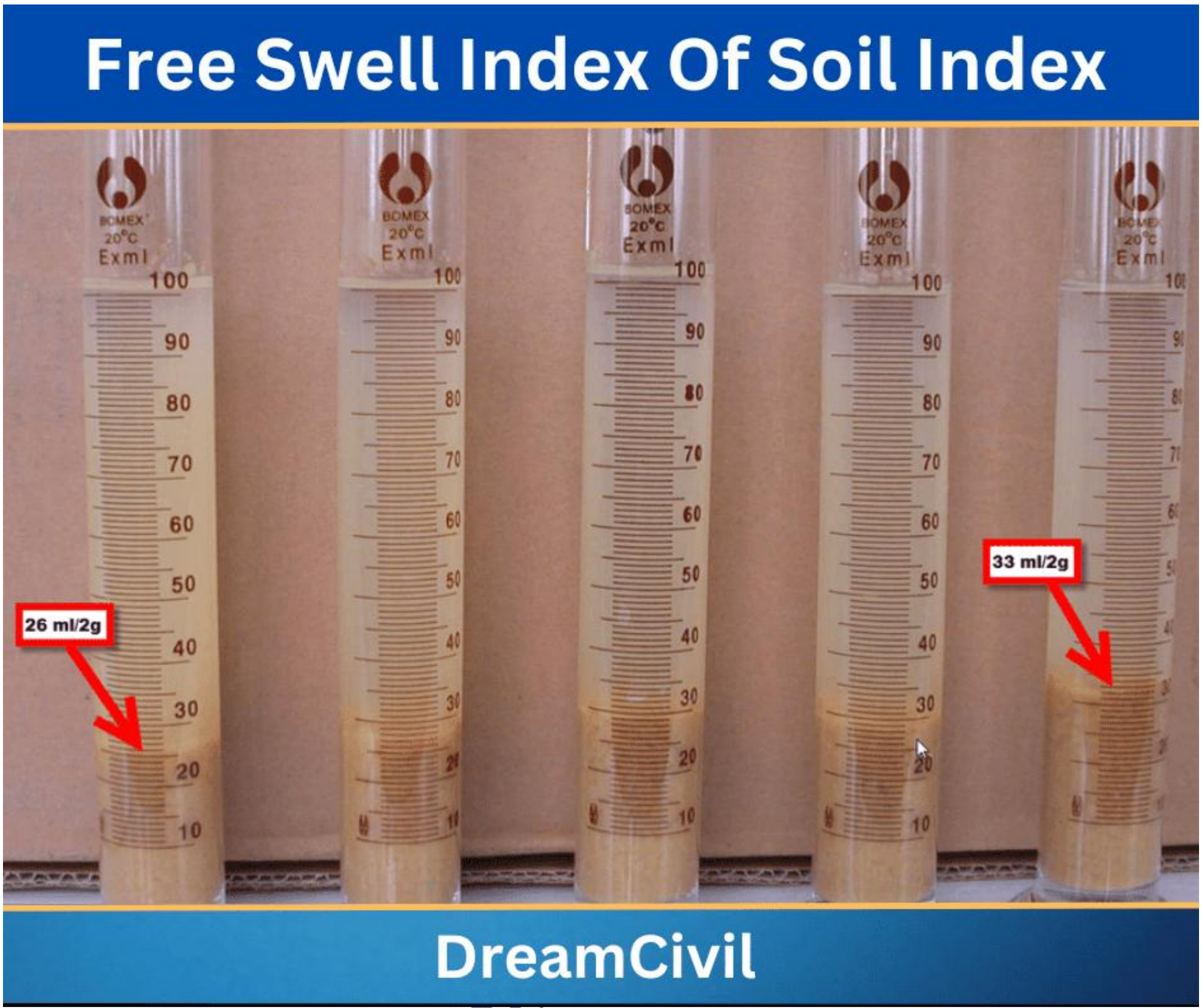
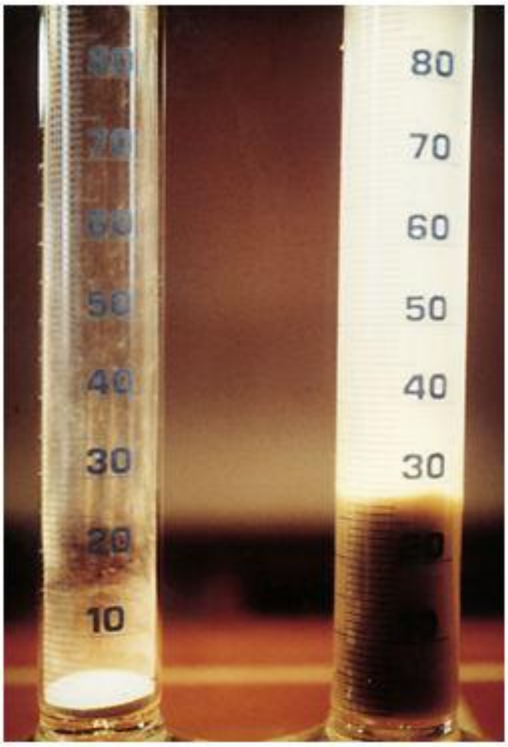
30


Free Swell Index
Of Soil Test
IS - 2720 - 40
AA
Civil


Free Swell Index Of Soil Index
26 ml/2g
33 ml/2g
DreamCivil



Definition:
The Free Swell Index (FSI) (sometimes called free swell ratio) is the increase in volume of a soil sample (typically oven-dried passing a certain sieve) when placed in distilled water (or kerosene for reference) without external load; expressed as a percentage of the original volume in the non-swelling medium. This index is used to assess the swelling potential (expansivity) of fine-grained soils (especially expansive clays). {[turn0search5]}

Test Procedure (Summary):

1. Oven-dry and sieve a specified mass of soil (e.g., 10 g passing 425 µm) and place in a graduated cylinder filled with kerosene or another non-swelling liquid; read the settled volume (V_k).
2. In another identical cylinder fill with distilled water, place same soil mass, allow to settle, read the volume (V_d).
3. Calculate:
$$\text{Free Swell Index (\%)} = \frac{V_d - V_k}{V_k} \times 100\%$$
4. Interpretation: A higher % means greater potential for swelling when soil is saturated in field condition (especially for mineralogies like montmorillonite). {[turn0search2]}

Significance:

- Provides a quick index of soil's potential to expand (which affects foundation and pavement performance).
- Helps identify soils requiring special foundation treatment (e.g., expansive clays).
- It is an index test, not a precise measure of swelling pressure, but useful for classification and early warning.

Exam tip:
Give definition, outline procedure in 3-4 bullet steps, provide formula, mention what high value indicates (expansive soil) and typical usage (foundation design precaution).

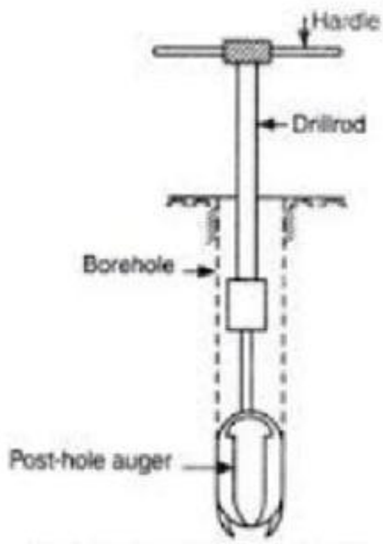
Summary of 5.1

5.1 covers the initial and critical stage of geotechnical investigation: exploring the site, choosing the correct methods and locations for exploration, performing quick field identification tests and assessing free-swell behaviour of fine-grained soils. For exam preparedness:

- Make sure you define every key term (site investigation, exploration, free swell index) clearly.
- Provide lists of methods and criteria with bullet points.
- For field tests, mention the procedure and what they indicate.
- For free swell index, include both definition and how to compute it.
- Where possible, include short sketches/diagrams in your notes (e.g., layout of boreholes, field test photos) to enhance clarity.

5.1 Site Investigation and Sub-soil Exploration

5.1.1 Necessity of Site Investigation & Sub-soil Exploration


Handle
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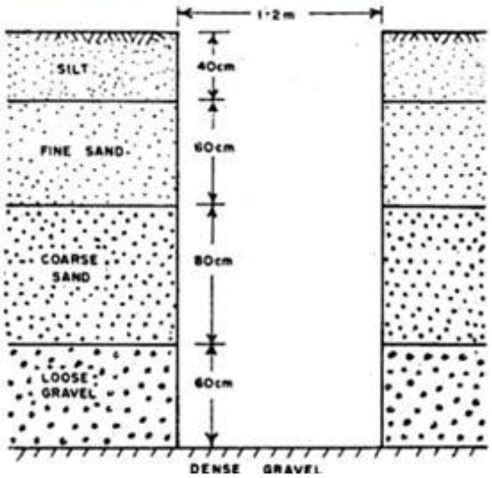
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- Mention that exploration covers soil classification, sampling, in-situ testing, ground water assessment, geophysical surveys if needed.
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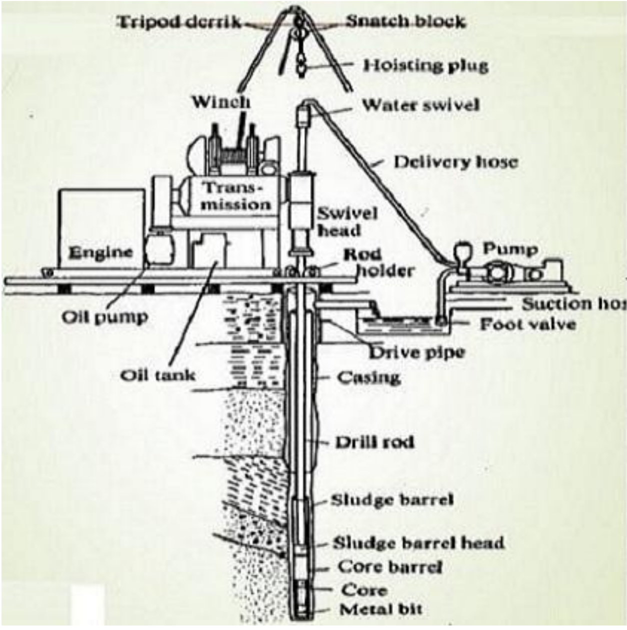
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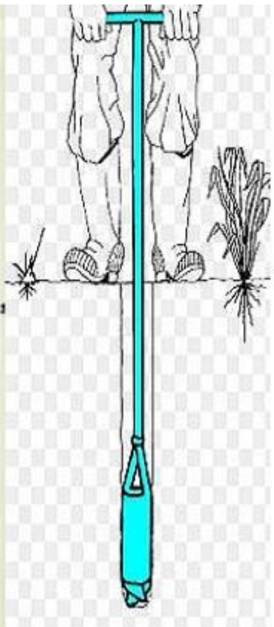

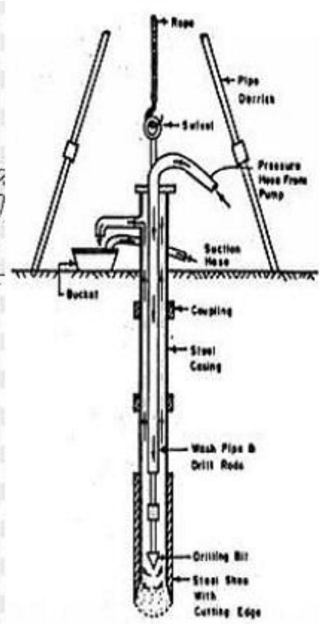
Rope
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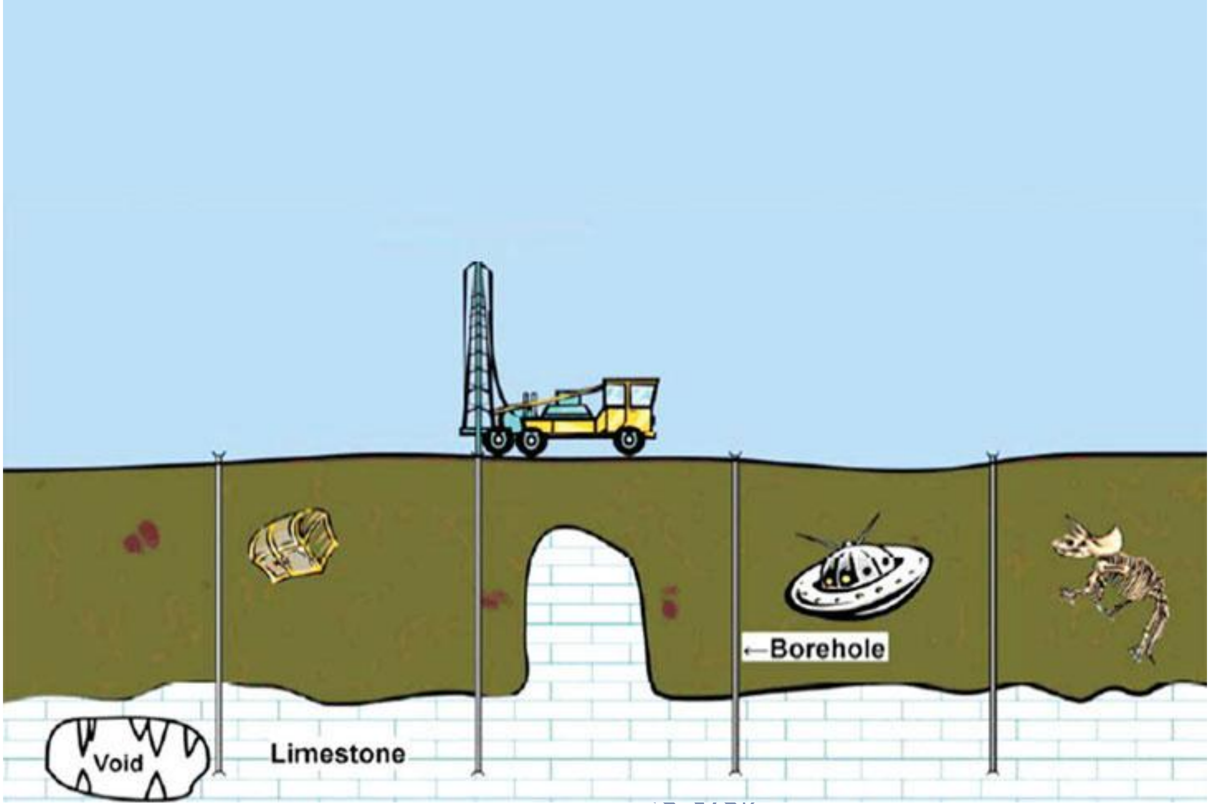

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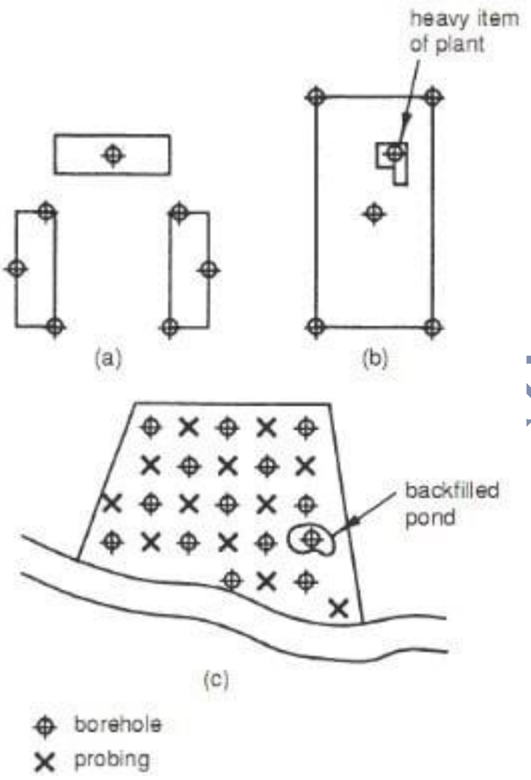

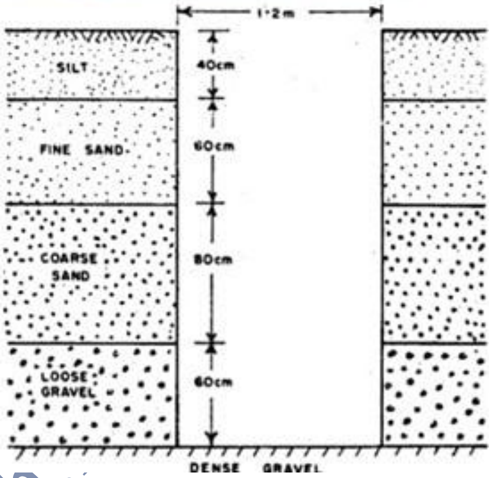
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Minimum depth of boring (ASCE, 1972)

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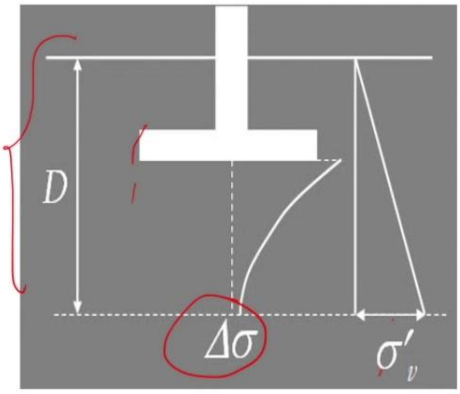

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Key criteria to determine how many exploration points and where to locate them:

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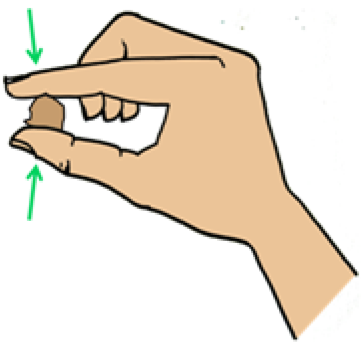
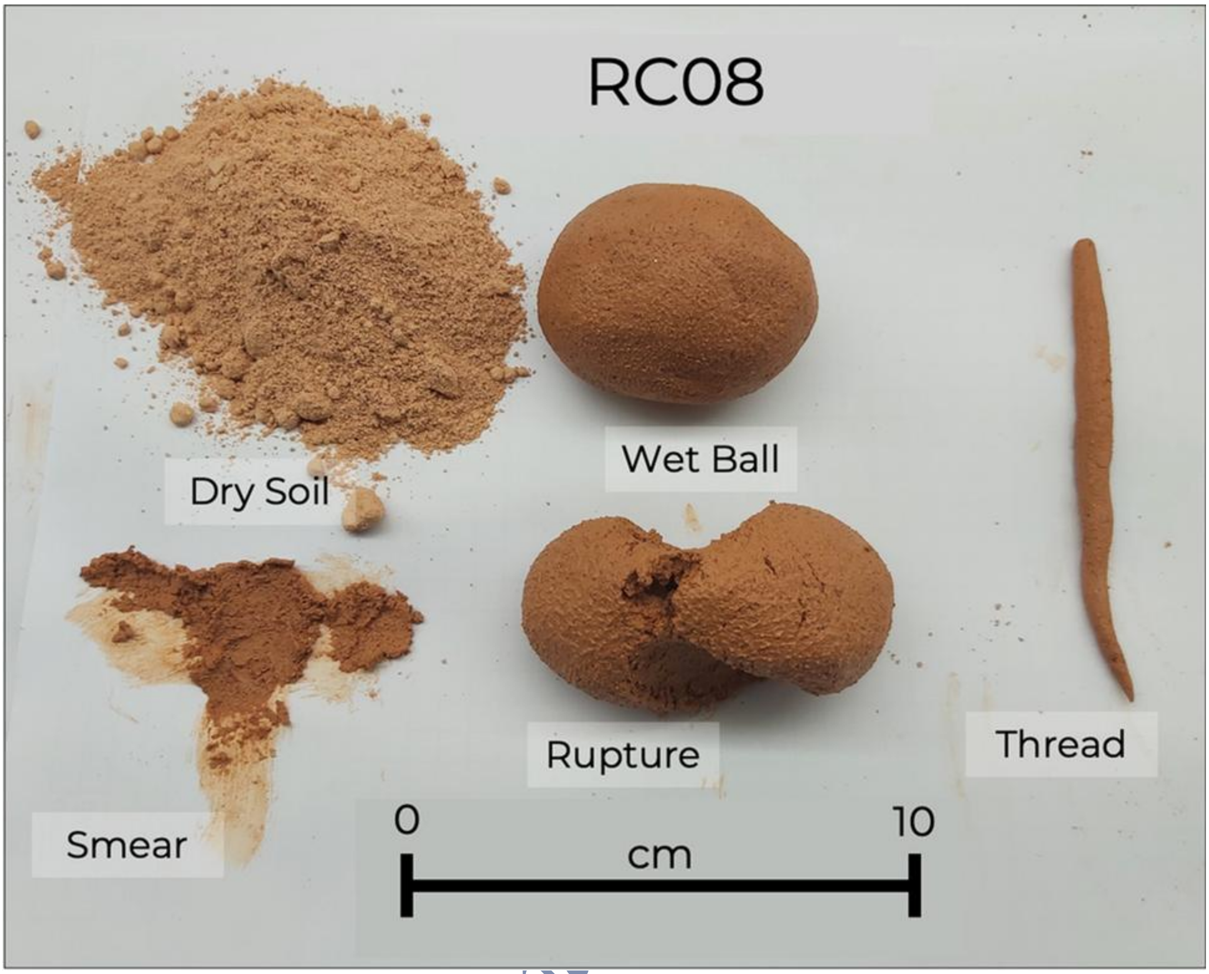
5.1.4 Field Identification of Soil: Dry Strength Test, Dilatancy Test and Toughness Test

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Wet Ball
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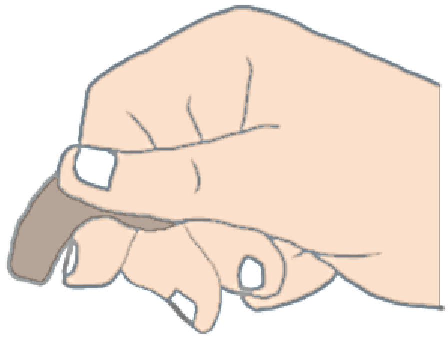


Gently press the ball of soil over the forefinger with the thumb, and extrude it in length to form a hanging ribbon

Purpose:
These quick field tests help the field engineer classify fine-grained soils (silts, clays) and assess their behaviour (plasticity, strength, dilatancy) before detailed laboratory testing. They inform judgement on site whether soil is clay, silt or sand and potential issues.

Tests & how to conduct them:

1. **Dry Strength Test:**
   - A small lump of air-dried soil is pressed between thumb and forefinger or lightly crushed.
   - Based on how easily it crumbles, it is categorised (for example: *very weak/crumbles easily* → likely fine sand or silt; *medium strength* → silt with some clay; *high strength / cannot be crumbled* → clay with high plasticity).
   - Helps indicate soil plasticity and clay content.
2. **Dilatancy (Shaking) Test:**
   - A moistened soil pat (just at saturation or slightly above) is swiftly shaken/horizontally rubbed in hand or between hands.

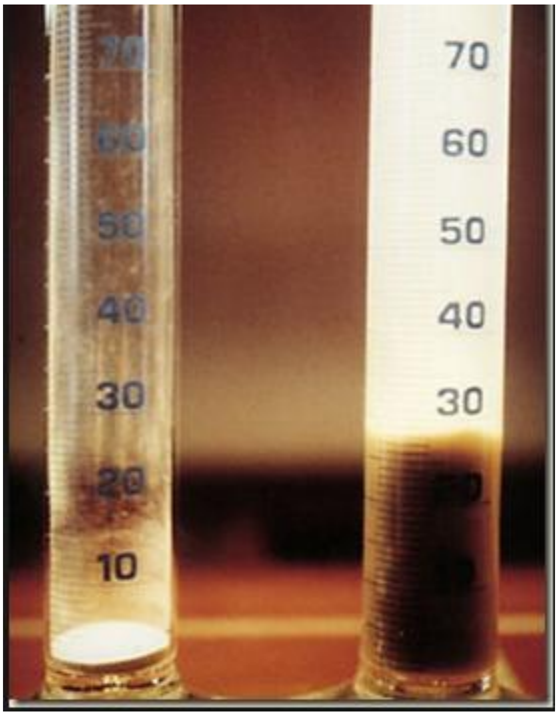
   - If water quickly appears on surface ("glossy wet surface"), the soil shows dilatant behaviour (common in dense granular soils or silts). If no water film appears, soil likely clay. If water appears slowly the soil may be mixture.
   - This test distinguishes soils that will dilate (granular/silty) from those that do not (clays). {[turn0search4]}
3. **Toughness Test / Thread Test / Ribbon Test:**
   - A soil sample is worked with water in hand until plastic consistency then rolled into a thin thread or ribbon between thumb and forefinger. The length and ease before it breaks gives an indication of 'toughness' (resistance to deformation) and thereby plasticity. A ribbon longer than e.g., 100 mm hints high plasticity clay.
   - Helps classify fine soils in terms of plasticity and strength (tough, medium, soft).

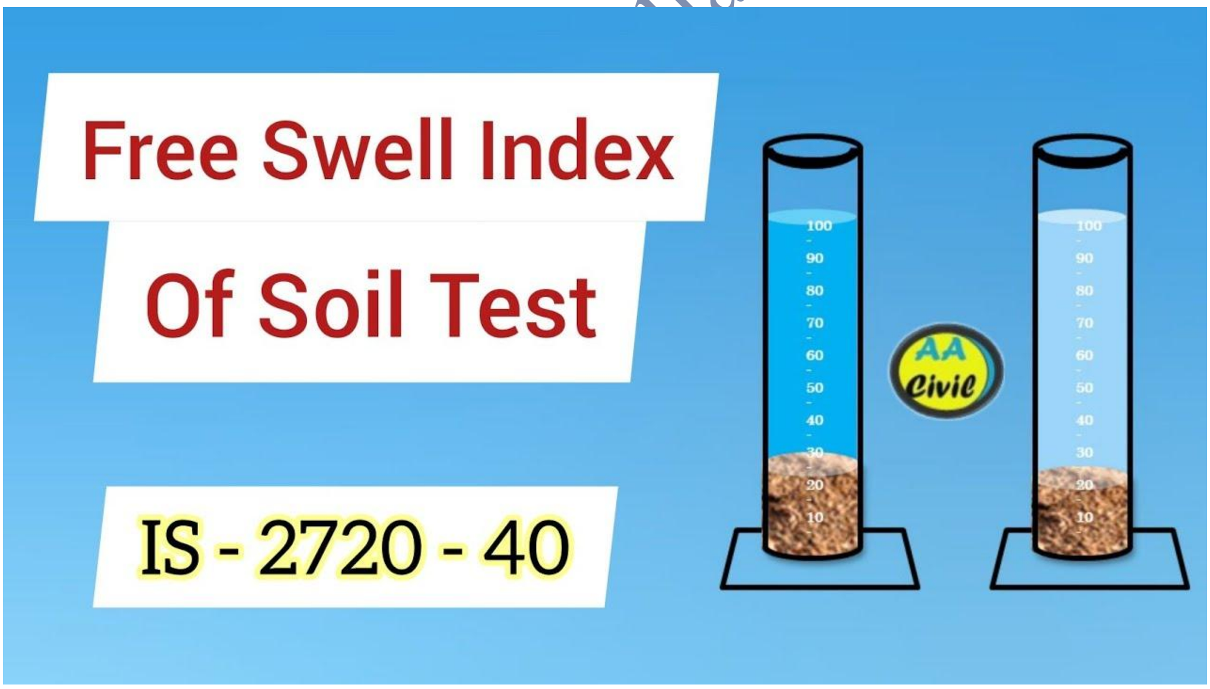
Importance in field work:

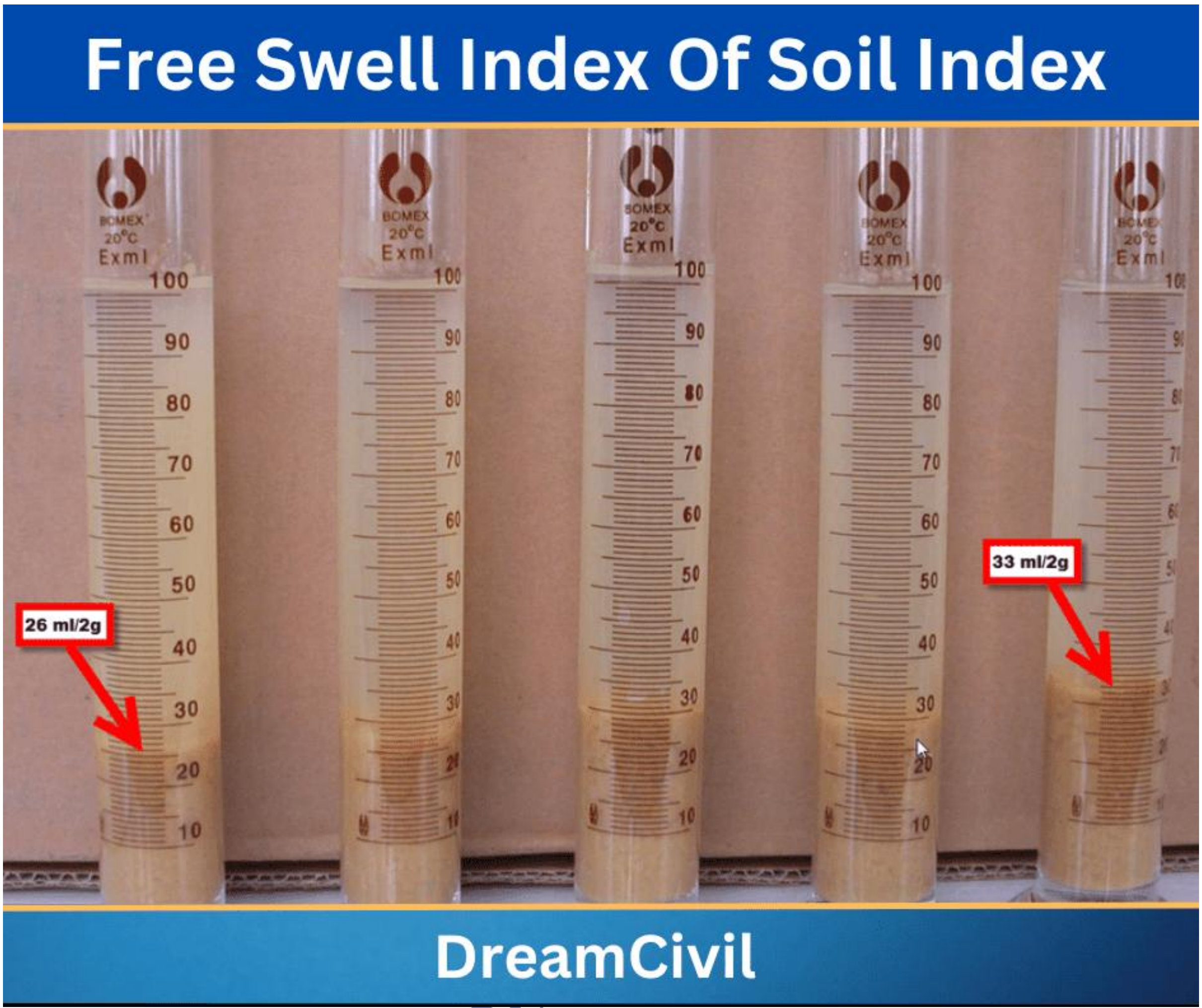
- These tests are low cost, quick, require no specialized equipment.
- They allow the engineer to make preliminary decisions (e.g., whether soil appears problematic, needs further testing or improvement) on site.
- They also assist in logging borehole/test pit records accurately (identifying soil types and behaviour).

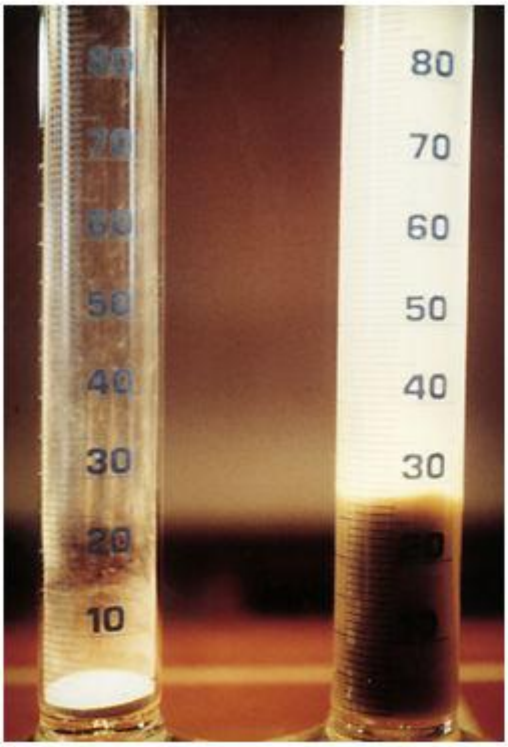
Exam tip:
List each test, describe procedure concisely, state what results indicate (e.g., clay vs silt vs sand). Provide reason for relevance (e.g., fast water film in dilatancy means dilating silt).

5.1.5 Determination of Free Swell Index


70
60
50
40
30
10


Free Swell Index
Of Soil Test
IS - 2720 - 40
AA Civil


Free Swell Index Of Soil Index
26 ml/2g
33 ml/2g
DreamCivil



Definition:
The Free Swell Index (FSI) (sometimes called free swell ratio) is the increase in volume of a soil sample (typically oven-dried passing a certain sieve) when placed in distilled water (or kerosene for reference) without external load; expressed as a percentage of the original volume in the non-swelling medium. This index is used to assess the swelling potential (expansivity) of fine-grained soils (especially expansive clays). {[turn0search5]}

Test Procedure (Summary):

1. Oven-dry and sieve a specified mass of soil (e.g., 10 g passing 425 µm) and place in a graduated cylinder filled with kerosene or another non-swelling liquid; read the settled volume (V_k).
2. In another identical cylinder fill with distilled water, place same soil mass, allow to settle, read the volume (V_d).
3. Calculate:
$$\text{Free Swell Index (\%)} = \frac{V_d - V_k}{V_k} \times 100\%$$
4. Interpretation: A higher % means greater potential for swelling when soil is saturated in field condition (especially for mineralogies like montmorillonite). {[turn0search2]}

Significance:

- Provides a quick index of soil's potential to expand (which affects foundation and pavement performance).
- Helps identify soils requiring special foundation treatment (e.g., expansive clays).
- It is an index test, not a precise measure of swelling pressure, but useful for classification and early warning.

Exam tip:
Give definition, outline procedure in 3-4 bullet steps, provide formula, mention what high value indicates (expansive soil) and typical usage (foundation design precaution).

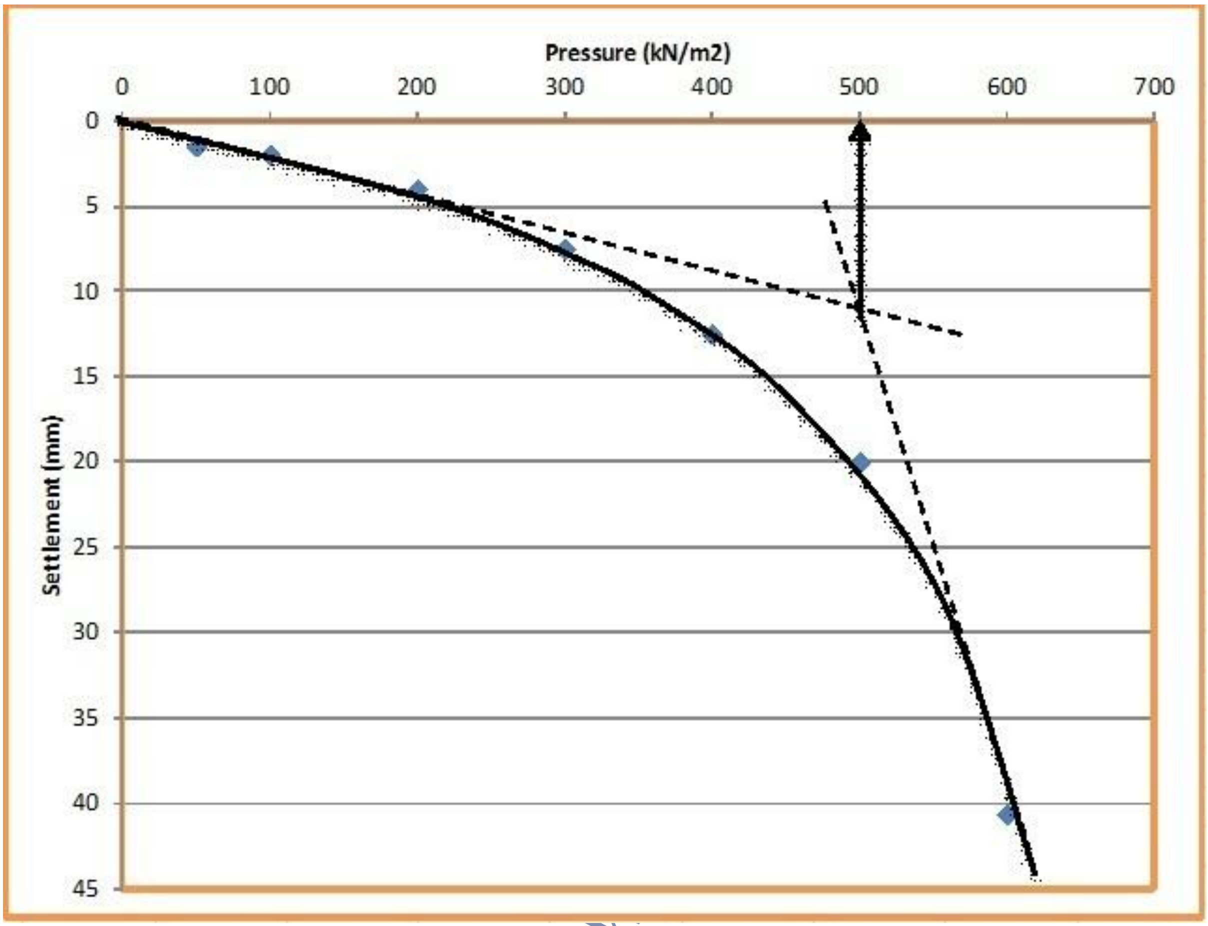
Summary of 5.1

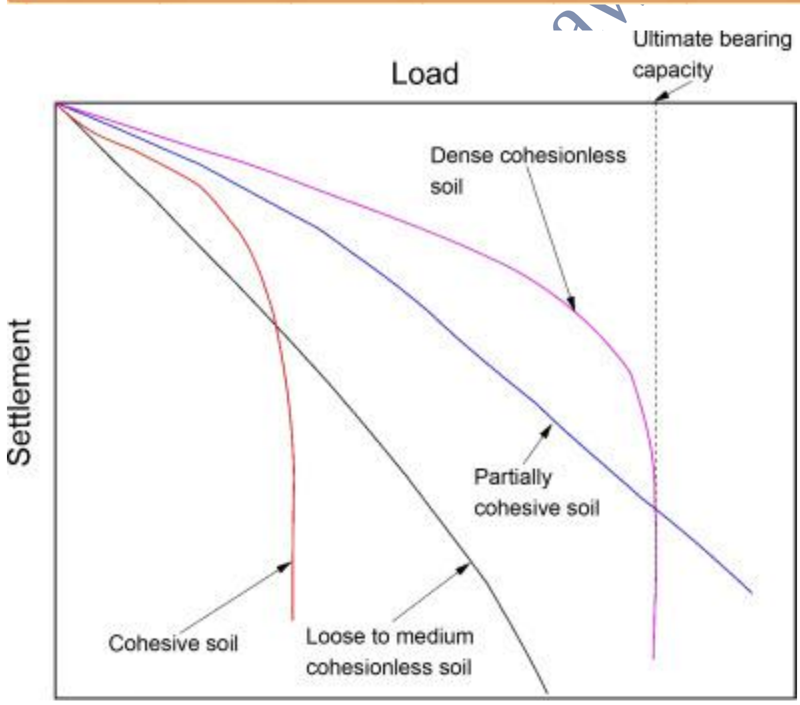
5.1 covers the initial and critical stage of geotechnical investigation: exploring the site, choosing the correct methods and locations for exploration, performing quick field identification tests and assessing free-swell behaviour of fine-grained soils. For exam preparedness:

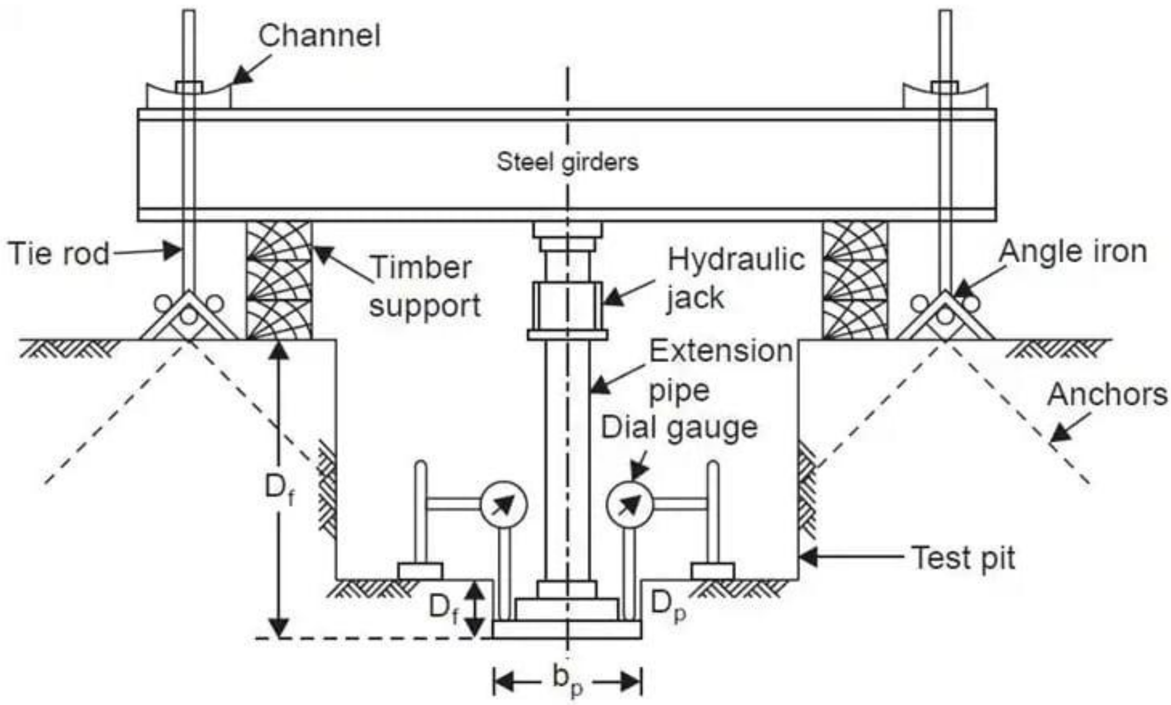
- Make sure you define every key term (site investigation, exploration, free swell index) clearly.
- Provide lists of methods and criteria with bullet points.
- For field tests, mention the procedure and what they indicate.
- For free swell index, include both definition and how to compute it.
- Where possible, include short sketches/diagrams in your notes (e.g., layout of boreholes, field test photos) to enhance clarity.

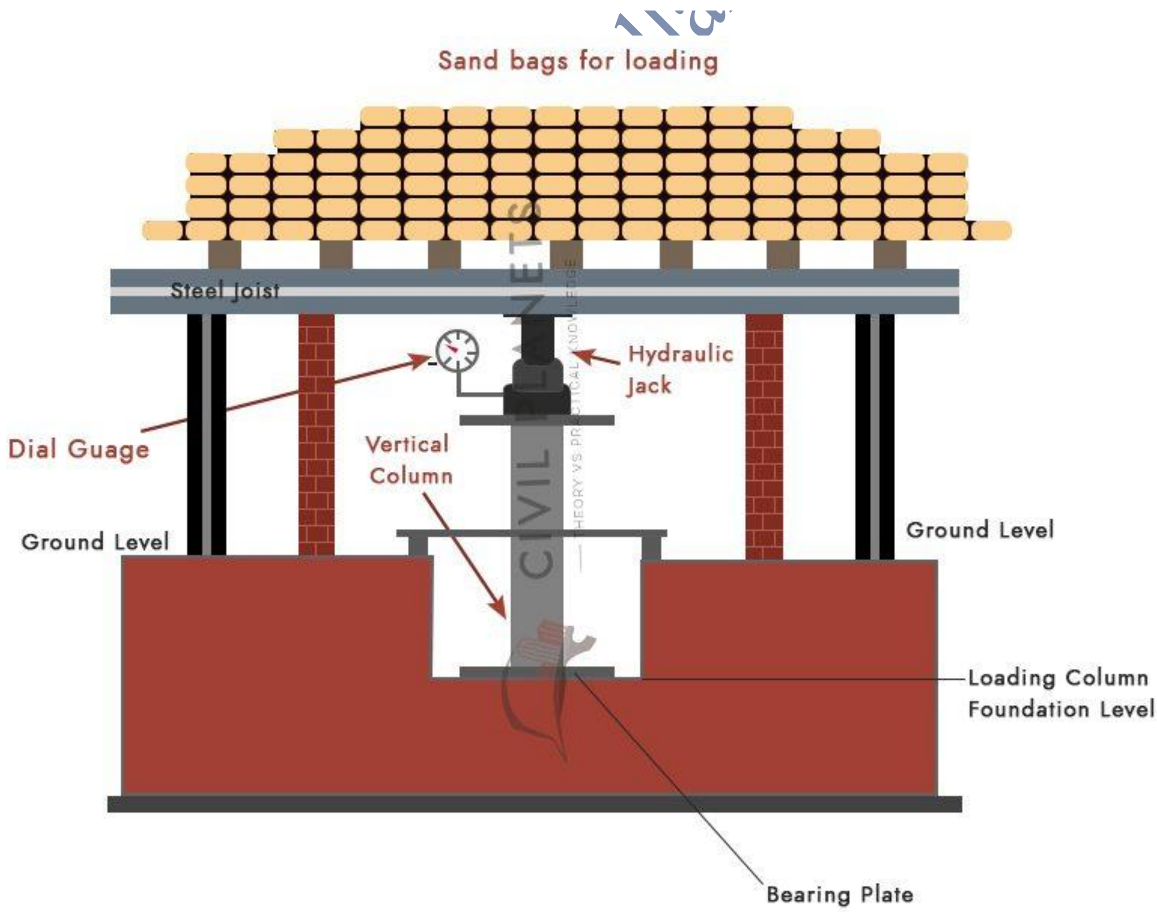
5.3 Field Methods for Determination of Bearing Capacity of Soil

A) Plate Load Test


Pressure (kN/m2)
0
100
200
300
400
500
600
700
Settlement (mm)
0
5
10
15
20
25
30
35
40
45


Ultimate bearing capacity
Load
Settlement
Dense cohesionless soil
Partially cohesive soil
Cohesive soil
Loose to medium cohesionless soil





Definition & Purpose:

The plate load test is an in-situ field test used to determine the bearing capacity and settlement behaviour of soil under a foundation or plate. It simulates the effect of a

foundation by loading a rigid plate placed at the depth of foundation level (or on prepared subgrade) and measuring settlement for increasing loads. (Civil Engineering Portal)
It helps directly assess the safe bearing pressure or modulus of subgrade reaction for designing shallow foundations or raft slabs.

Standard & Reference:
In India the procedure is given in IS 1888 (1982) "Method of Load Test on Soils". (nfrlyconstruction.org)

Apparatus:

- Rigid steel plate (typically square or circular) of known area and thickness.
- Hydraulic jack / loading system or dead weights.
- Reaction frame or surface to provide counter-forces.
- Dial gauges or settlement measuring devices.
- Load measuring device (load cell / jack gauge).

Procedure (summary):

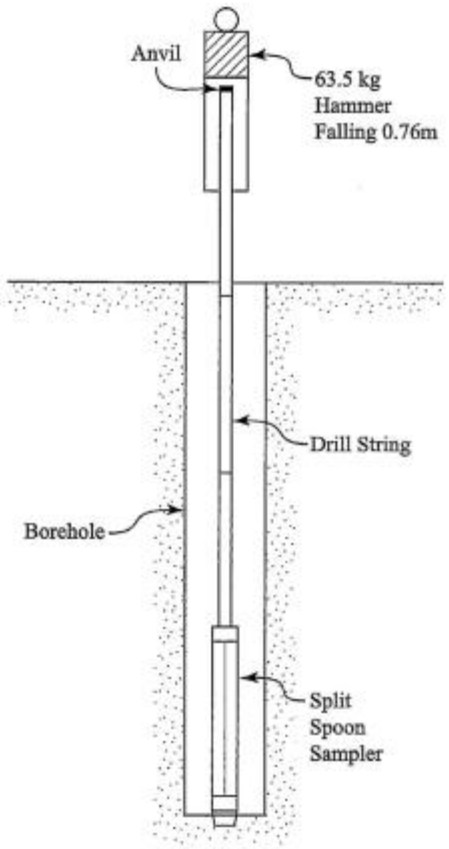
1. Excavate to the required foundation level or subgrade level. Ensure the plate rests on the soil surface with good contact. (qaqccivil.com)
2. Place the plate, ensure level seating and ensure removal of loose material beneath plate.
3. Apply an initial seating load to flatten surface irregularities.
4. Incrementally apply load in steps (each step may increase by a certain percentage, e.g., 30–50%) and hold each load for specified time (depending on soil type) while recording settlement at intervals. (Civil Engineering Portal)
5. Continue loading until a specified settlement is reached (e.g., 25 mm) or clear failure behaviour is observed (for coarse soils) or until a specified time if settlement rate becomes small.
6. Plot load vs settlement curve and determine bearing capacity & settlement characteristics.

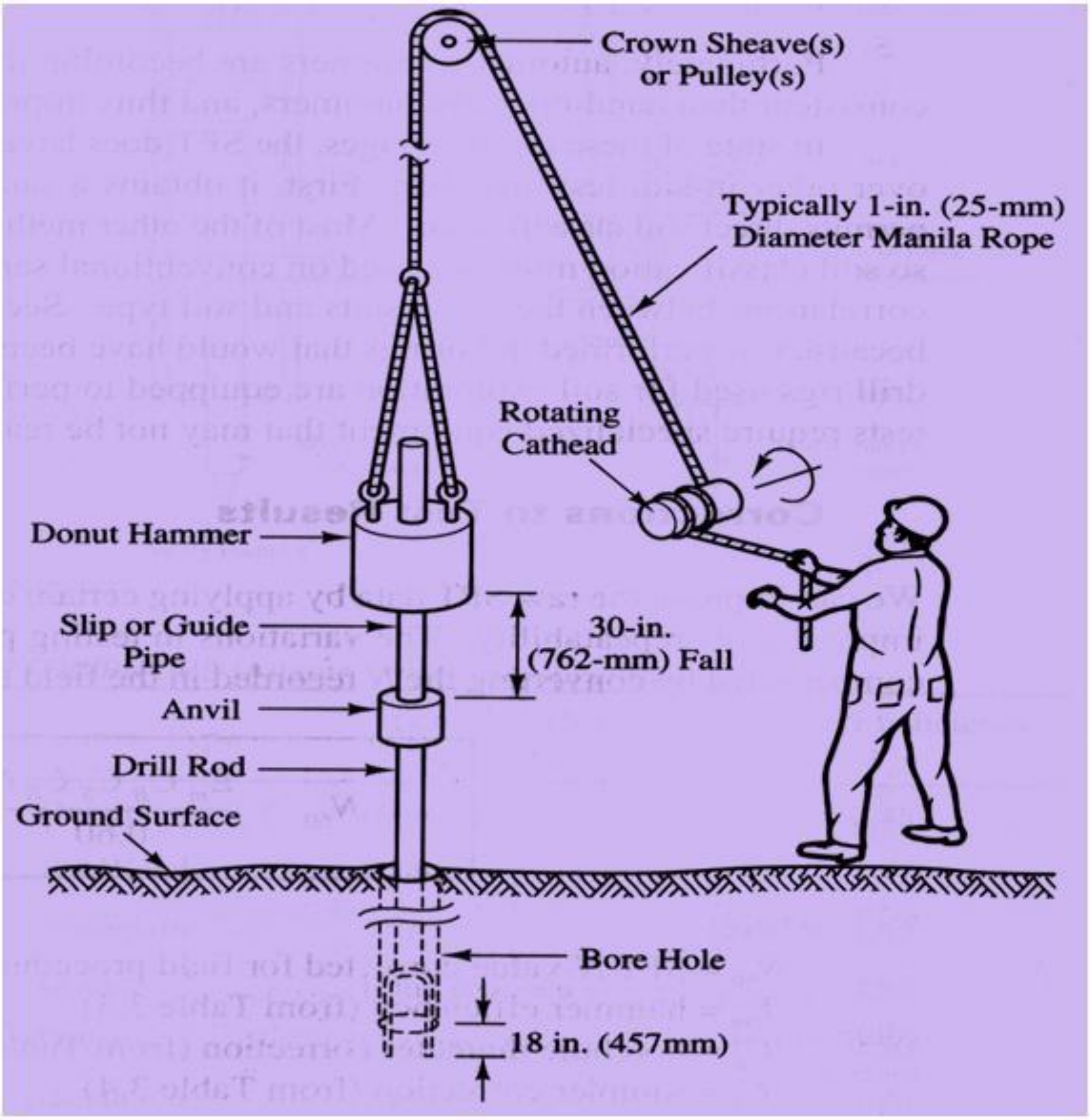
Interpretation:

- The load at which rapid increase in settlement occurs (or slope of settlement curve becomes steep) is indicative of the ultimate bearing capacity for the plate size.
- For design, a factor may be applied to convert plate result to footing size.

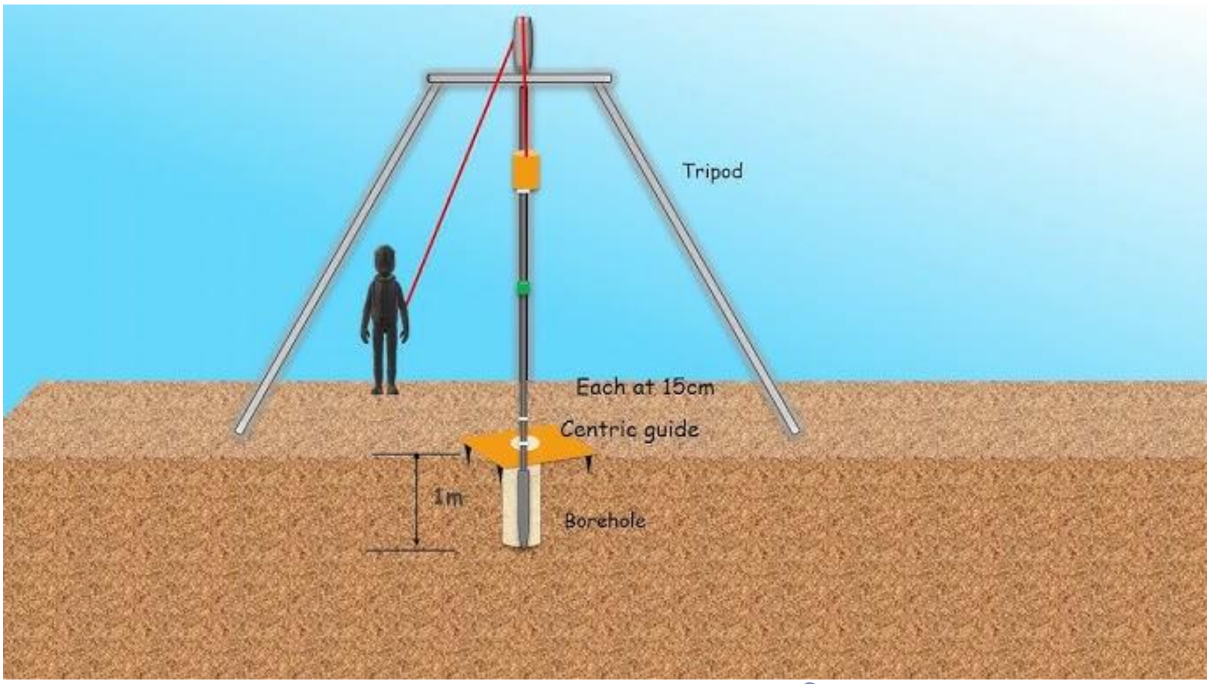
- The settlement behaviour (e.g., 25mm at certain load) gives indication of allowable pressure for acceptable settlement.
  Limitations & Considerations:
- The plate size may be much smaller than actual foundation, so scale effects should be considered.
- Plate test gives result for that specific depth/soil condition; heterogeneity of soil means multiple tests may be needed.
- Time required for settlement in clays may be long; tests on clays need longer hold times.
- Reaction loading arrangement must ensure vertical load is applied uniformly and settlement measurement accurate.
  Exam Tip: When writing, mention "As per IS 1888:1982", outline procedure steps, mention what you obtain (ultimate & allowable bearing capacity, settlement characteristics), and drawbacks/precautions.

B) Standard Penetration Test (SPT)





Crown Sheave(s) or Pulley(s)
Typically 1-in. (25-mm) Diameter Manila Rope
Rotating Cathead
Donut Hammer
Slip or Guide Pipe
30-in. (762-mm) Fall
Anvil
Drill Rod
Ground Surface
Bore Hole
18 in. (457mm)



Definition & Purpose:
The Standard Penetration Test (SPT) is a widely used in-situ dynamic test where a standard sampler (split-spoon) is driven into the soil at the bottom of a borehole by repeated blows of a hammer. The number of blows required for the last two increments of penetration (usually 300 mm) gives the "N-value" which is used as a measure of soil resistance (density or strength) and can be correlated to bearing capacity, settlement and liquefaction potential. (Wikipedia)
Standard & Reference:
In India the procedure is governed by IS 2131:1981 (and more recently IS 2131:2025) – "Method for Standard Penetration Test for Soils". (standardsbis.bsbedge.com)
Apparatus:

- Borehole of suitable diameter (typically 60-75 mm).
- Hammer of specified mass (63.5 kg) dropping a specified height (75 cm) per blow. (Prepp)
- Split-spoon sampler (outer diameter ~50 mm, inner ~35 mm) attached to drill rods.
- Anvil, drive rods, tripod/derrick and hammer release mechanism.

Procedure (summary):

1. Drill the borehole to the required depth. Clean and flush out any loose material. (Rohini Engineering College)
2. Seat the sampler 150 mm (or 150 mm penetration) (seating drive). Then record number of blows required to drive the sampler 150 mm (first interval) and then next 150 mm. The number of blows for the second and third 150 mm

penetration (total 300 mm) is summed and recorded as the SPT N-value. (Rohini Engineering College)

3. If the number of blows exceeds 50 for any 150 mm interval, the test may be stopped (refusal).
4. Record groundwater level, soil sampling from split-spoon if needed, soil stratification.
5. The N-value is then corrected for overburden and dilatancy if required before using in correlation. (igs.org.in)

Interpretation & Use for Bearing Capacity:

- The N-value is empirically correlated with soil density, internal friction angle, relative density or bearing capacity. (Testbook)
- For instance, a higher N indicates higher density/strength and likely higher allowable bearing capacity.
- Because the SPT is less direct than plate load, one often uses charts or empirical relationships to obtain allowable bearing capacity from N-values.

Advantages & Limitations:

Advantages:

- Can be carried out during borehole drilling; simultaneous sampling.
- Widely used, large database of empirical correlations.

Limitations:

- Disturbed sample; energy delivered may vary (hammer efficiency issues) → N-value may have inherent variability. (igs.org.in)
- Correlations are empirical; need judgement and experience.
- In very soft clays or very hard rock conditions, SPT may be less reliable.

Exam Tip: For exam answer, mention "As per IS 2131", describe equipment & procedure (hammer weight, fall height, intervals of penetration), define N-value, its use for bearing capacity/settlement, mention corrections and limitations.

Summary of Field Methods (5.3)

- Plate Load Test gives a **direct measurement** of bearing capacity and settlement for the actual site under the plate size used; best for shallow foundations and critical loads.
- Standard Penetration Test (SPT) provides **indirect measure** (N-value) of soil resistance; used widely for subsurface exploration and initial estimation of bearing capacity among other soil parameters.

- Both tests are complementary: plate load for direct design-verification; SPT for mapping subsurface conditions, soil classification, preliminary bearing capacity & settlement estimates.
- For exam purposes: mention the applicable IS codes (IS 1888 for plate load; IS 2131 for SPT), outline procedure steps, key outputs, uses and limitations.

Diploma Wallah

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