# UNIT 1:

# Geotechnical Engineering–II

*B Tech Civil Engineering – 6th Semester*

Course Materials

# Chapter I: SOIL EXPLORATION

# Soil Exploration

# WHAT ?? WHY ??

- For construction of any structure, a **knowledge about the ground** conditions is important. The soil structure, **capacity and behaviour** under various loading conditions will help design the substructures and retaining structures, and to suggest remedial actions to **improve** ground conditions when required.

- Exploration in soil- involves a site visit, quick visual inspection and detailed tests to determine the behaviour

- ***"The field and laboratory investigations required to obtain necessary data regarding the soil, for proper design and successful construction of any structure at the site are collectively called soil exploration."***

# Objectives of Soil Investigation

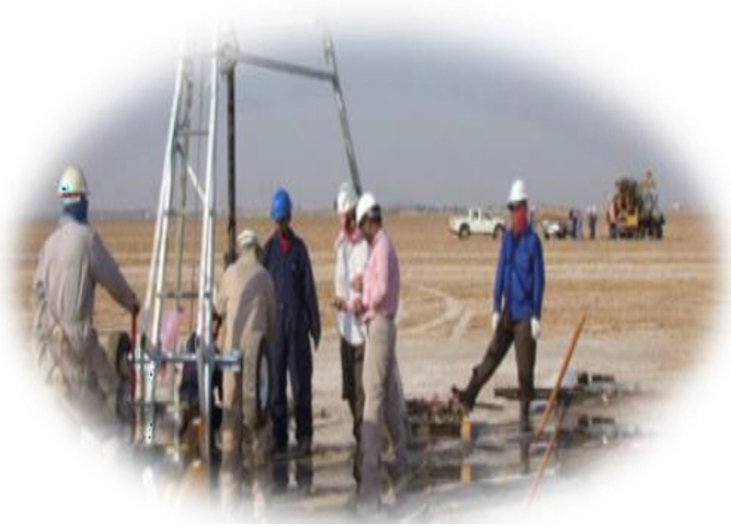
1. To assess the general suitability of site
2. To determine the bearing capacity of the soil
3. To Select the type and depth of foundation for a given structure Estimate max. probable settlement (total and differential)
4. Investigate the nature and depth of each stratum and assess required properties
5. To select the suitable construction technology based on availability and economy
6. To know the ground water conditions
7. Predict possible difficulties and problems in site and suggest remedial actions
8. Ensure safety of existing structures
9. Investigate the occurrence of any natural or manmade changes in conditions and the result from those changes

This information obtained by -

Drilling holes, taking samples,
finding Index and Engineering properties
Conducting some field tests

# HOW TO DO IT??

- For any project, soil investigation Costs of 0.2%- Even 1% in some cases- So proper planning must!!
- Depends on
  - Type and importance of structure
  - Nature of subsoil(strata variability)
  - Budget/economy



- Involves
  - Location and depth of boreholes
  - Tests to be done, and test methods
  - Sampling methods
- 3 important phases: Planning→ execution→ report writing

**Detailed information→ Less uncertainty later→ less factor of safety(or *factor of Ignorance!!*)→less cost of construction**

# Stages in Subsoil Exploration


**Reconnaissance**

Preliminary Investigation

Detailed investigation

Involves a site visit and visual inspections at the site

Rough Idea about work that how to start

- To assess the need for detailed investigation
- Determination of depth, thickness, extent and composition of each layer
- Depth of bedrock and Ground water table also studied
- Lab and field tests to assess basic properties
- Chemical and bacteriological tests if needed
- Methods:
    - Boreholes, test pits, Cone penetrometer, Sounding rods, Geophysical methods

- Mainly for big projects- Dams, bridges, multistoried buildings
- Also for newly built up soil
- Involves extensive boring programme → sampling → lab and field testing
- For small projects on site with uniform strata or clear history, info. from reconnaissance and prelim. investigation sufficient
- Uniform strata→ boreholes at regular spacing

# Some Visual indications about site

- Random depressions and marked irregularities→ *Sink holes*
- Wrinkling of surface on hillside→ *soil creep*
- Shafts or heaps of mineral waste→ *abandoned mines*
- Low lying flat areas→ *river or lake bed*
- Springs, wells→ *High water table*
- Marshy ground→ *High water table with poor drainage*

# BOREHOLE (BH)

- Depth, lateral extent and number of boreholes data are important for any soil investigation before construction
- **Depth of Exploration:** Depends on *type of structure*, *intensity of load*, *soil profile, and the physical properties of soil*

*(Based on few trial pits and test borings, or an experienced person's judgement)*

***Significant Depth:***

*"Depth upto which the superimposed loads can produce considerable settlement and shear stresses"*

- Generally, significant depth is that at which vertical stress is 20% ( or 1/5$^{th}$)of the load intensity (considering 2:1 load distribution, stress at D=1.5B is nearly 1/5$^{th}$)
- ***Depth of exploration must be greater than or equal to significant depth***

# Depth of exploration for some structures

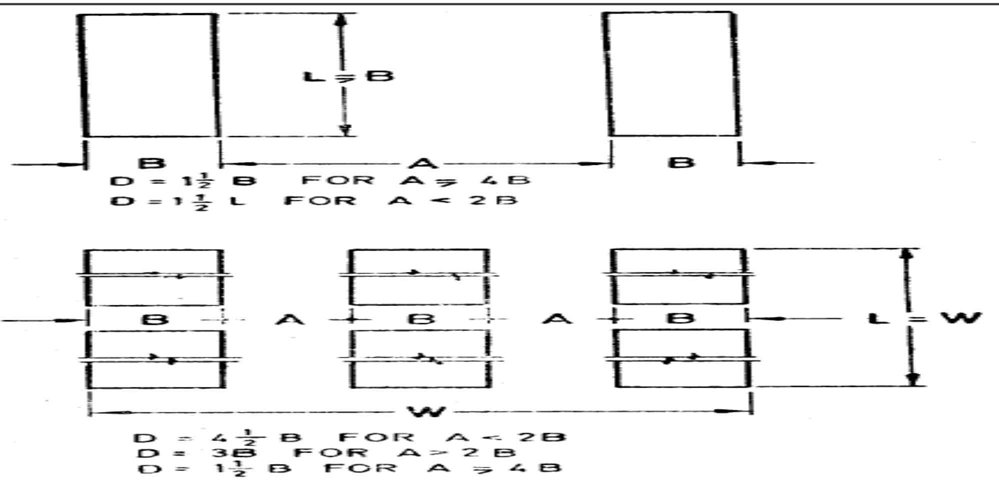
(Code: IS 1892-1979)

IS : 1892 - 1979

**TABLE 1 DEPTH OF EXPLORATION**

( *Clause* 2.3.2.1 )

| Sl No. | Type of Foundation | Depth of Exploration ( *D* ) |
|---|---|---|
| i) | Isolated spread footing or raft | One and a half times the width ( *B* ) ( *see* Fig. 1 ) |
| ii) | Adjacent footings with clear spacing less than twice the width | One and a half times the length ( *L* ) of the footing ( *see* Fig. 1 ) |
| iii) | Adjacent rows of footings | *See* Fig. 1 |
| iv) | Pile and well foundations | To a depth of one and a half times the width of structure from the bearing level ( toe of pile or bottom of well ) |
| v) | 1. Road cuts | Equal to the bottom width of the cut |
| | 2. Fill | Two metres below ground level or equal to the height of the fill whichever is greater |



- For hospitals and office buildings, the following rule could be use to determine boring depth

**$D_b = 3S^{0.7}$ (for light steel or narrow concrete buildings)**

**$D_b = 6S^{0.7}$ (for heavy steel or wide concrete buildings)**

**where:**

**$D_b$ = depth of boring, in meters**

**S = number of stories**

- Deep excavations, the depth of boring should be at, least 1.5 times the depth of excavation.

- ***The minimum depth of core boring into the bedrock is about 3m.*** If the bedrock is irregular or weathered, the core borings may have to be extended to greater depths.

- If there are weak zones at depth ( zone of volume change, seasonal variations, swelling and shrinkage), boring should be continued below this weak zones.

**Always ensure:** Exploration depth such that load can be carried by that stratum without undesirable settlement and shear failure

# Lateral extent of exploration

- Number and spacing of boreholes must be such as to reveal any major changes in  the thickness, depth and properties of strata over the base area of the structure and its immediate surroundings.
- More uniform strata- less no: of BH and more spacing can be adopted
- Erratic variation- more no: of boreholes  at reduced spacing
- Wherever possible, BH must be sunk close to the proposed foundation, especially in soils of erratic variation
- When layout not planned before- Best pattern is evenly spaced grid of BH
- Cone penetration tests can be performed T every 50m intervals
- Gravelly and boulderous strata- CPT not feasible, hence geophysical methods adopted

# Lateral extent of exploration (IS: 1892)

| UNIT | NO OR SPACING OF BORE HOLES |
|---|---|
| Small &less important **buildings** | **1** at centre may suffice. |
| Compact **buildings** ( covering an area of 0.4 hectares) | At least **5** ( 1 at centre & 4 at corner). |
| Large multistoreyed **buildings** | At all important locations, spacing should be **10 to 30m.** |
| Highways | Along centre line, spacing should be **150 to 300m.** |
| Concrete dams | Spacing generally varies between **40 to 80m.** |

# Different Methods of Exploration in soils

## Direct/Open excavation (<6m)

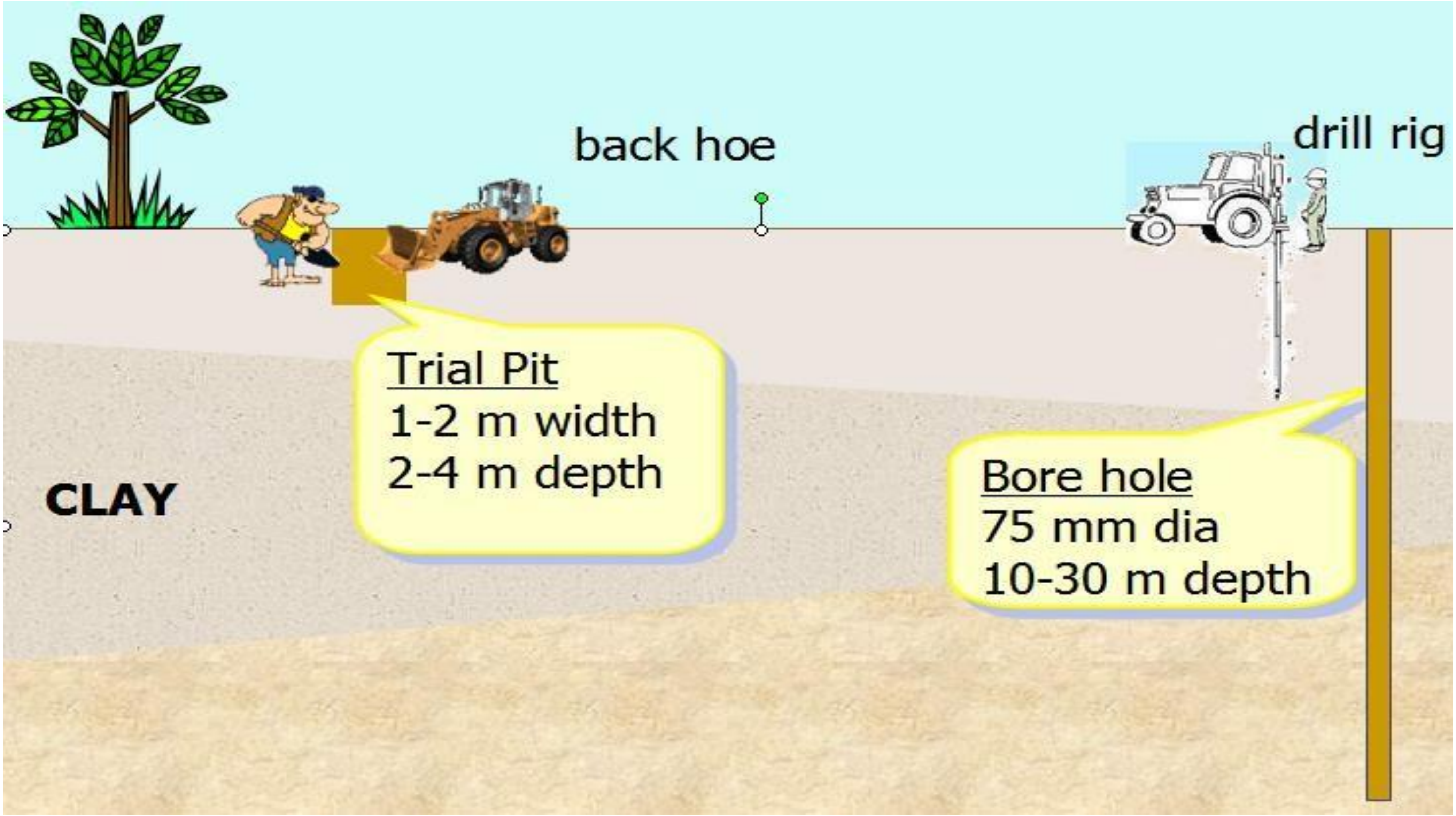
- Drifts
- Shafts
- Pits
- Trenches

## Semi direct/Boring

- Auger boring
- Wash boring
- Percussion boring
- Rotary boring
- Core Drilling

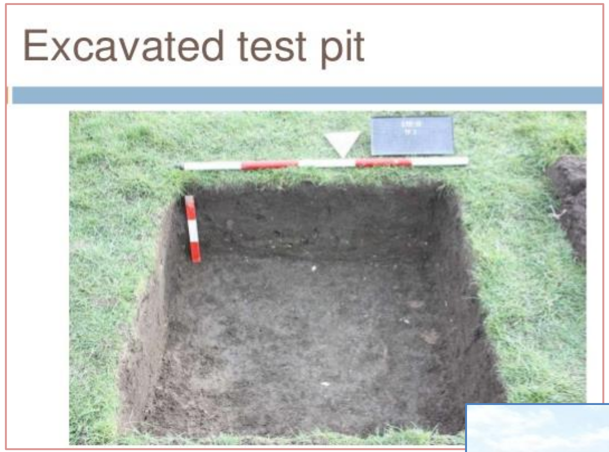
## Indirect methods

- Geophysical methods
- Sounding rods


back hoe
drill rig
Trial Pit
1-2 m width
2-4 m depth
CLAY
Bore hole
75 mm dia
10-30 m depth

# Open excavation (for depth <6m)

- **Trial pits**-1.2m X1.2m ( IS 4453-1967)
  - Depth > 3m →lateral support
  - Proper ventilation and dewatering if necessary




- **Trenches**-long shallow continuous pit, exposing a line

- **Drifts(adits)**-horizontal tunnels along hillside, especially for rocks
  - Min 1.5m(b) X 2m (h)
  - Lateral support if unstable
  - Generally expensive
  - Helps to establish minimum excavation limits to reach sound rocks, & to locate failure and shear zones


- **Shafts:** Large vertical holes (min 2.4m width or diameter)
  - For D>4m
  - Proper support and ventilation required

# Boring methods

- Boring refers to advancing a hole in the ground, used especially when $D > 6m$
- It is a semi direct method of exploration
- **Necessity:**
  - To obtain representative soil and rock samples for laboratory tests.
  - To identify the groundwater conditions.
  - Performance of in-situ tests to assess appropriate soil characteristics.
- Extensometers and pressure meters can be installed
- Results ⟶ Borelog and subsurface profiles can be obtained

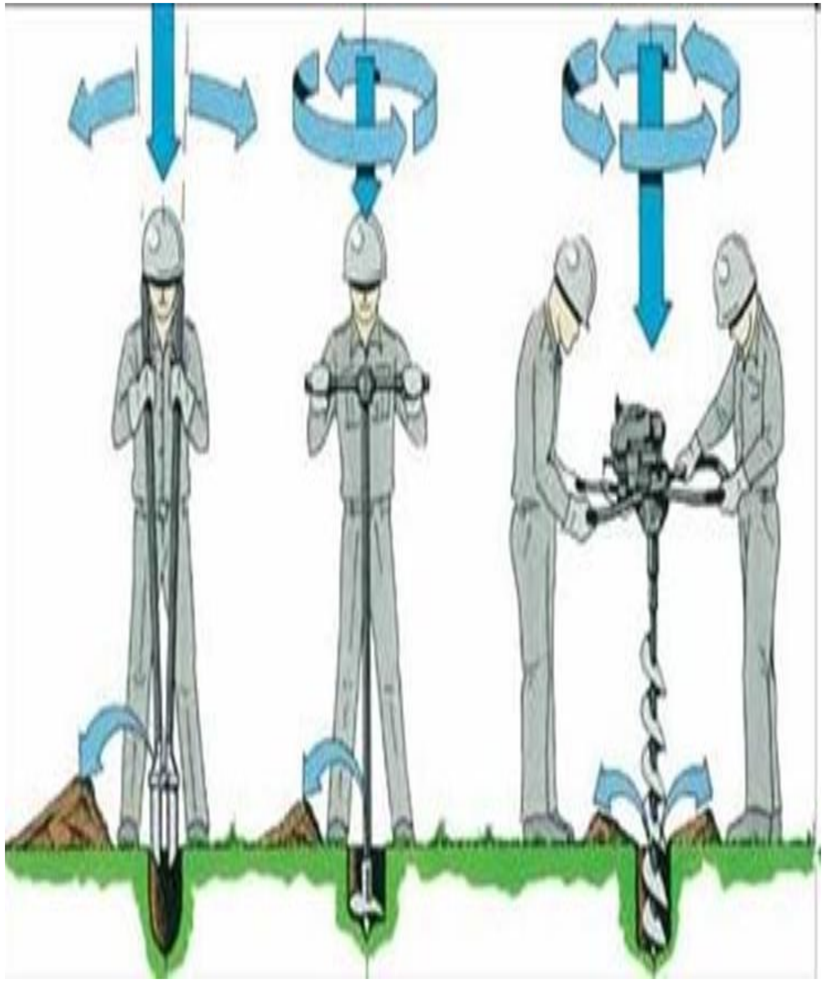
**Drilling borehole ⇨ taking samples ⇨ testing ⇨ Borelog**

- Types: (1)Auger boring (2)Wash boring (3) Percussion drilling (4) Rotary drilling (5) Core drilling

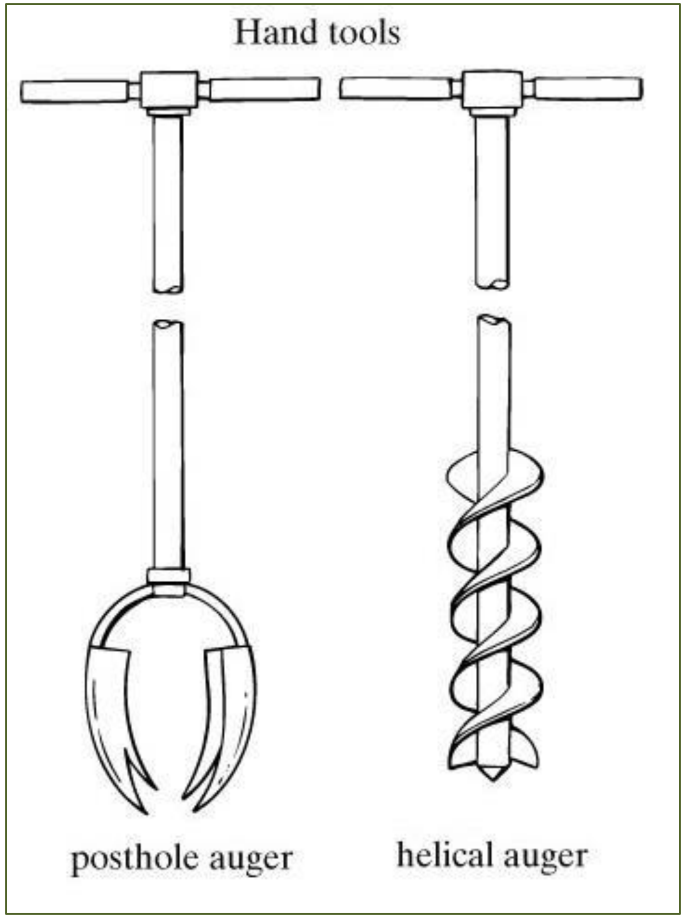
# Auger Boring

- Simplest and most common method of boring for small projects in soft cohesive soils. – *Fast, economical, light, inexpensive and flexible*

- Auger a drill for advancing holes
  - Has a shank with cross wise handle to apply torque
  - The length of the auger blade varies from 0.3-0.5m.
  - Diameter of central rod almost 18mm
  - Auger held vertically and driven by applying torque, either manually or mechanically
  - **Driving force: Torque on handle+ downward pressing force**
  - The auger is rotated until it is full of soil, then it is withdrawn to remove the soil and the soil type present at various depths is noted.
  - Hand augers and mechanically operated auger
  - Post hole augers: for taking samples when hole is already dug/driven



- **Hand-operated** →can be made upto about 6m depth
- Usually used for shallow depth applications→ rail road, highways etc
- Highly disturbed samples (but better than other boring methods)→ used for classification purpose and basic tests only




- **Power operated** →The power required to rotate the auger depends on the type and size of auger and the type of soil.
- can be made upto about 12m depth

Downwards pressure → applied hydraulically, mechanically or by dead weight

## Hand operating augers

## Mechanical/Power operating augers

**Outcomes of Auger boring:**

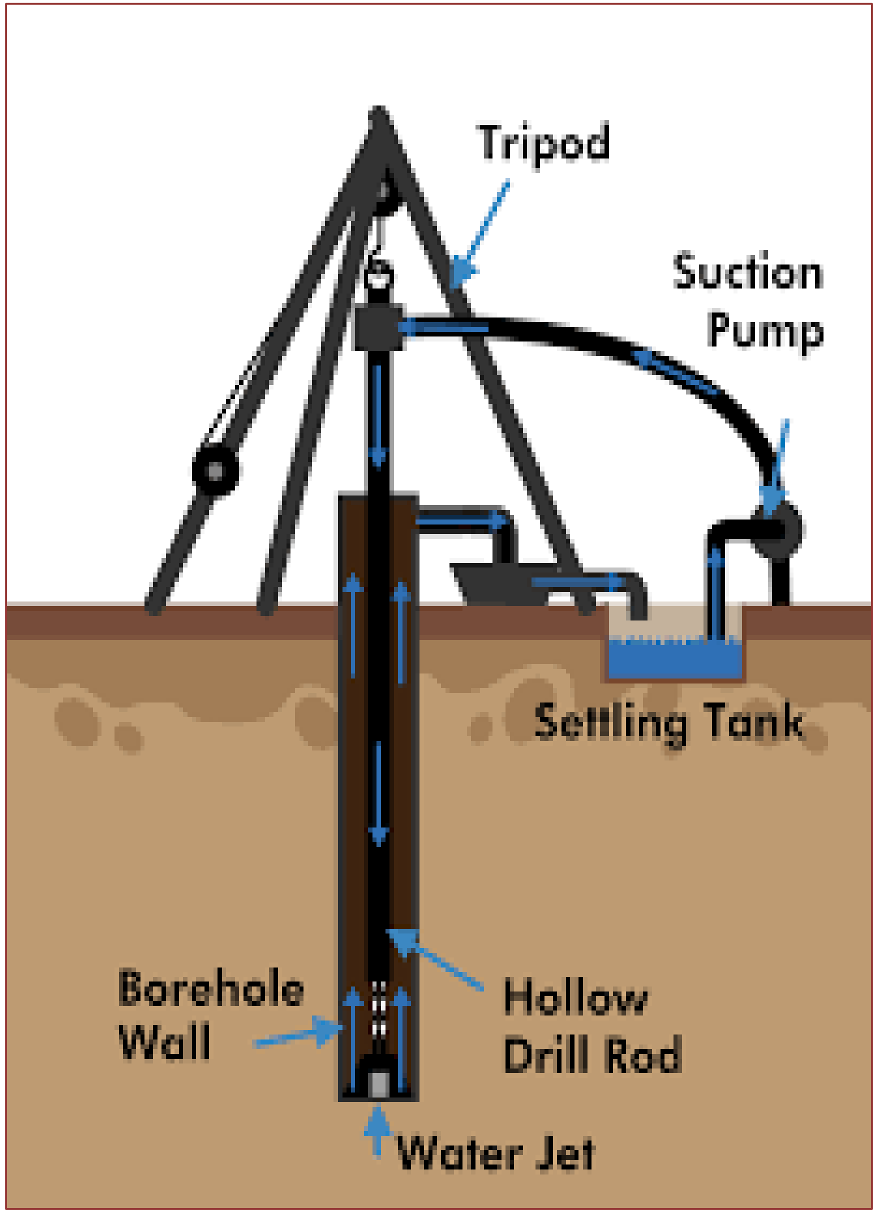
- Disturbed soil we get
- Below Water table not possible
- Changes in soil strata not known

# Wash Boring

- Fast and simple→ do works at > 12 m depths
- Casing pipe –5-10cm diameter → driven to the ground first, upto certain depth (~1.5m)
- Wash pipe- lower dia→ upper end connected to water supply system, and lower end to chisel shaped chopping bit
- Water with high pressure pumped through hallow boring rods → released from narrow holes in a chisel attached to the lower end of the rods.

**Driving force: jetting action of water + chopping action of chisel**

- Slurry comes up through annular space between casing pipe and wash pipe→ taken in tub→ settles→ samples can be taken if required
- Further advancement of hole can be done by raising and lowering of chopping bit
- Casings can be extended→ or drilling fluids can be pumped instead



## Wash Boring

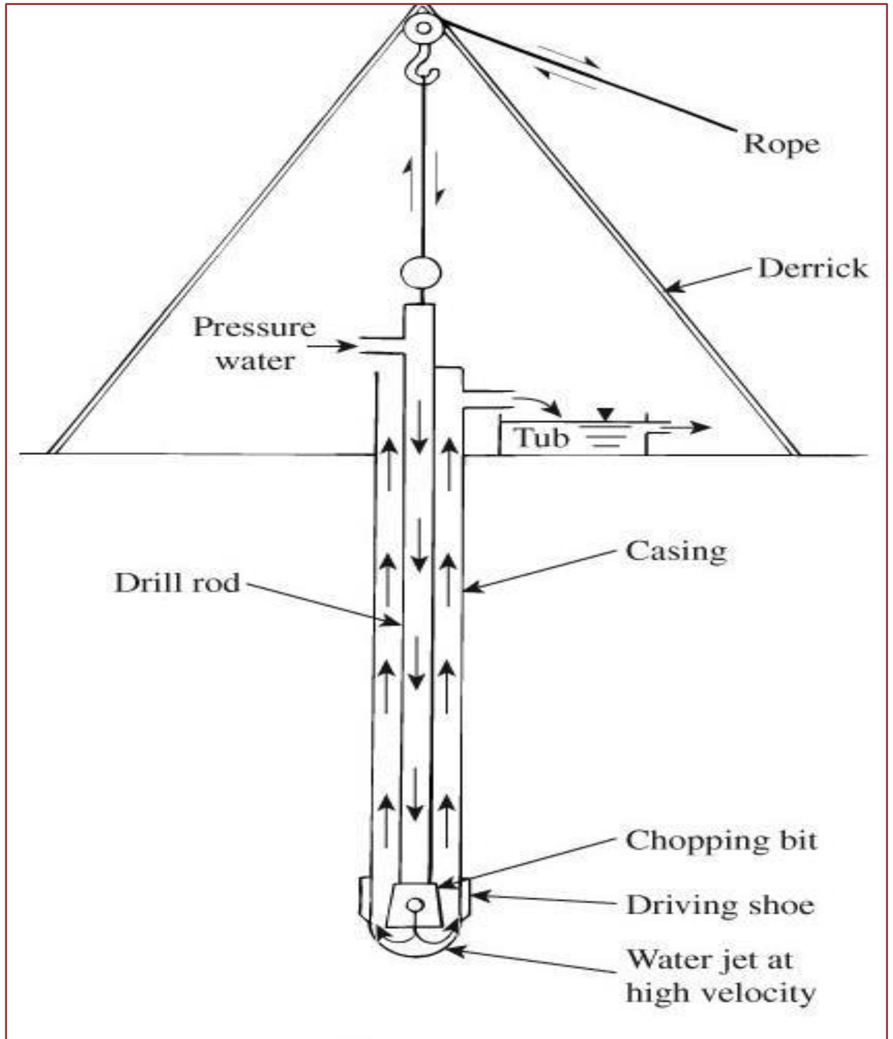
# Outcomes:

- Highly disturbed samples
- Finer particles (clay, loam etc.) wont settle, and heavier particles not brought up
- Exact strata identification not possible due to mixing of soil particles
- Slow in coarse grained and stiff soils
- Not effective in hard soils, rocks , boulders

- Can be used in most type of soil but the progress is slow in coarse gravel strata

- Some indications about strata→ from slurry colour and drill penetration resistance

- It is only used for advancing the borehole to enable tube samples to be taken or field test to be carried at the hole bottom.



Wash boring

# Wash Boring

# Percussion drilling

- Consists of breaking up of the formation by **repeated blows from a bit or a chisel**.
- Water should be added to the hole at the time of boring, and the debris removed at intervals.
- Where the boring is in soil or into soft rocks and provided that a sampler can be driven into them, cores may be obtained at intervals using suitable tools
- But in soils, the material tends to become disturbed by the action of this method of boring and for this reason, the sample may not be much reliable
- As these machines are devised for rapid drilling by pulverizing the material, they are not suitable for careful investigation.
- The **only method suitable for <u>drilling bore holes in boulderous and gravelly strata.</u>**

# Percussion drilling

- Change in soil character identified by composition of outgoing slurry
- Disadvantages:
  - Bottom material highly disturbed due to heavy blows
  - Expensive- requires large equipments
  - Minor changes cannot be detected from the slurry
- Uneconomical for holes of diameter< 10cm
- Also used for drilling tubewells

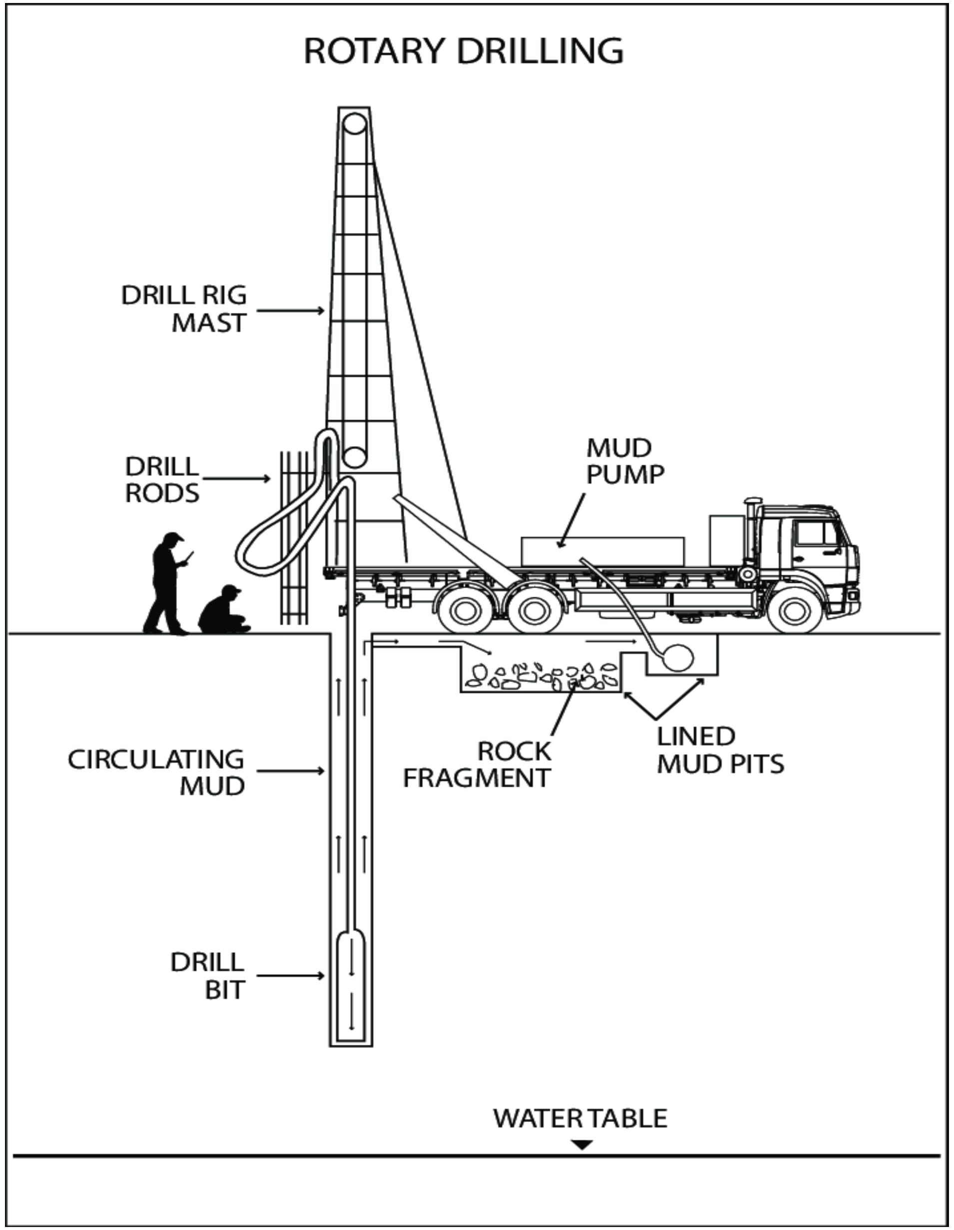
# Rotary drilling

- Similar to wash boring, but **hole advanced by rotating a hollow drill rod with cutting bit at the lower end** and drill head at upper portion
- Primarily intended for investigation in rock, but also used in soils.
- Water or drilling fluid is pumped down the hollow rods and passes under pressure through narrow holes in the bit or barrel
- Drilling rod rotates→ cutting bit shears off chips of material→ materials removed by circulating drilling fluids
- Functions of drilling fluid:
    - cools and lubricates the drilling tool
    - carries the loose debris to the surface between the rods and the side of the hole.
    - Provides some support to the sides of the hole if no casing is used .
- Useful for highly resistant strata and for **clay, sand,rocks**
- **Not for gravelly soil** since they keep rotating beneath drill rod

# Rotary drilling

- Two forms of rotary drilling→ open-hole drilling and core drilling.
- Open- hole drilling→ generally used in soils and weak rock→ just for advancing the hole → The drilling rods can then be removed to allow tube samples to be taken or in-situ tests to be carried out.
- Core drilling →used in rocks and hard clays →the diamond or tungsten carbide bit cuts an annular hole in the material and an intact core enters the barrel, to be removed as a sample.
- Typical core diameters are 41, 54 and 76mm, but can range up to 165 mm.
- Suitable for holes of 15-20cm dia; uneconomical for diameter < 10cm
- **Advantage**s :progress much faster, and disturbance of the soil below the borehole is slight.
- **Limitations** The method is not suitable if the soil contains a high percentage of **gravel/cobbles**, as they tend to rotate beneath the bit and are not broken up. The natural water content of the material is liable to be increased due to contact with the drilling fluid

# Rotary drilling




# Core drilling

- A type of rotary drilling→ **used for rocks**
- Similar to rotary drilling, but provided with a sharper cutting edge(made of diamond or tungsten)
- Drilling rod with core barrel fitted with drilling bit→ Rotated→ drill bit advances down→ cuts an annular hole around an intact core.
- Core then removed and retained by core lifter
- Water pumped continuously → to cool the drilling bit, and bring up the disintegrated materials
- **Important:** ensure that boulders, or layers of cemented soils are not mistaken for bed rock. This necessitates core drilling to a depth of at least 3 m ***in*** bed rock in areas where boulders are known to occur.
- For shear strength determination, a core with diameter to height ratio of 1 : 1 is required.
- Rock pieces may be used for determination of specific gravity and classification.

# Core drilling

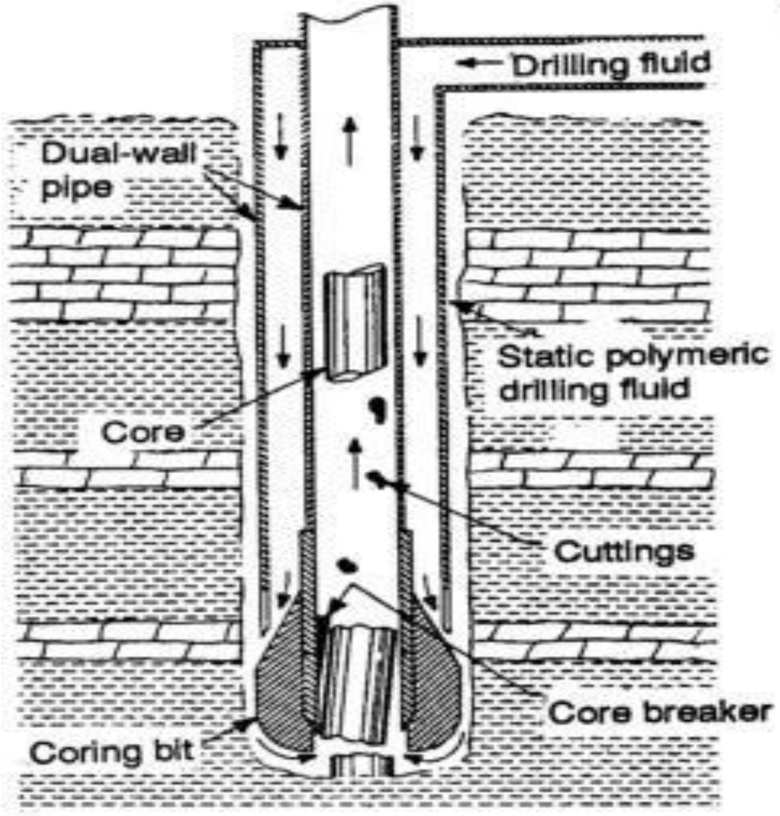
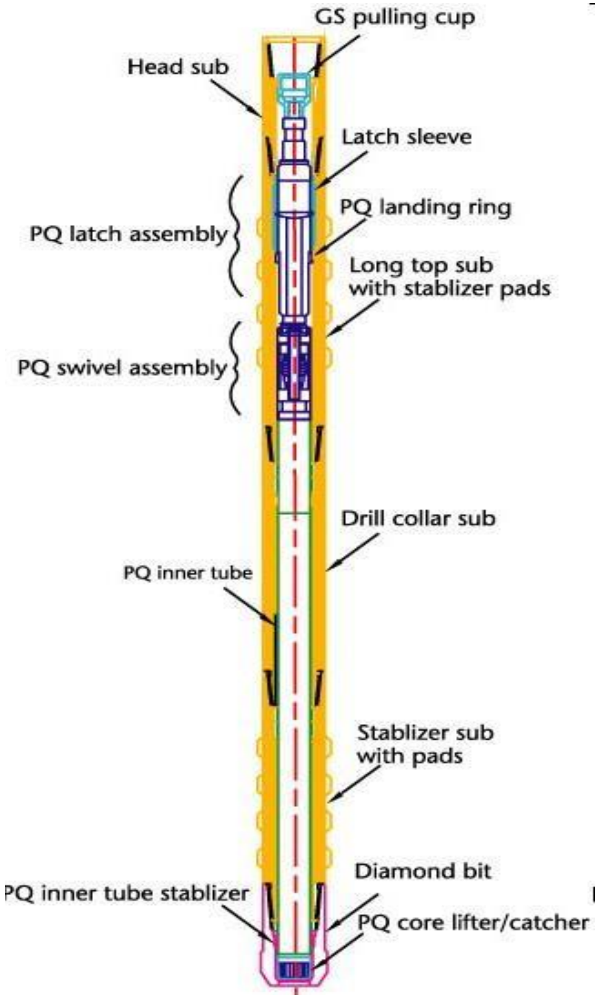



**Figure 11-1. Core-drilling equipment**



# SAMPLING TOOLS AND SAMPLERS


## Samples

**Undisturbed samples**

The natural state of soil structure remain as it is

To find: Shear parameters, Compressibility, Permeability, Field Moisture-Density, Void ratio

**Disturbed samples**

The natural state of soil structure get disturbed while sampling

To find: Atterberg limits, GSD, Compaction, SG

Representative samples

- Structure get disturbed but mineral composition is same

(Used to find index properties)

Non representative samples

- Mineral composition is changed

# Design features affecting degree of disturbance

Cutting edge

Inside wall friction

Method of applying force

Non-return valve

# Design features affecting degree of disturbance

**1. CUTTING EDGE**

**Inside Clearance: $C_i = (D_3 - D_1)/D_1 \times 100$**

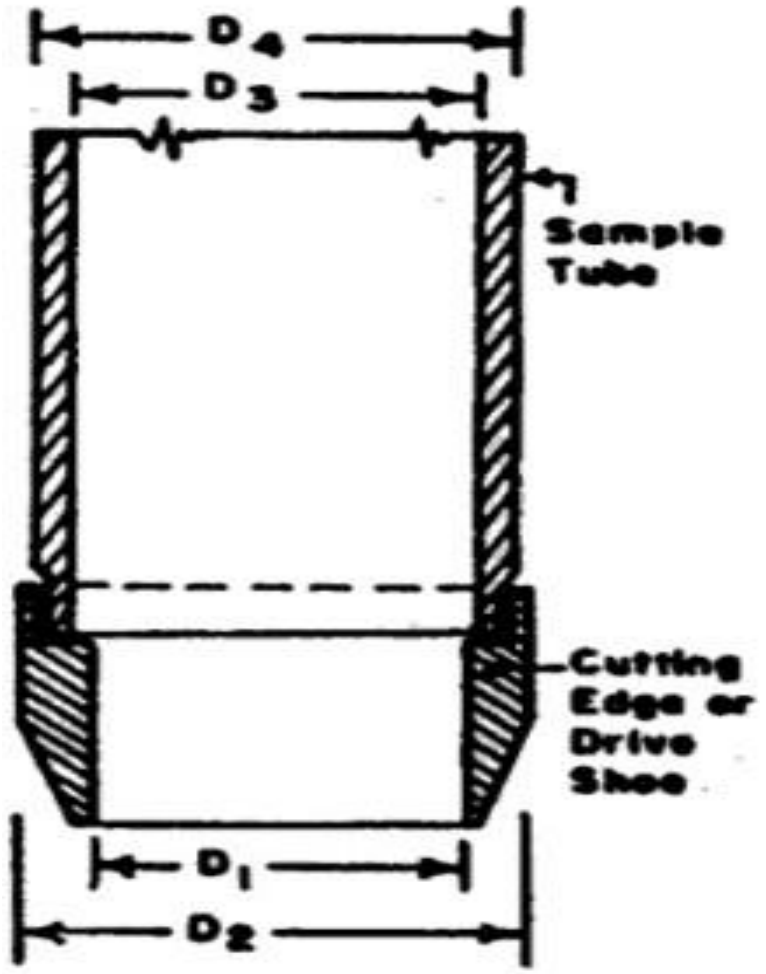
- Internal dia of cutting edge must be slightly less than internal dia of sampling tube
- It allows elastic expansion of the sample and reduces frictional drag

For undisturbed sample, **$C_i$ = 1 to 3%**

**Outside clearance: $C_o = (D_2 - D_4)/D_4 \times 100$**

- Outside dia of cutting edge must be more than outer dia of tube
- To facilitate the withdrawal of sampler from soil, this must be least

For undisturbed sample, It should lie between **0 to 2%**
**( But $C_o$ must not be much more than $C_i$)**



**Area ratio $A_r = (D_2^2 - D_1^2)/D_1^2 \times 100$**

- $A_r$= Ratio of Maximum cross-sectional area of the cutting edge to total area of the soil sample
- Should be as low as possible, consistent with strength requirement of sample tube
- Generally, for **Undisturbed samples**: Area ratio **less than 10%**

**2. Inside wall Friction:** The inside wall should be smooth .

Can be done by:

- Applying oil inside the tube
- Providing smooth finish to sample tube
- Ensuring suitable inside clearance

**3.Design of Non return Valve:**

- The sampler must have a large orifice to allow quick escaping of air, water or slurry.

**4. Method of applying force:**

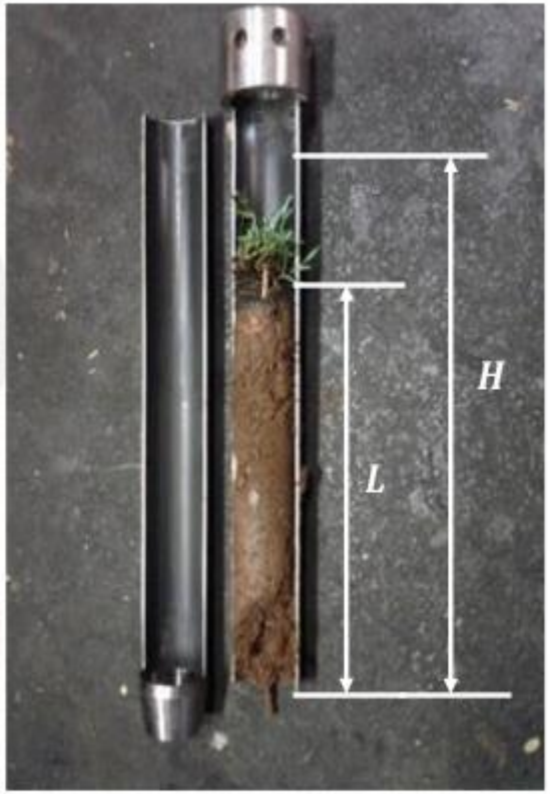
- The rate of advancement and method of application of force controls the sample disturbance.
- The sampler must be pushed not driven

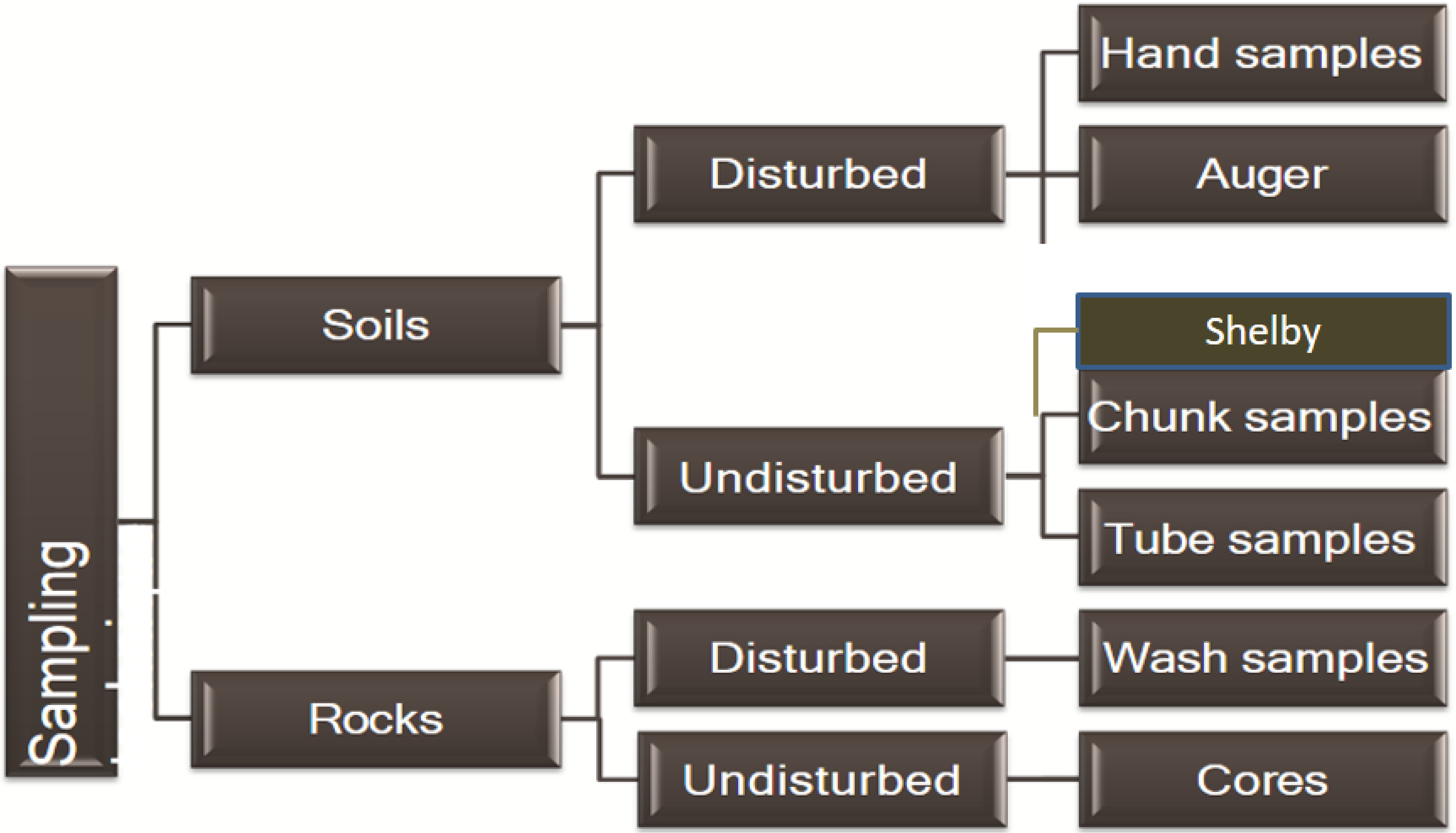
**5.Recovery ratio:**

$$R=L/H$$

L = length of sample within the tube;  H= depth of the penetration of sampling tube

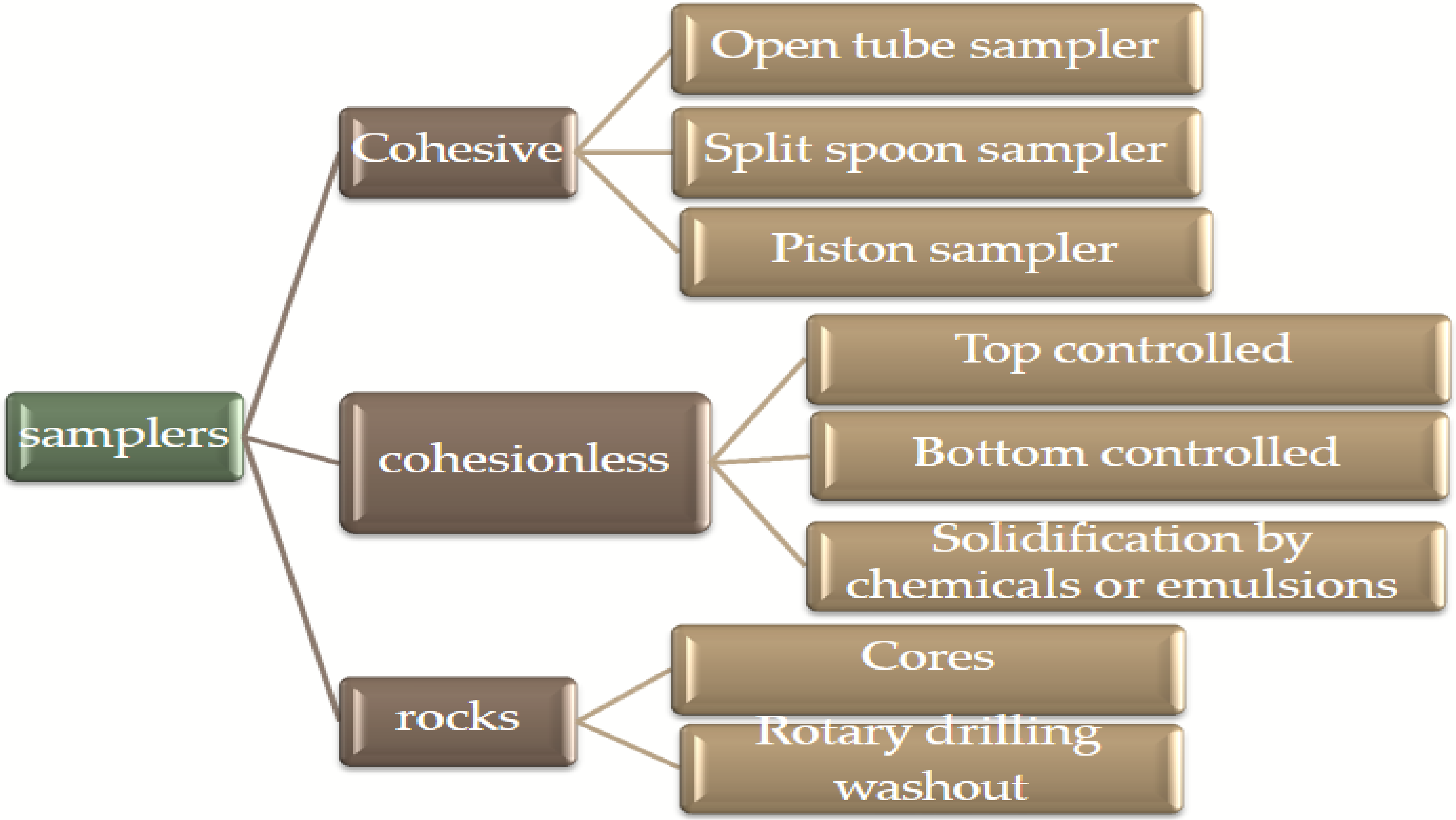
- It should be 96-98% for good undisturbed sample





Sampling
Soils
Rocks
Disturbed
Undisturbed
Hand samples
Auger
Shelby
Chunk samples
Tube samples
Disturbed
Undisturbed
Wash samples
Cores

# Samplers


samplers
Cohesive
Open tube sampler
Split spoon sampler
Piston sampler
cohesionless
Top controlled
Bottom controlled
Solidification by chemicals or emulsions
rocks
Cores
Rotary drilling washout

# Open tube sampler/ Shelby tubes

- Thin walled, **Undisturbed samples**
- Made of seamless steel with chamfered lower end for easy penetration
- Outside dia: 45mm,65mm,80mm,100mm etc.
- Thickness:1.25-3.15mm
- Commonly used: outside dia 50.8mm ,inside dia 47.63 mm =>Area ratio~ 10% (always < 15%)➔ Undisturbed
- Casing driven upto sampling level→ hole is cleaned→ sampling done
- Length of tube: 5-10 times dia for sandy soils, and 10-15 time sdia for clayey soils
- Sampler pushed, not driven→ least disturbance
- **Suitable in very soft to medium soft clays and silts**


# Split spoon sampler

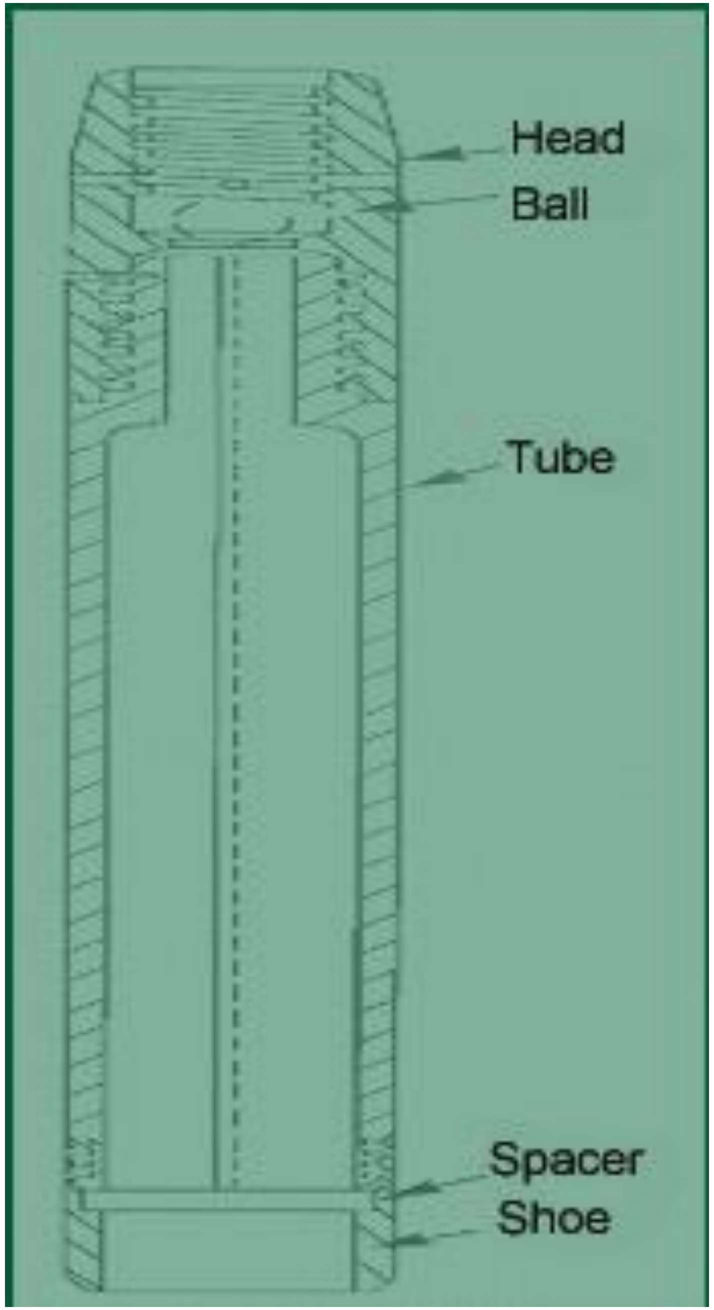
- 3 parts
- Driving shoe at bottom- 75mm long
- Steel tube, split longitudinally into 2 halves-450mm long
- Coupling at the top-150mm long

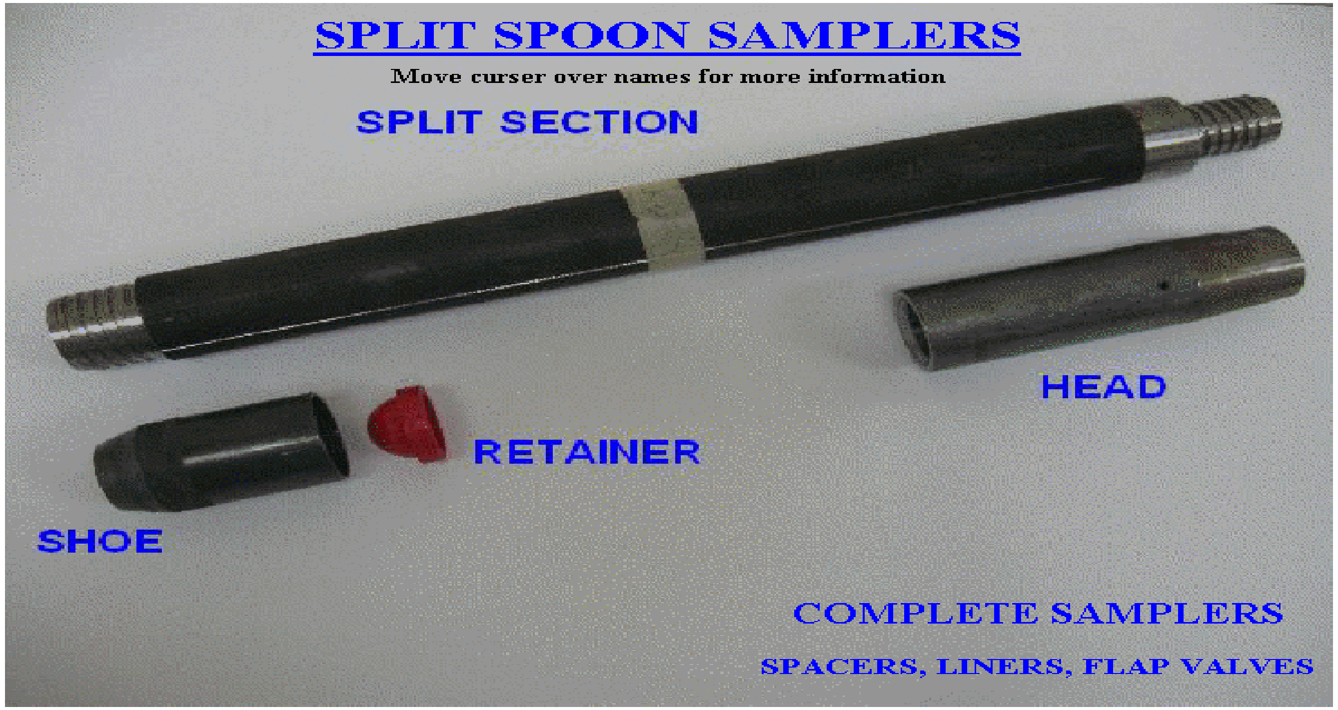
- Procedure:
  - Sampler lowered to the bottom of the borehole by attaching it to the drill rod→ Then driven by forcing it into the soil by blows of a standard hammer→ Sampler assembly then taken out→ coupling an driving shoe removed→ steel tube split into halves→ samples taken

- **Standard penetration Test:** Uses split spoon sampler→ Hammer 63.5Kg; height of fall 762mm

- Samples generally taken at intervals of 1.53m
- Commonly used dia: Outside dia 50.8mm and inside dia 34.9mm=> Area ratio > 100%→ **highly disturbed samples**

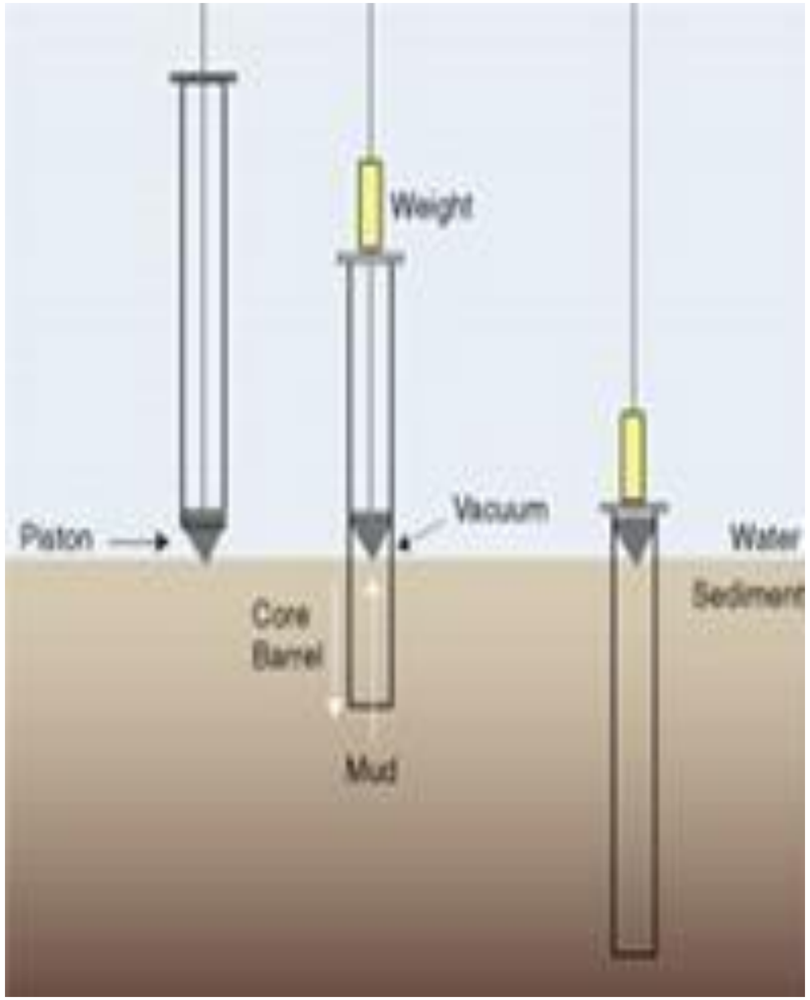
- When used in sand, ―spring core catcher‖ placed inside the split tube, to retain the sample

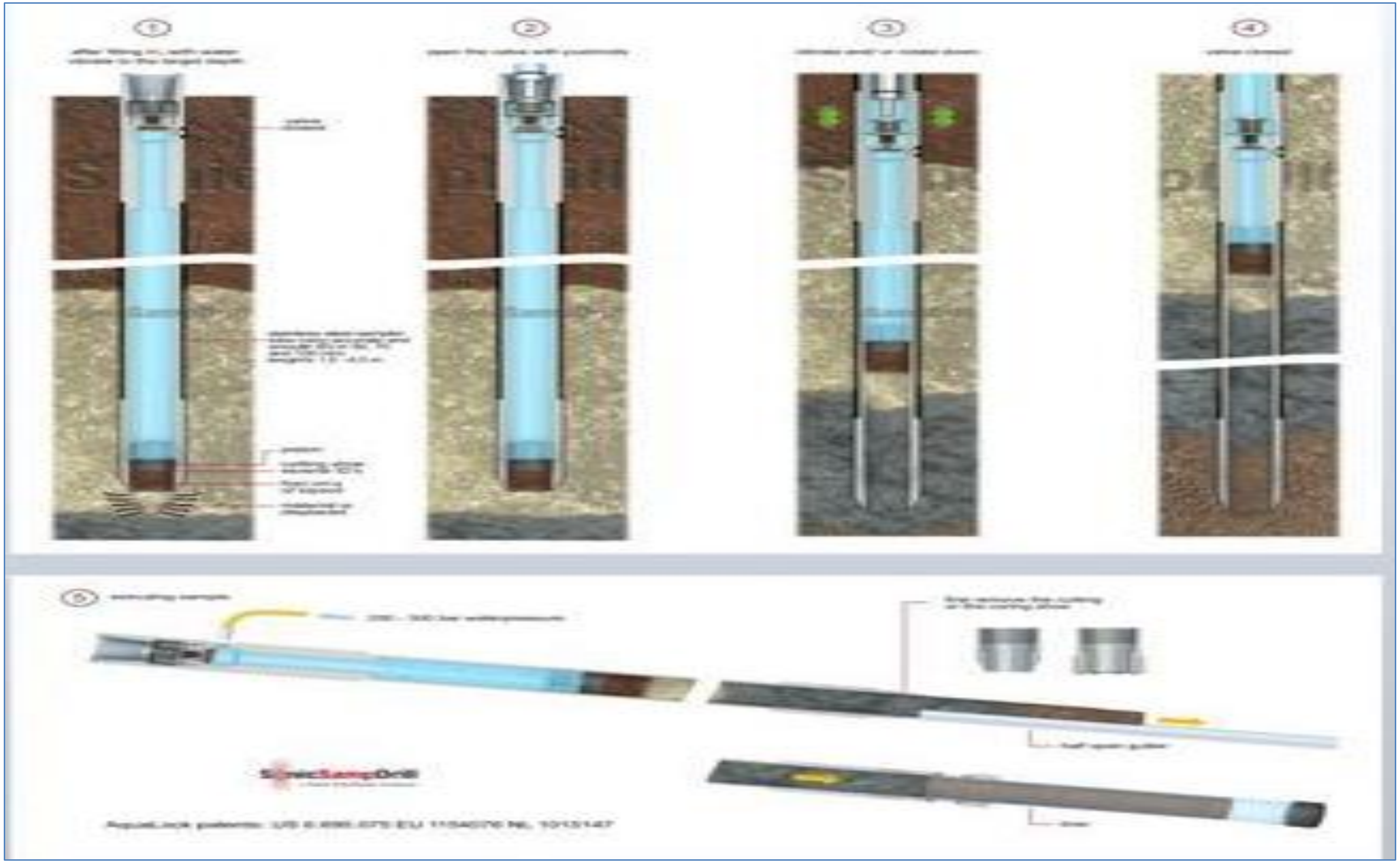

Head
Ball
Tube
Spacer
Shoe


SPLIT SPOON SAMPLERS
Move curser over names for more information
SPLIT SECTION
HEAD
RETAINER
SHOE
COMPLETE SAMPLERS
SPACERS, LINERS, FLAP VALVES

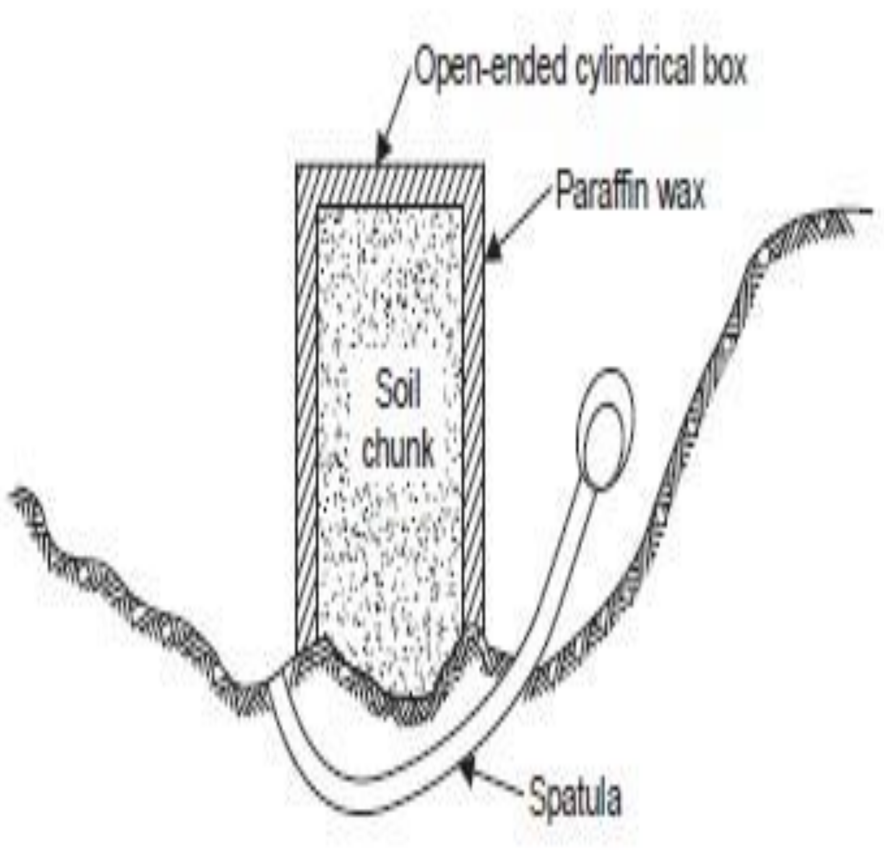
# Piston sampler

- Consists of two separate parts, (a) the sample cylinder and (b) the piston system
- Piston fits tightly in the sampler cylinder and is actuated separately.
- During the driving and till the start of the sampling operation, the bottom of the piston flush with the cutting edge of the sampler.
- At the desired sampling elevation, the piston fixed in to the ground and the sampler cylinder forced independently into the ground, thus punching a sample out of the soil
- The piston prevents water and dirt from entering the tube during the lowering operation. It also keeps the recovery ratio constant during the punch.
- As the sampler tube slides past the tight fitting piston during the sampling operation, a negative pressure is developed above the sample, which holds back the sampleduring withdrawal





# Hand carved samples



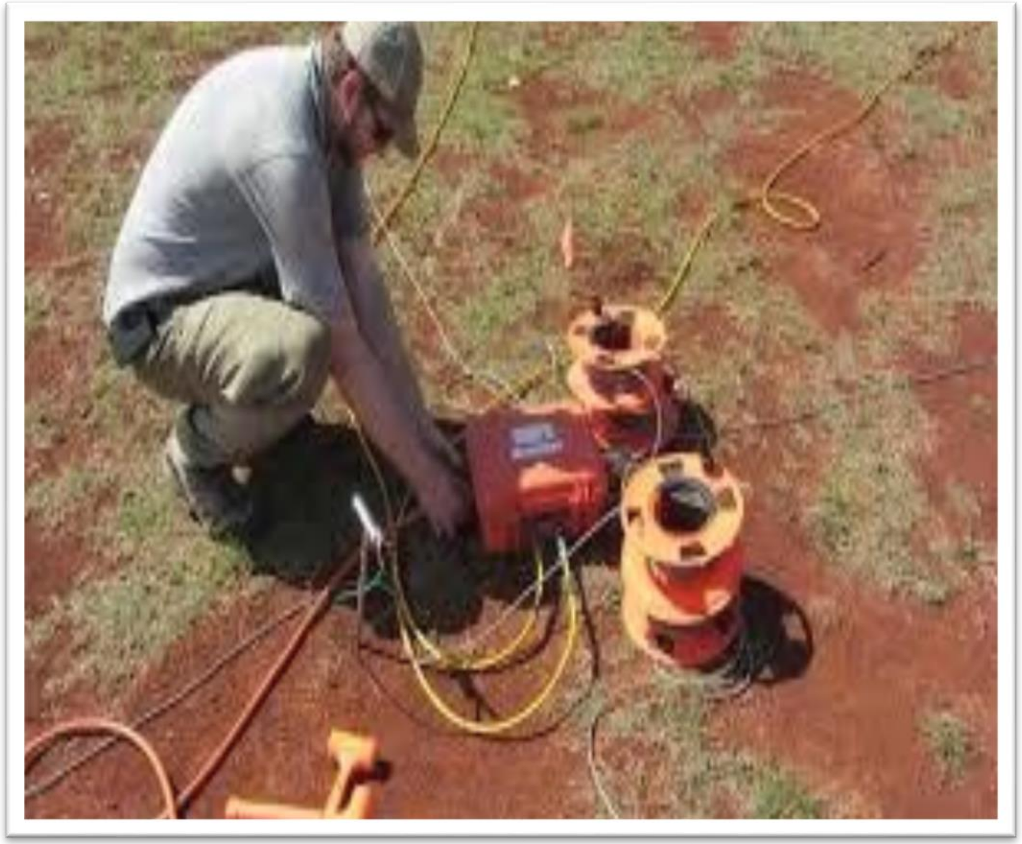

- A cylindrical container open at both the ends is used for sampling.
- The soil is trimmed to shape at the bottom of the test pit
- One end of container is closed and inverted over the soil chunk and the soil sample is removed using spatula
- **This method is suitable for cohesive soil.**

# GEOPHYSICAL METHODS

- ***Indirect method :*** From surface→ measuring certain physical properties → interpret the subsurface soil properties
- Based on the changes in **gravitational, magnetic, electrical, radioactive or elastic** properties of the different elements of the subsoil
- Gravitational, magnetic and radioactive properties→ minor change near surface
- **Resistivity method** based on the **electrical properties** and the **seismic refraction method** based on the **elastic properties** → widely used

**ADVANTAGES:** simple, fast, economical, portable instruments, large area easily investigated

**APPLICATIONS:** subsurface soil, mineral ores, geologic structures, groundwater studies

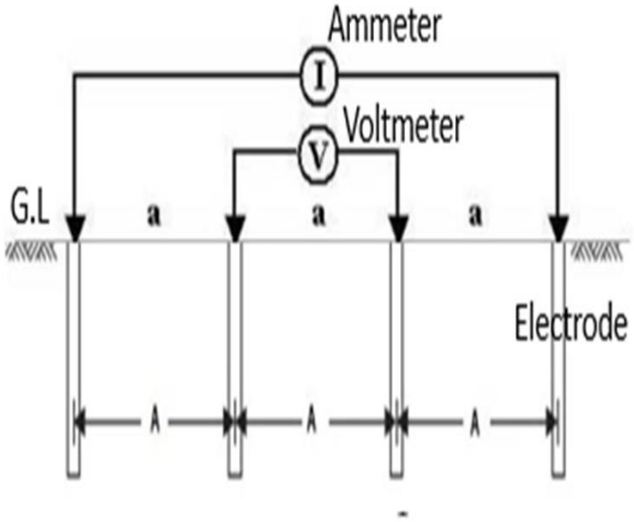


# Electrical methods

### Principle

- Electric methods are based on the fact that the **subsurface formation, structures, ore deposits, etc. possess different electrical properties**.
- Numerous and versatile applications → groundwater studies, subsurface structures and many others
- Properties considered: electrical resistivity, dielectric constant
- Types: electrical resistivity method, electromagnetic methods, self potential methods and induce polarization method
- **Subsurface soil exploration→ electrical resistivity method used**

Electrical Resistivity Measurements




$$\rho_A = 2\pi a \frac{V}{I}$$

# Electrical Resistivity method- Pros and Cons

**Advantages**

- It is a very rapid and economical method.
- It is good up to 30m depth.
- The instrumentation of this method is very simple.
- It is a non-destructive method.

**Disadvantages of this method are:**

- It can only detect absolutely different strata like rock and water.
- It provides no information about the sample.
- Cultural problems cause interference, e.g., power lines, pipelines, buried casings, fences.

# Seismic Methods


**Controlling Properties** : Elastic property

**Principle :**

- Subsurface soil and rock formations bear **different elastic properties**→ seismic waves have different velocities in different types of soils (or rock) →waves refract at boundaries
- Artificial impulse produced either by **detonation of explosive or mechanical blow** with a heavy hammer at ground surface or at the shallow depth within a hole.
- Assumes that soil gets denser with depth and hence velocity of seismic waves increase with depth.
- **Geophones** fixed at suitable intervals on the ground

- Seismic waves→ compressive waves, shear waves and surface waves→ **compressive waves** recorded

- These waves are classified as **direct, reflected and refracted** waves.

- The direct wave travel in approximately straight line from the source of impulse.

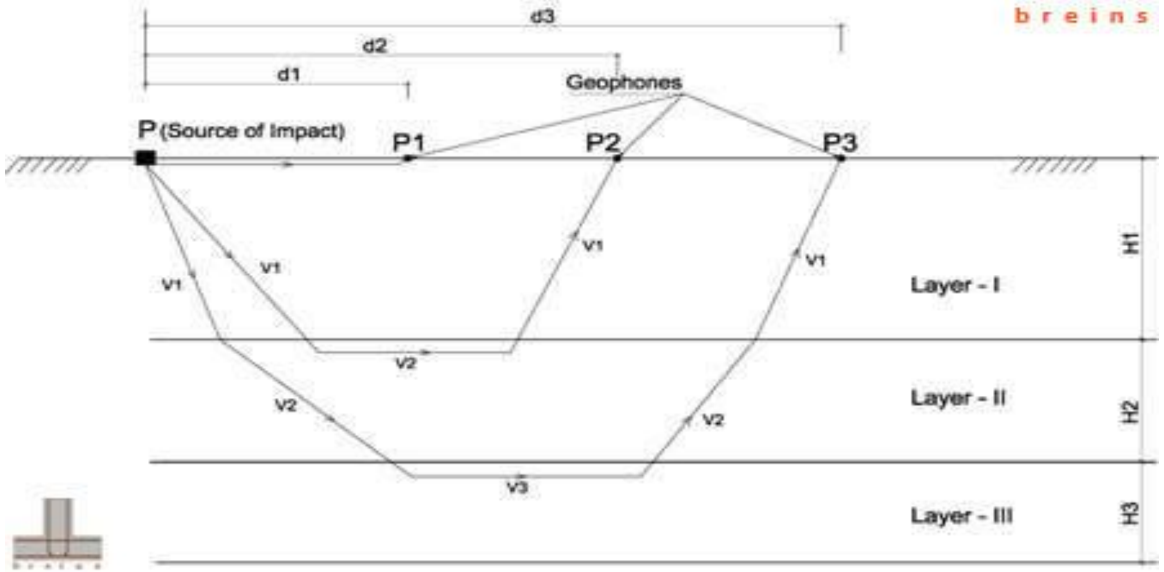
- The reflected and refracted wave undergoes a change in direction when they encounter a boundary separating media of different seismic velocities

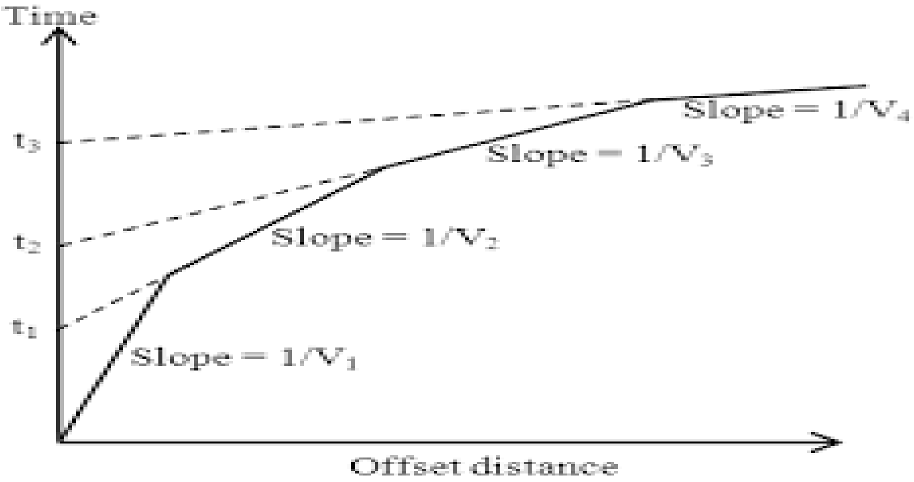
- This method is **more suited to the shallow explorations** for civil engineering purpose.

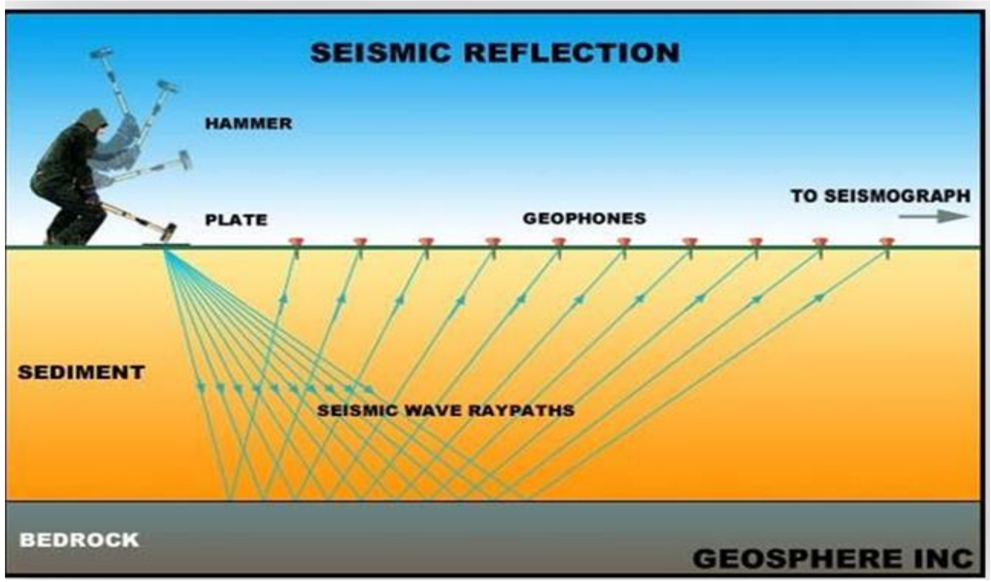
**Assumption:**

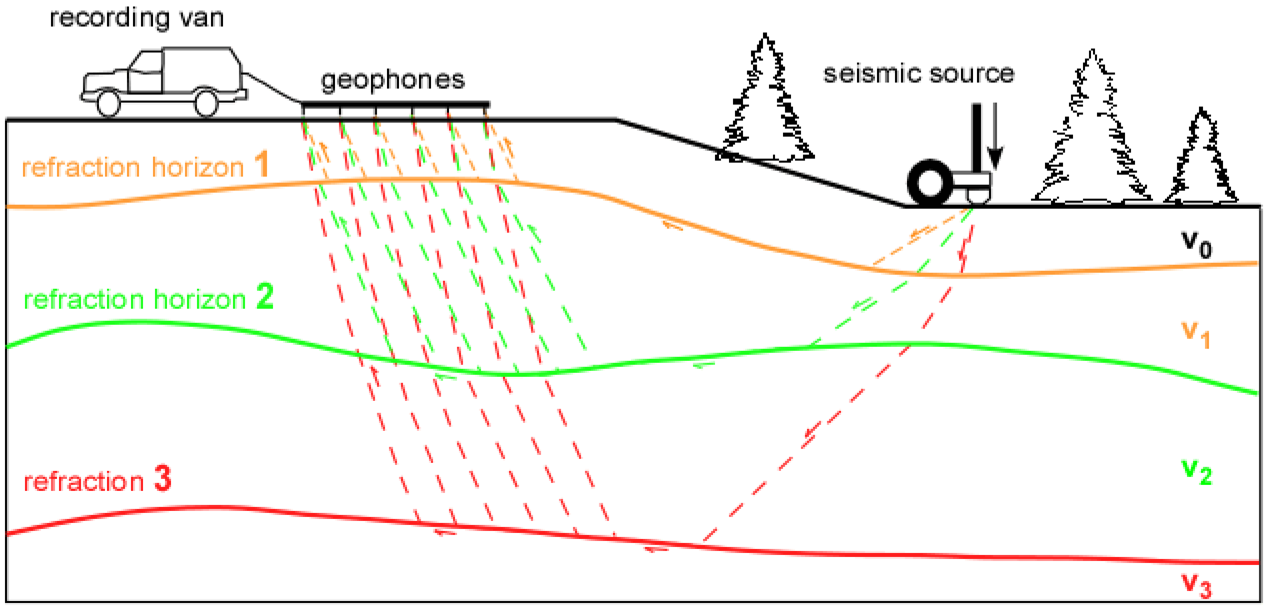
- All soil layers are horizontal.
- The layer is sufficiently thick to produce a response.
- Each layer is homogeneous and isotropic.
- Velocity should increase with depth, following the Snell's law

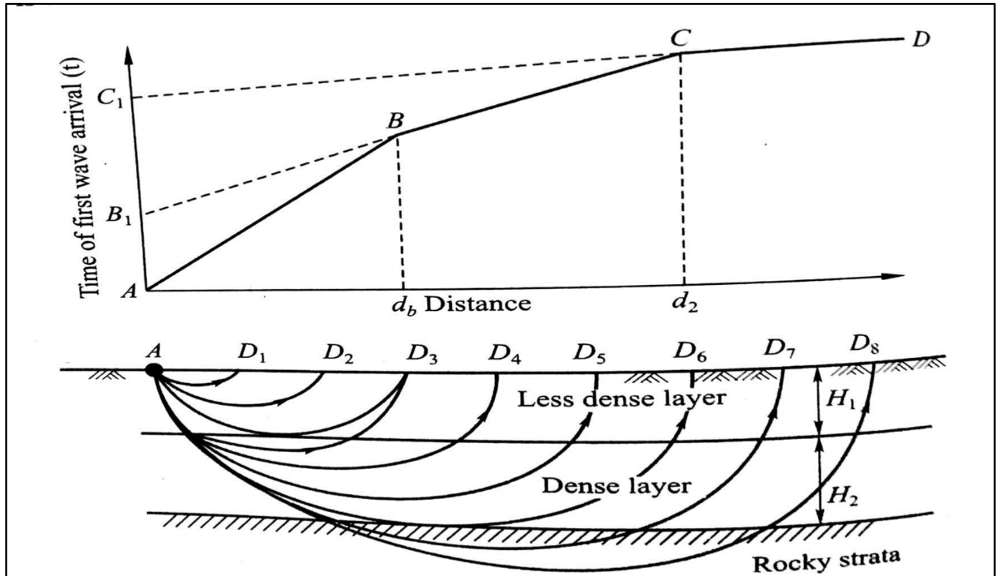
# Seismic refraction test



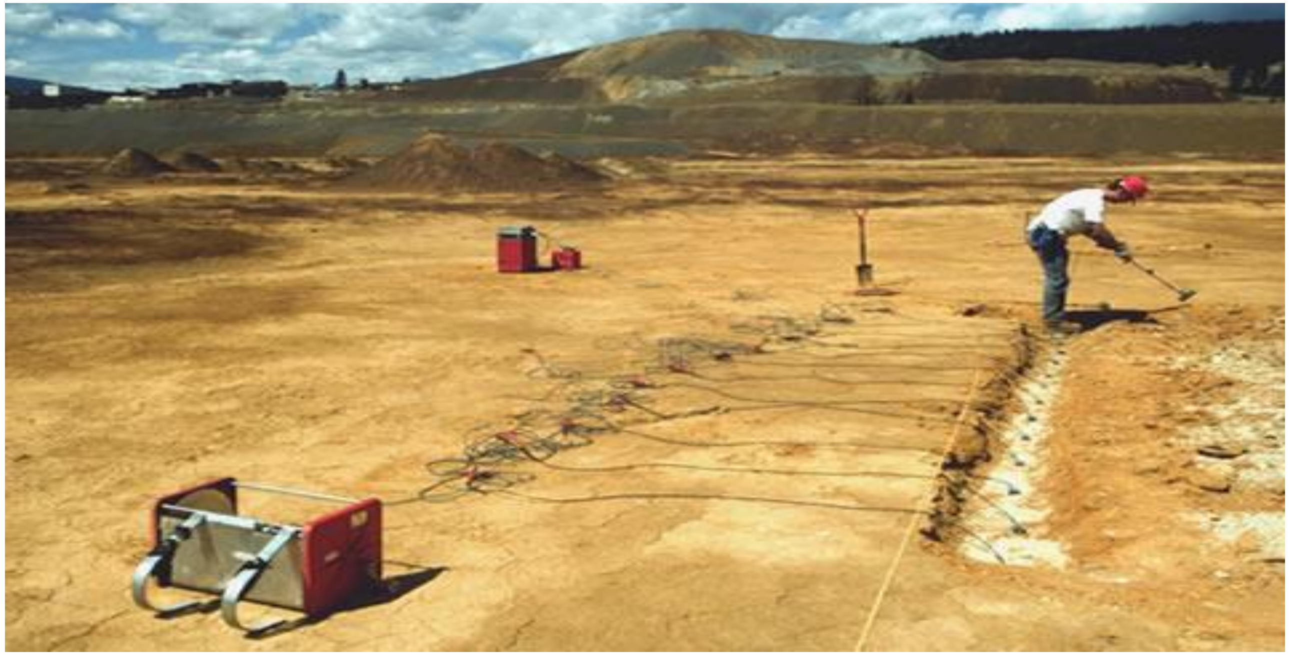






(a) Schematic representation of refraction method



Detectors placed at varying distances along same line on ground

Shock waves or impact waves produced at a location.

Refracts at interfaces and reaches surface, depending on velocity in each layer

Geophones record the first vibration of shock waves and arrival time→ time distance curves plotted

Converts it into electric signal and transmit to recording unit

- Spacing of geophones: depend upon amount of detail required and the depth to be investigated; Generally spaced such that **total distance from first to last geophone is 3-4 times the depth of investigation**

- Upto certain distance (critical distance, say L1), direct waves reach first from layer 1.

- After L1, the refracted wave will reach first since it passes through a denser layer 2.

- So at L1, both reaches simultaneously.- one travelling L1 distance at V1 and other , getting refracted from layer 2, ie travelling 2H1 at V1 and L1 at V2. i.e,

$$\frac{L1}{V1} = \frac{2H1}{V1} + \frac{L2}{V2} \quad \text{so H1} = \left(\frac{V2-V1}{V2}\right) * \frac{L1}{2}$$

## Applications:

- Depth and characterization of the bed rock surfaces
- Buried channel location
- Depth of the water table
- Depth and continuity of the stratigraphy interfaces
- Mapping of faults and other structural features.

# Advantages

- Complete picture of stratification of layer upto 10m depth.
- **Simple equipments and easy** execution
- **Little processing** required
- Provides seismic velocity information for estimating material properties.
- Provides **greater vertical resolution** than electrical, magnetic, or gravity methods.
  Data acquistion requires very limited intrusive activity is **non-destructive.**

# Disadvantages

- Cannot be used when hard layer overlies soft layer
- Cannot be used in areas like concrete or bitumen
- Presence of buried conduits and services
- Cannot be used in frozen layers
- High cost, and skilled labour

# Role of geophysical methods in solving geotechnical problems

- Gravitational and magnetic methods → in mining and petroleum engineering.
  - Geotechnical → limited use for survey of unconsolidated sediments over the dense bedrock.

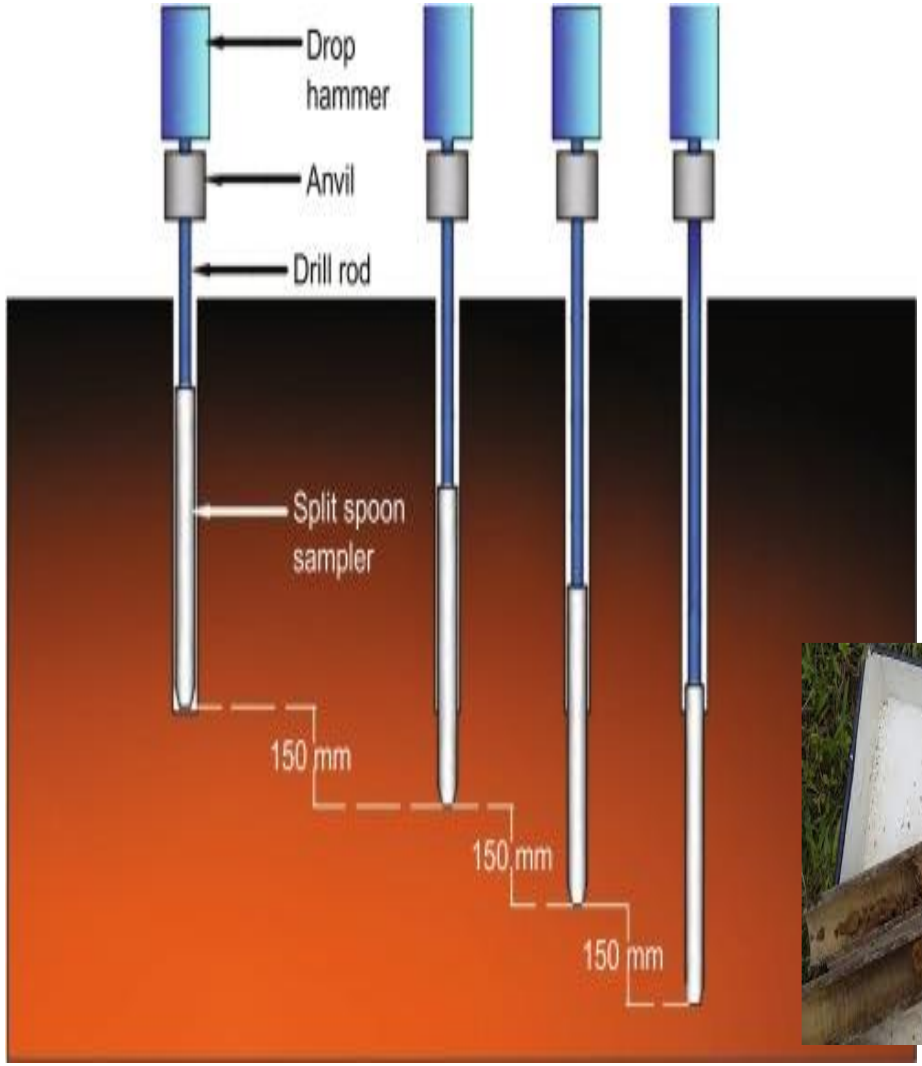
- Magnetic method is applied to locate dikes, faults and buried pipes and other concealed magnetic metal works.

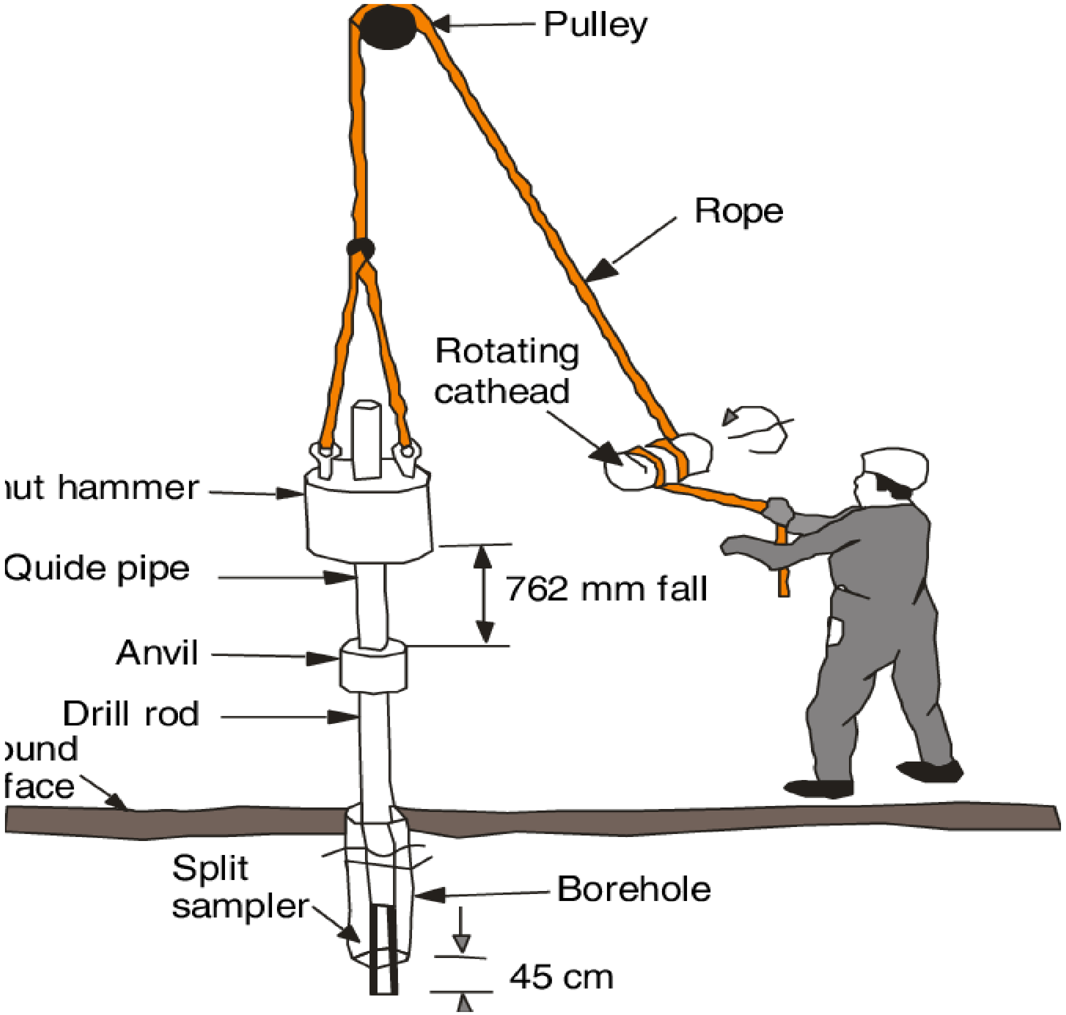
- **Seismic and resistivity methods** :
  - For dam and bridge sites, to locate depth of the solid rock
  - For design of the underwater foundation
  - For building sites to locate hard rock strata/ soft strata seismic method is used.
  - Slope design and the landslide investigation
  - To locate the shallow deposits
  - Ground water investigation

- In the **insitu evaluation of concrete**, geophysical methods are used to determine uniformity of concrete.

# Some Fields tests

## Standard Penetration Test (SPT)

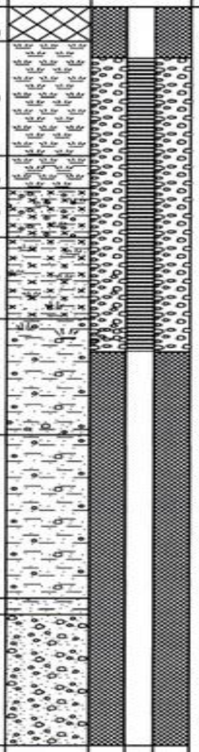



**GEOINVESTIGATE Ltd.**

Your Ref. Our Ref. BH No.2 Sheet No. 1 of 1

Location: Irlam, Greater Manchester DATE: 14/01/14



| Depth (m) | Description of Strata | Thick-ness |
|---|---|---|
| 0.50 | MADE GROUND Paving slab underlain by by compact ash and gravel | 0.50 |
| 1.90 | Soft and firm brownish black, odorous slightly clayey PEAT | 1.40 |
| 2.20 | Firm brown very sandy peaty CLAY | 0.30 |
| 2.80 | Very loose/very soft grey and brown silty and sandy CLAY with some fine gravel and peat inclusions | 0.60 |
| 3.90 | Very loose/Soft brownish grey clayey silty SAND with organic traces<br>Becoming firm sandy clay towards bottom<br>Root traces towards base | 1.00 |
| 5.20 | Stiff brown sandy CLAY with some gravel and pockets of sand. Slightly laminated in places. Root traces towards top | 1.30 |
| 7.30 | Firm and stiff brown laminated silty CLAY with occassional fine rounded gravel and lenses of silt and sand | 2.10 |
| 7.40 | Stiff brown sandy CLAY | 0.10 |
| 8.90 | Medium dense grey and brown gravelly SAND. Gravel is fine sub-rounded and rounded. Occassional pockets of clay<br>Becomes dense towards bottom | 1.50 |
| | E.O.H at 8.90m | |

| Sample | Test Type Result (Cv kN/m$^2$) | SPT N Value | Depth to Water | Depth (m) |
|---|---|---|---|---|
| O | | 1 | | 0.50 |
| O | | 3 | | 1.00 |
| O | | 5 | | 1.50 |
| | | 3 | | |
| O | | | | 2.00 |
| O | | 2 | | 2.50 |
| | | 1 | | |
| O | | | | 3.00 |
| | | 2 | | |
| O | | 4 | | 3.50 |
| O | | 8 | | 4.00 |
| | 85 | | | |
| O | | 10 | 4.50 | 4.50 |
| | 97 | 12 | | |
| O | | | | 5.00 |
| | | 10 | | |
| O | 78 | | | 5.50 |
| | | 7 | | |
| O | | | | 6.00 |
| O | 80 | 9 | | 6.50 |
| O | 77 | | | 7.00 |
| | | 13 | | |
| O | | | | 7.50 |
| | | 18 | | |
| O | | | | 8.00 |
| O | | 25 | | 8.50 |
| O | | 32 | | 9.00 |
| | | | | 9.50 |
| | | | | 10.00 |

**Remarks:**
Casing to 8.00m
Dynamic windowless sampling by Terrier Rig to 8.90m
Water standing at 4.50m
Gas well installed to 4.40m with gas bung and cover

**Key:** Slotted Pipe, Plain Pipe, Bentonite, Gravel Filter

O Disturbed sample
Cv Shear vane
W Water sample
S Standard Penetration Test
C Cone Penetration Test

**BH2**

Link: https://www.youtube.com/watch?v=DjWDOqQjsyQ

## DILATANCY CORRECTION

Terzaghi and Peck (1967) recommended the following correction-

$$\boxed{N_c = 15 + \frac{1}{2}(N_R - 15)}$$

Where;

$N_c$ - Corrected Penetration Number

$N_R$ - Recorded Value

- If $N_R$<=15 ; $N_c$= $N_R$

### 1. GIBBS AND HOLTZ' CORRECTION (1957)

- Applicable for $\overline{\sigma_o} \leq 280$ kN/$m^2$ and for dry or moist clean sand.

$$\boxed{N_C = N_R \times \frac{350}{\overline{\sigma_o} + 70}}$$

where;

$N_C$ – Corrected N-Value

$N_R$ – Observed N-Value

$\overline{\sigma_o}$ – Effective Overburden Pressure (kN/$m^2$)

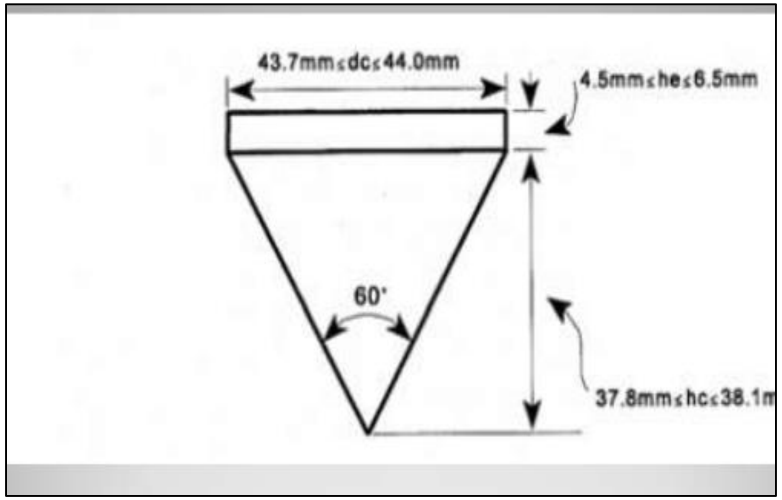
- Ratio ($N_C$/ $N_R$) should lie between 0.45 and 2.0
- If this ratio is greater than 2.0, $N_C$ should be divided by 2.0 to obtain the design value used in finding the bearing capacity of the soil
- Overburden pressure correction is applied first and then the dilatancy correction is applied.

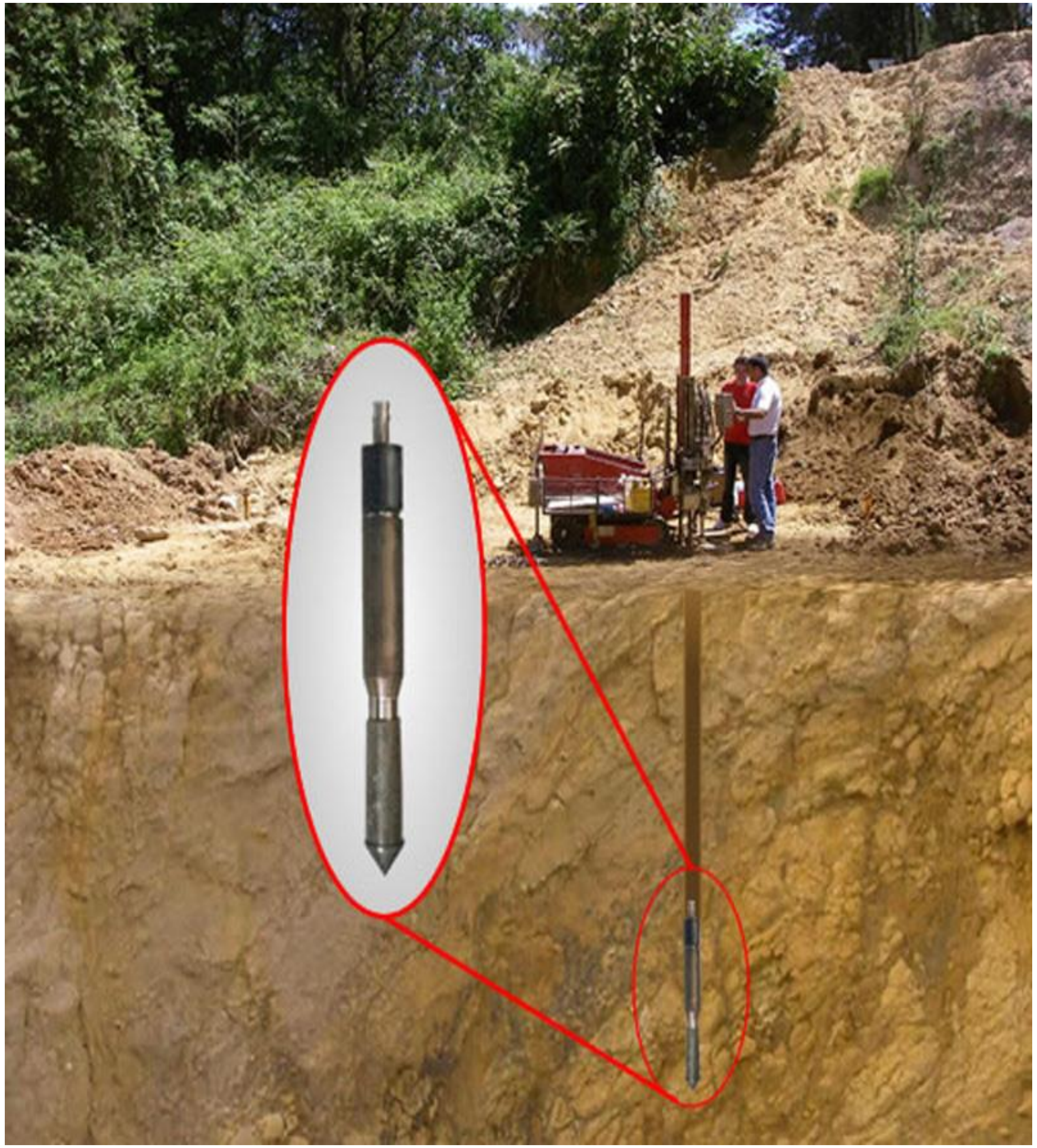
### 3. PECK AND BAZARAA'S CORRECTION

- One of the most commonly used corrections
- According to them,
  - If $\overline{\sigma_o} < 71.8$ kN/$m^2$,
    $N = \frac{4\,N_R}{1+0.0418\overline{\sigma_o}}$
  - If $\overline{\sigma_o} > 71.8$ kN/$m^2$,
    $N = \frac{4\,N_R}{3.25+0.0104\overline{\sigma_o}}$
  - If $\overline{\sigma_o}$ = 71.8 kN/$m^2$,
    N = $N_R$

# Static cone penetration test

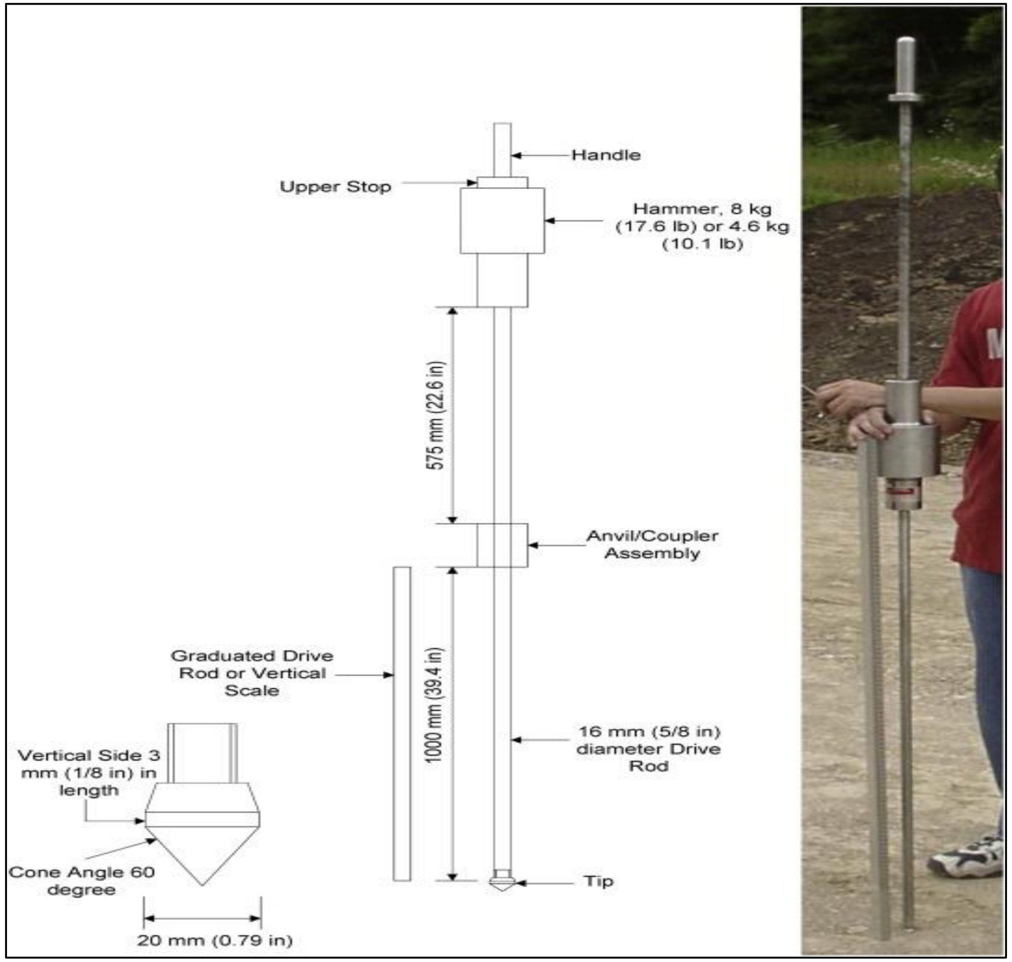
Cone resistance, static load @ 10mm/sec,
to a depth of 35mm each time

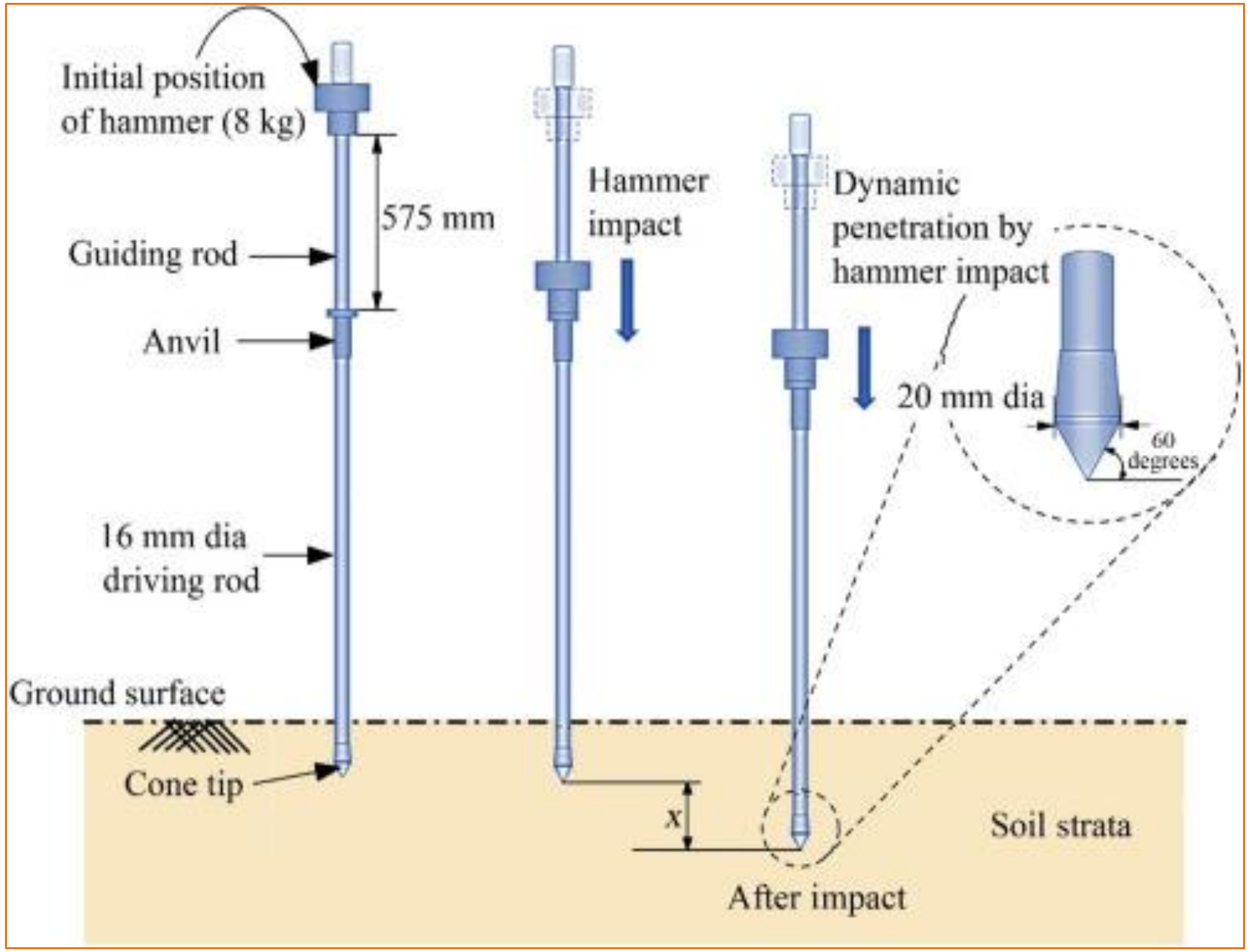


# Dynamic cone penetration test

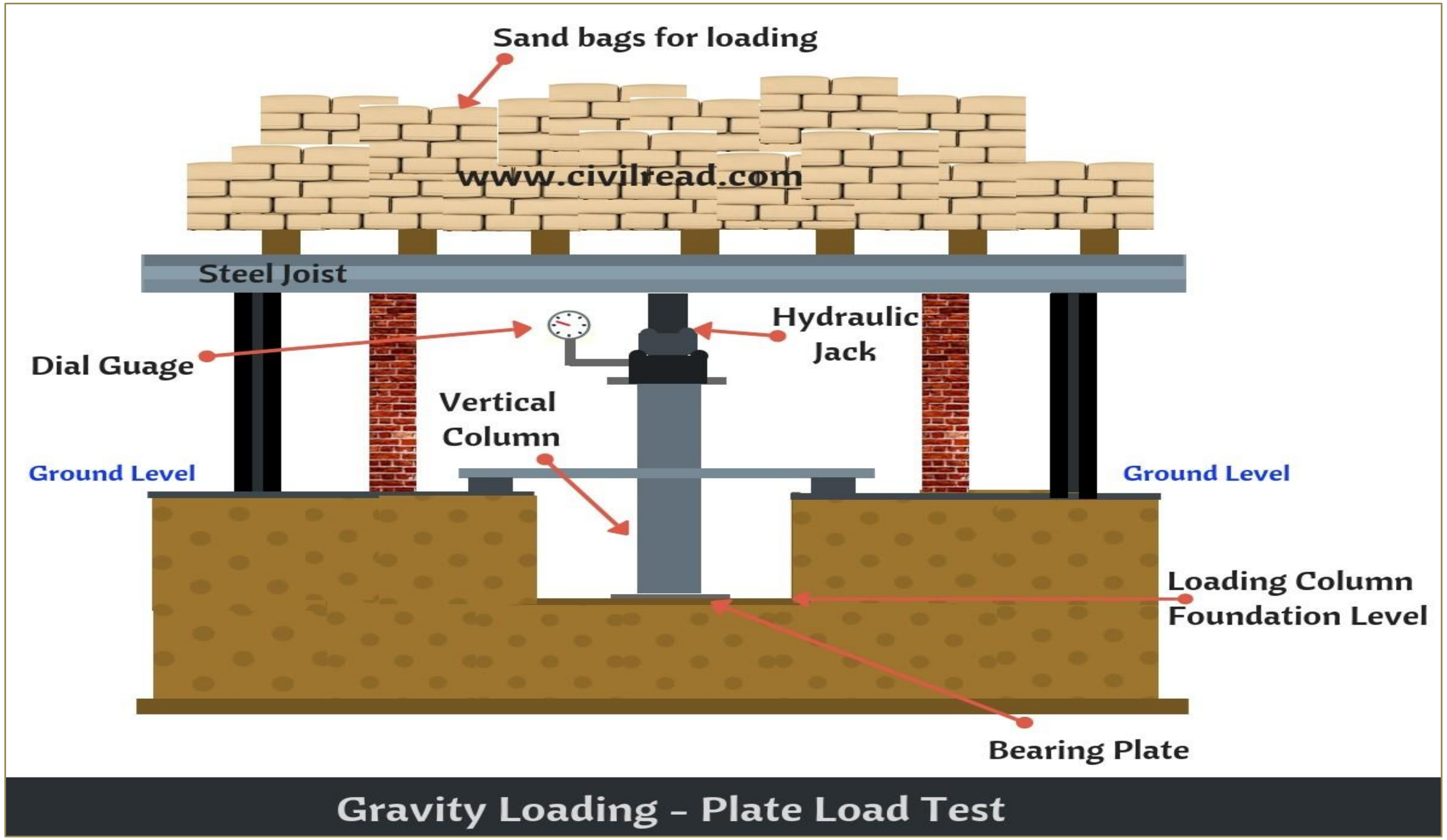
Cone resistance is measured by measuring no of blows for driving cone for specific distance



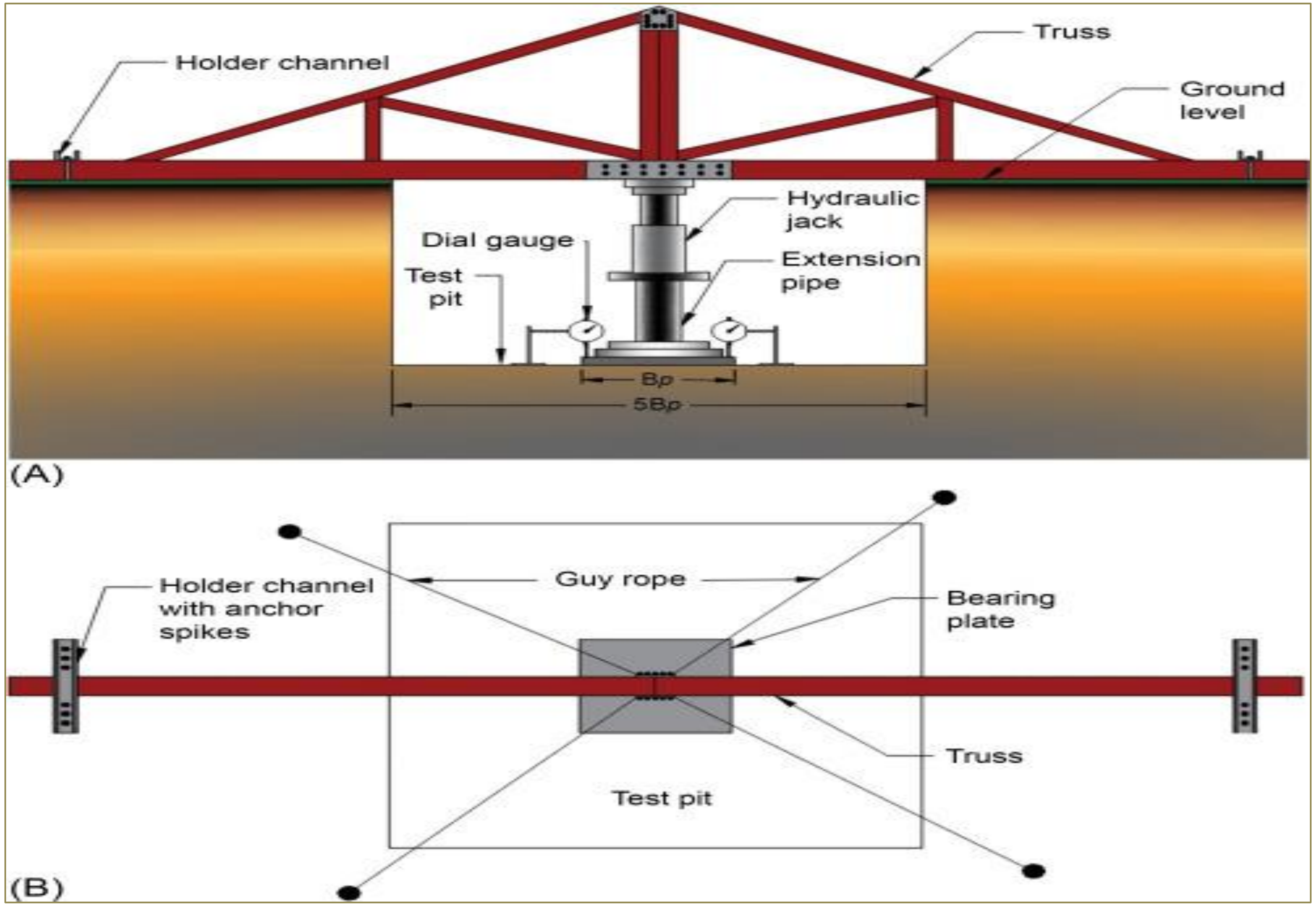




https://www.youtube.com/watch?v=_pjOs7NqntQ

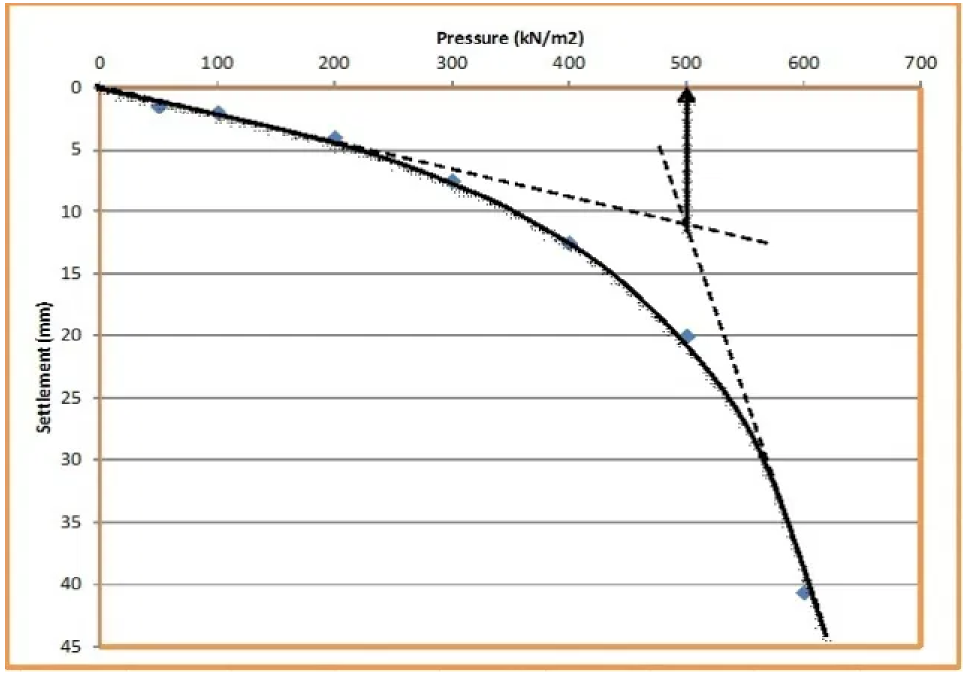
# Plate load test




# PLT (Cont..)




https://www.youtube.com/watch?v=QuE4tEK-5iY



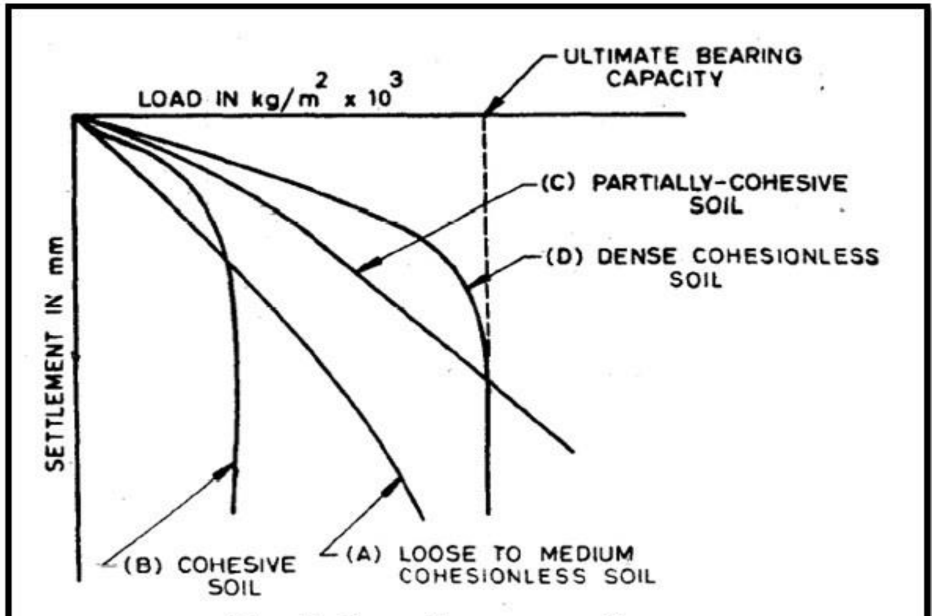




FIG. 5 LOAD SETTLEMENT CURVES

# PLATE LOAD TEST OBSERVATION SHEET

Project name:

Site location:

Depth of testing:

Depth of water table:

Date of testing:

| Load (kN) | Time | Settlement dial gauge -1 | | | Settlement dial gauge - 2 | | |
|---|---|---|---|---|---|---|---|
| | | Dial gauge reading | Settlement (mm) | Cumulative settlement | Dial gauge reading | Settlement (mm) | Cumulative settlement |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

## (Geotechnical Engineering Division)

SBC of proposed site for construction

*****

Please find herewith the test results of plate load test conducted at the site The test results are as under:-

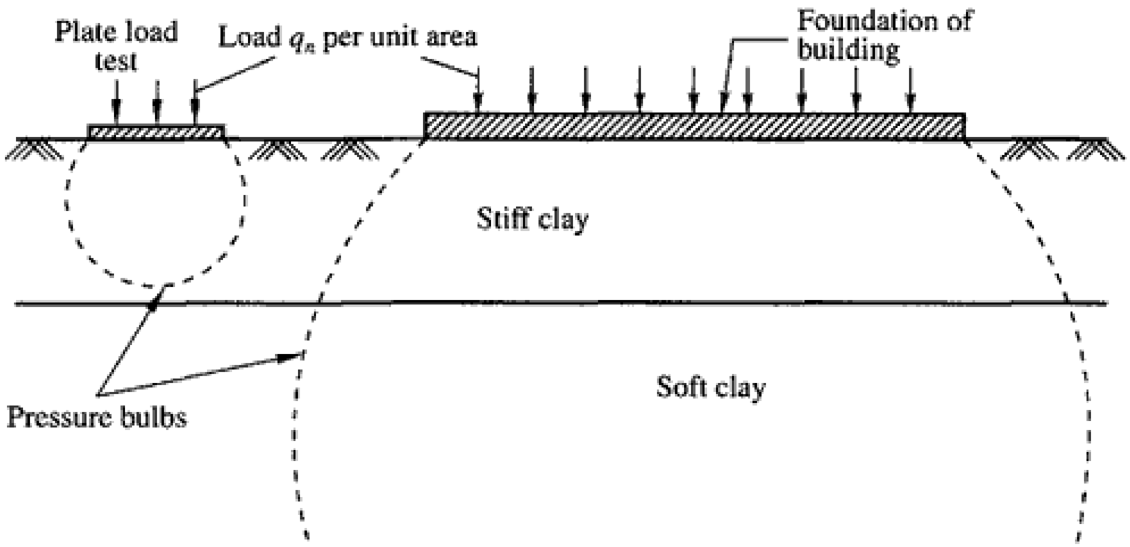
| | | |
|---|---|---|
| 1. | Depth of pit | = 0.5m (10.5m below G. L. approx.) |
| 2. | Size of plate used | = 0.30m X 0.30m |
| 3. | Type of soil existing at 10.5m depth | = dense gravelly soil |

The test was conducted as per IS 1888:1982.

| | |
|---|---|
| Failure load | = 10.5 t |
| Corresponding settlement of plate | = 3.7 mm |
| Ultimate bearing capacity $Q_u$ | = 116 $t/m^2$ |
| Safe Bearing Capacity of soil (assuming factor of safety = 3.0) | = **38 $t/m^2$** |

**Observations of Plate Load Test**

| Load (ton) | Dial gauge 1 Cumulative. Settlement (mm). | Dial gauge 2 Cumulative. Settlement (mm). | Dial gauge 3 Cumulative. Settlement (mm). | Dial gauge 4 Cumulative. Settlement (mm). | Avg cum. Sett. mm |
|---|---|---|---|---|---|
| 1 | 0.52 | 0.31 | 1.22 | 1.22 | 0.82 |
| 2 | 1.11 | 0.74 | 2.48 | 2.48 | 1.70 |
| 3 | 1.9 | 1.35 | 2.8 | 2.8 | 2.21 |
| 5 | 2.06 | 1.54 | 3.47 | 3.47 | 2.64 |
| 6 | 2.21 | 1.81 | 3.75 | 3.75 | 2.88 |
| 7 | 2.36 | 1.85 | 3.95 | 3.95 | 3.03 |
| 8 | 2.37 | 2.09 | 4.16 | 4.16 | 3.20 |
| 9 | 3.99 | 2.61 | 4.72 | 4.72 | 4.01 |
| 10 | 4.27 | 2.8 | 4.93 | 4.93 | 4.23 |
| 11 | 4.64 | 3.2 | 5.22 | 5.22 | 4.57 |
| 12 | 5.5 | 3.94 | 6.02 | 6.02 | 5.37 |
| 13 | 6.42 | 4.75 | 6.84 | 6.84 | 6.21 |



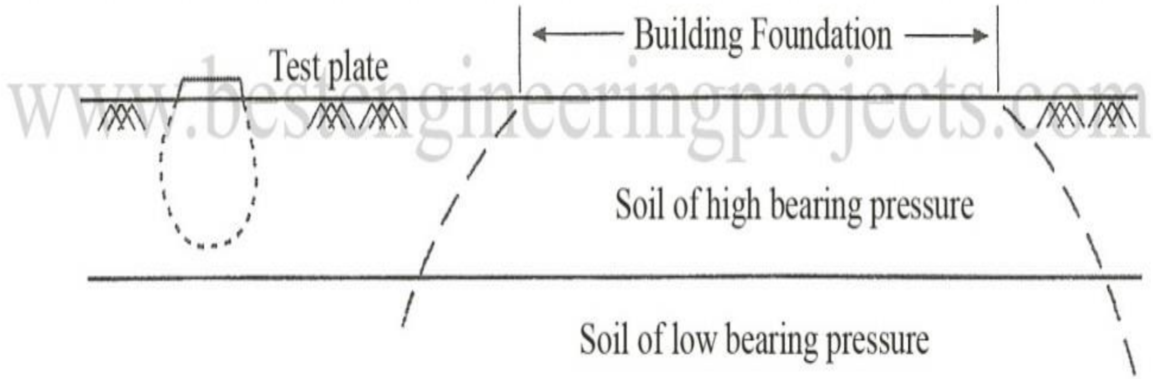



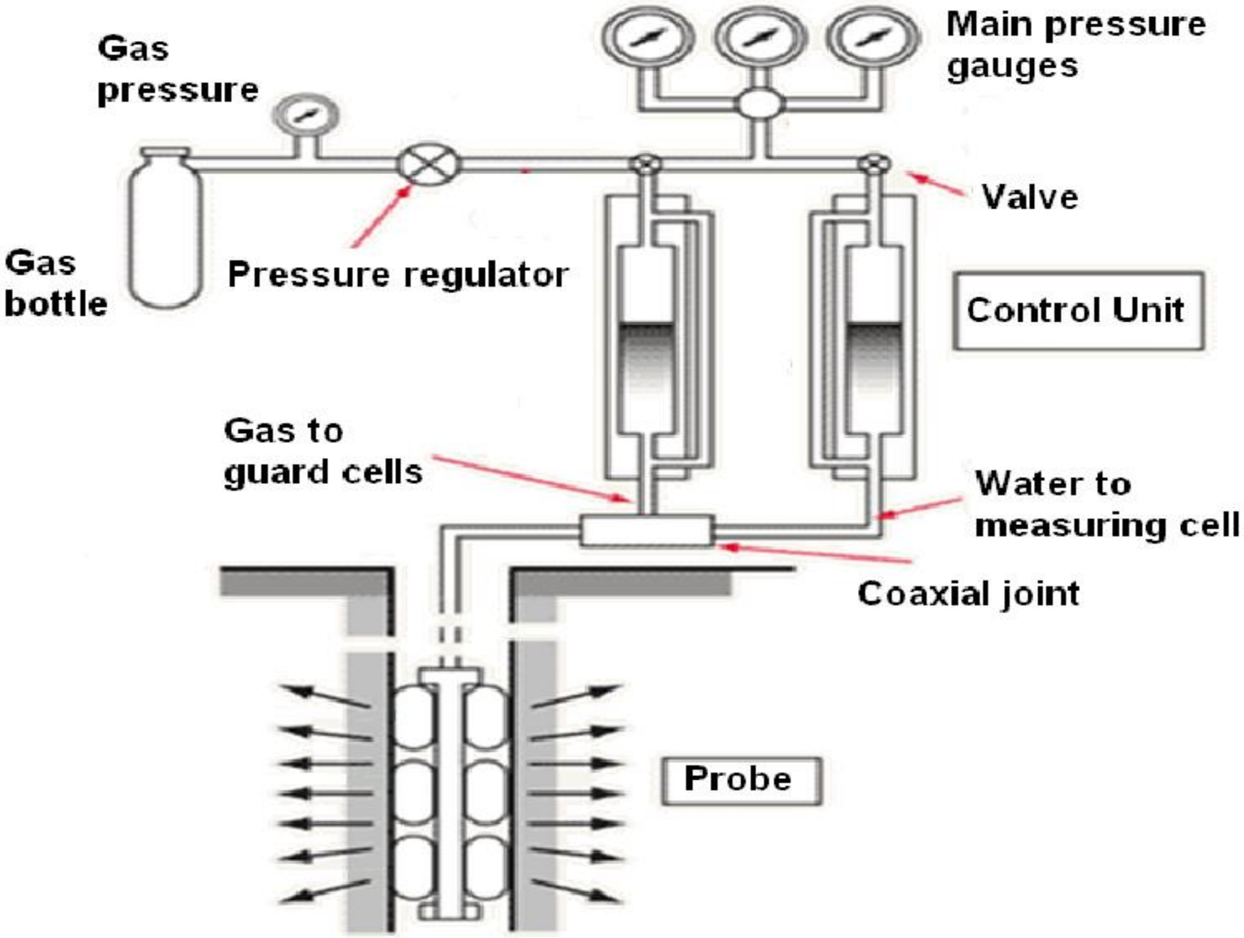


Fig 1 Situation Where Plate Load Test is Misleading

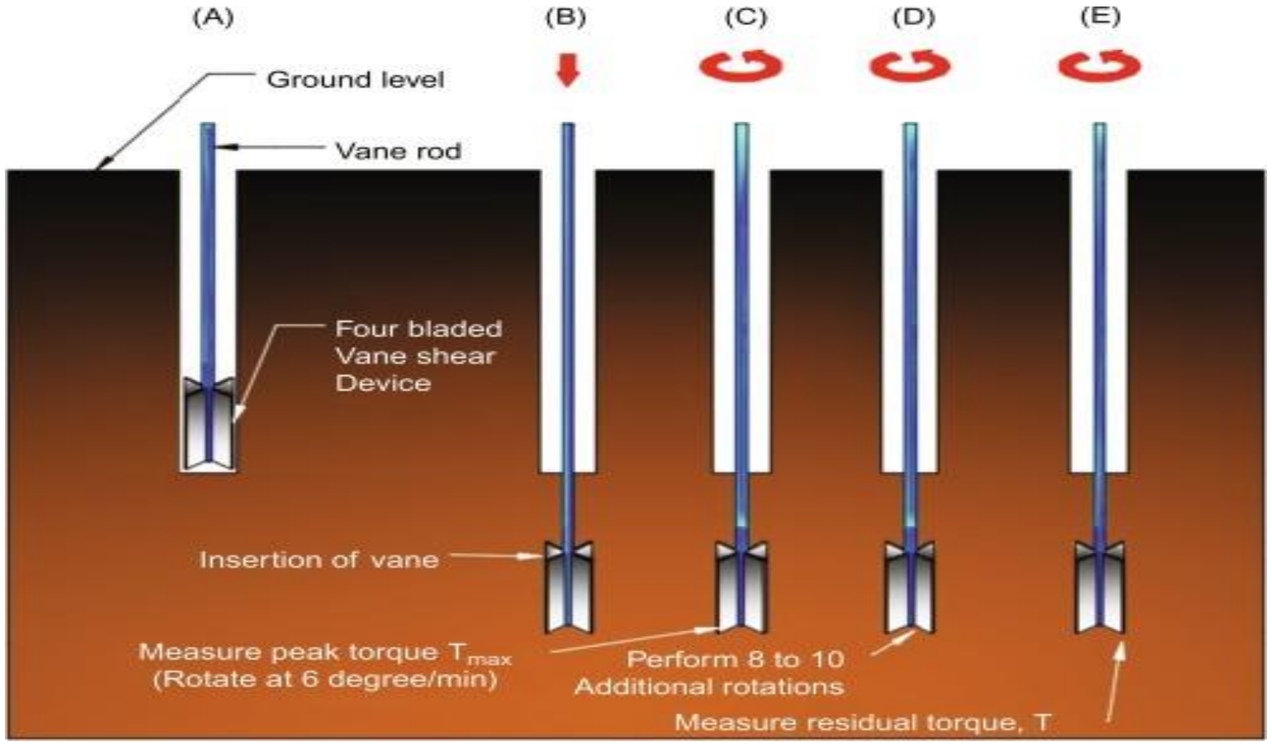
## LIMITATION

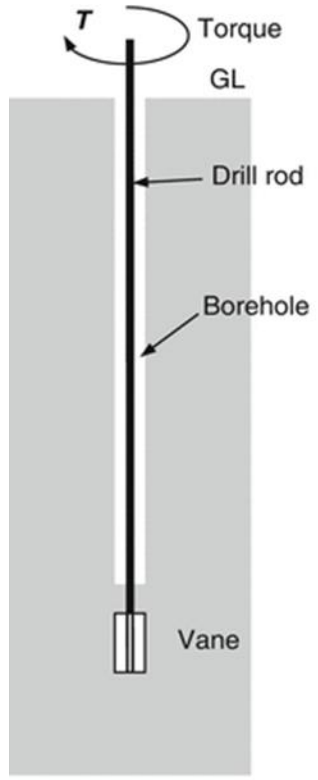
- (i) The Plate Load Test being of short duration , does not give the ultimate settlements particularly in case of cohesive soils.
- (ii) The width of the plate should not be less than 30cm. It is experimentally shown that the load settlement behaviour of soil is qualitatively different for smaller width.
- (iii) The foundation settlements is loose sands are usually much larger than what is predicted by plate load test.
- (iv) The settlement influence zone is much larger for the real foundation sizes than that for the test plate.

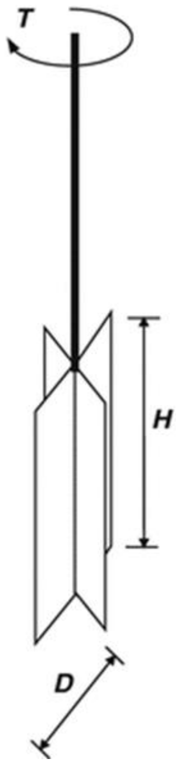
# Pressure meter test




# Vane shear test (Field)






When both end of vane below soil surface

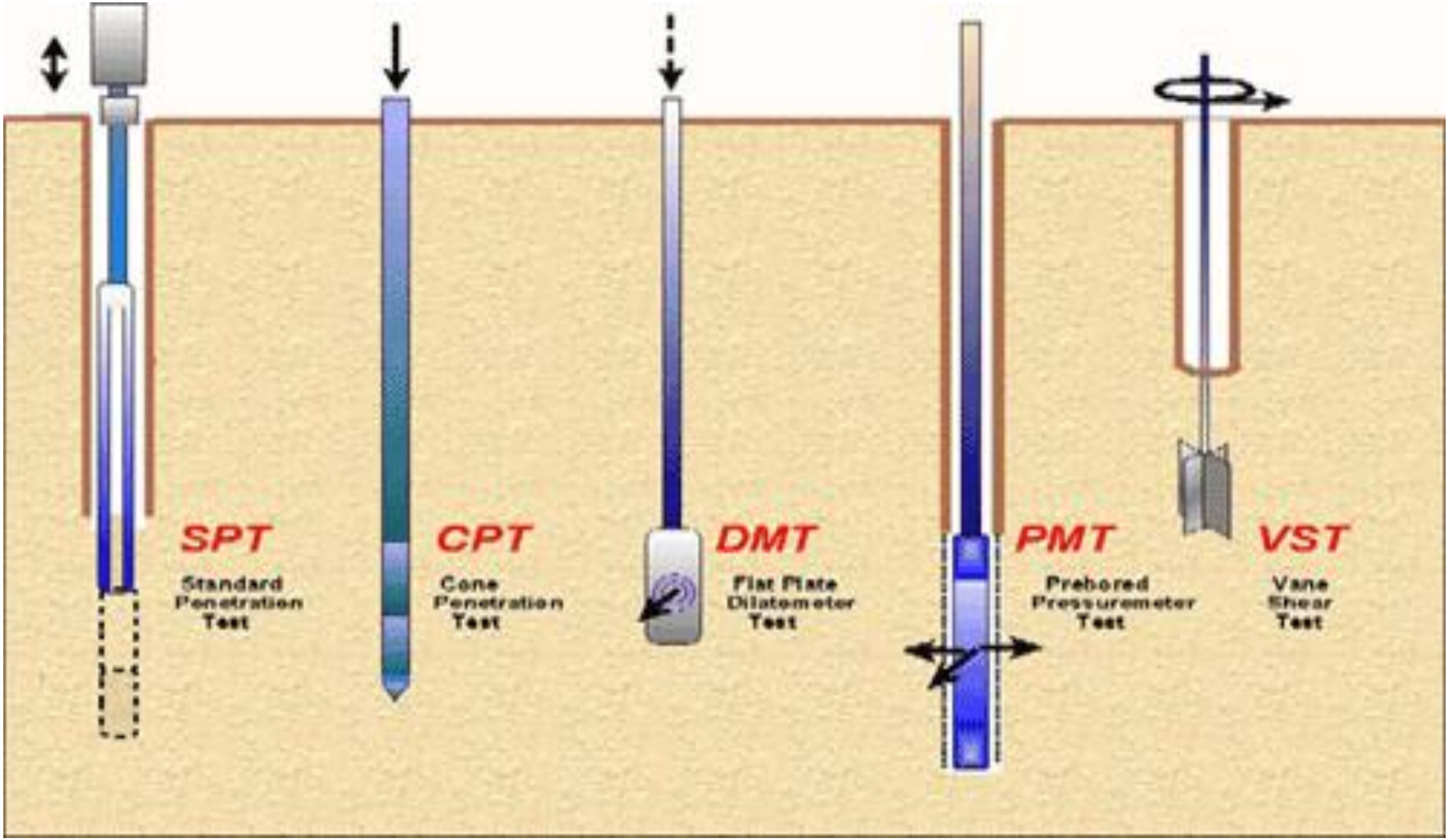
$$C_u = \frac{T}{\pi d^2 \left[\frac{H}{2} + \frac{d}{6}\right]}$$

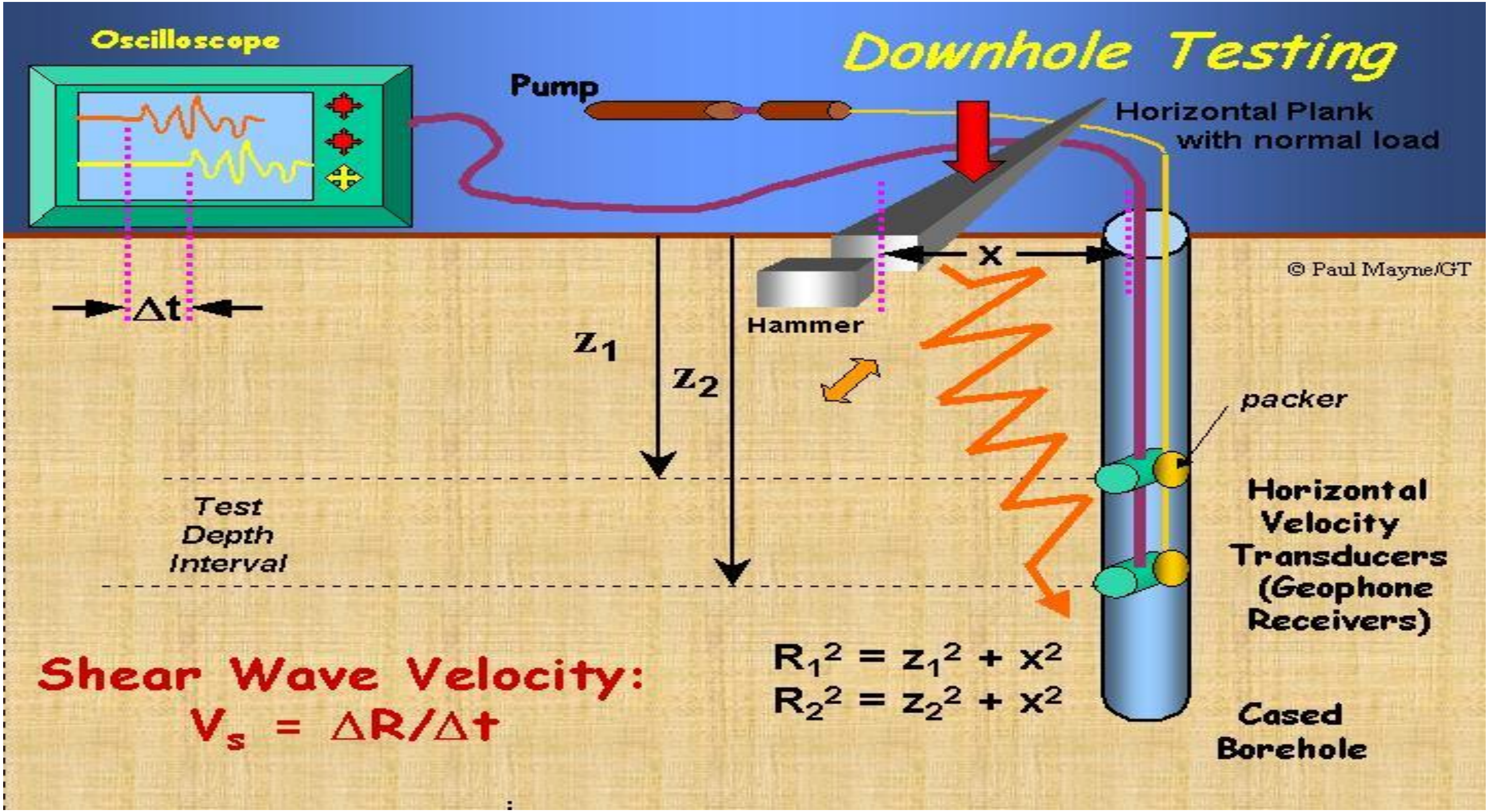
When top of vane above soil surface

$$C_u = \frac{T}{\pi d^2 \left[\frac{H_1}{2} + \frac{d}{12}\right]}$$

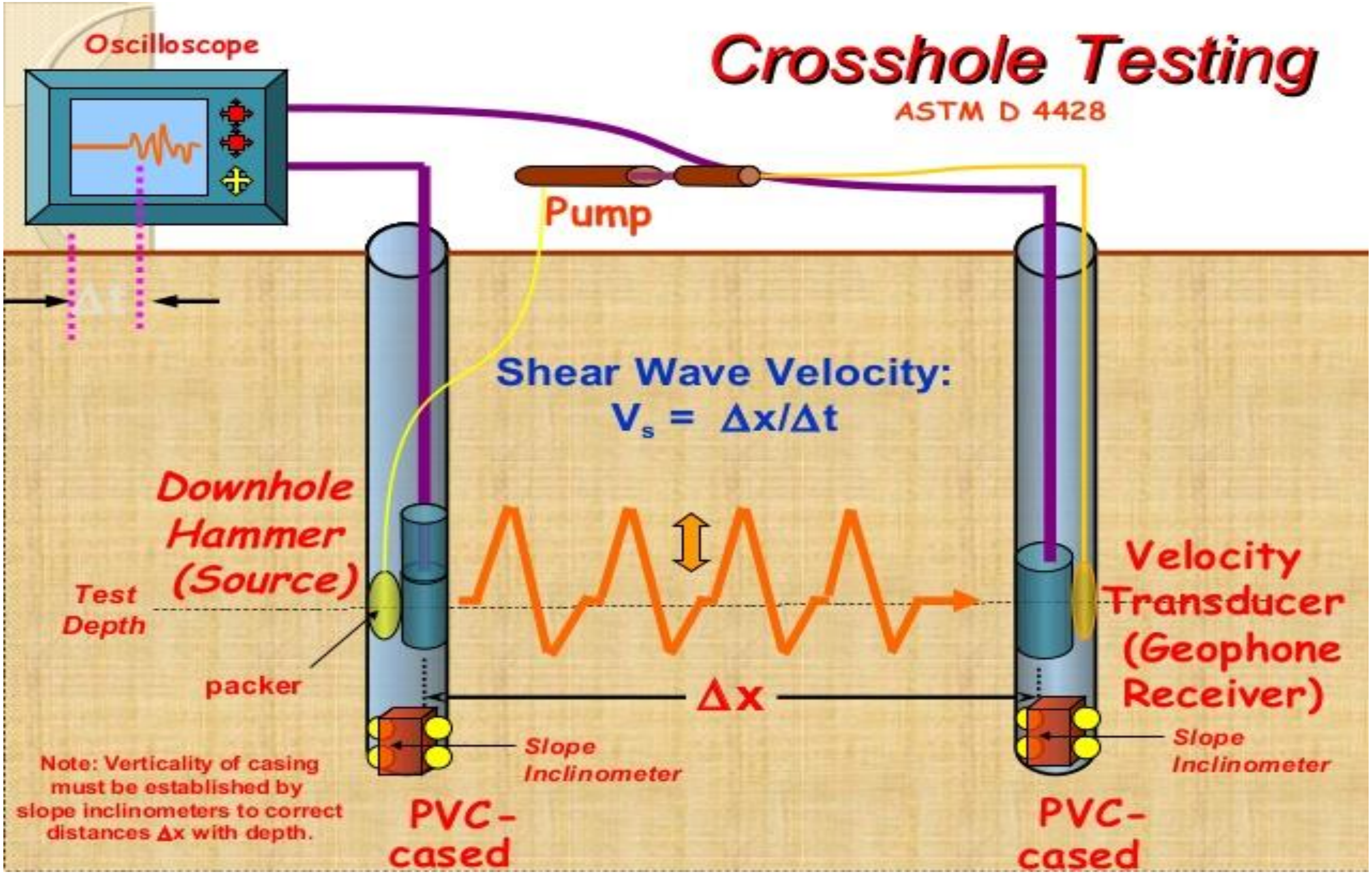
**Example:**

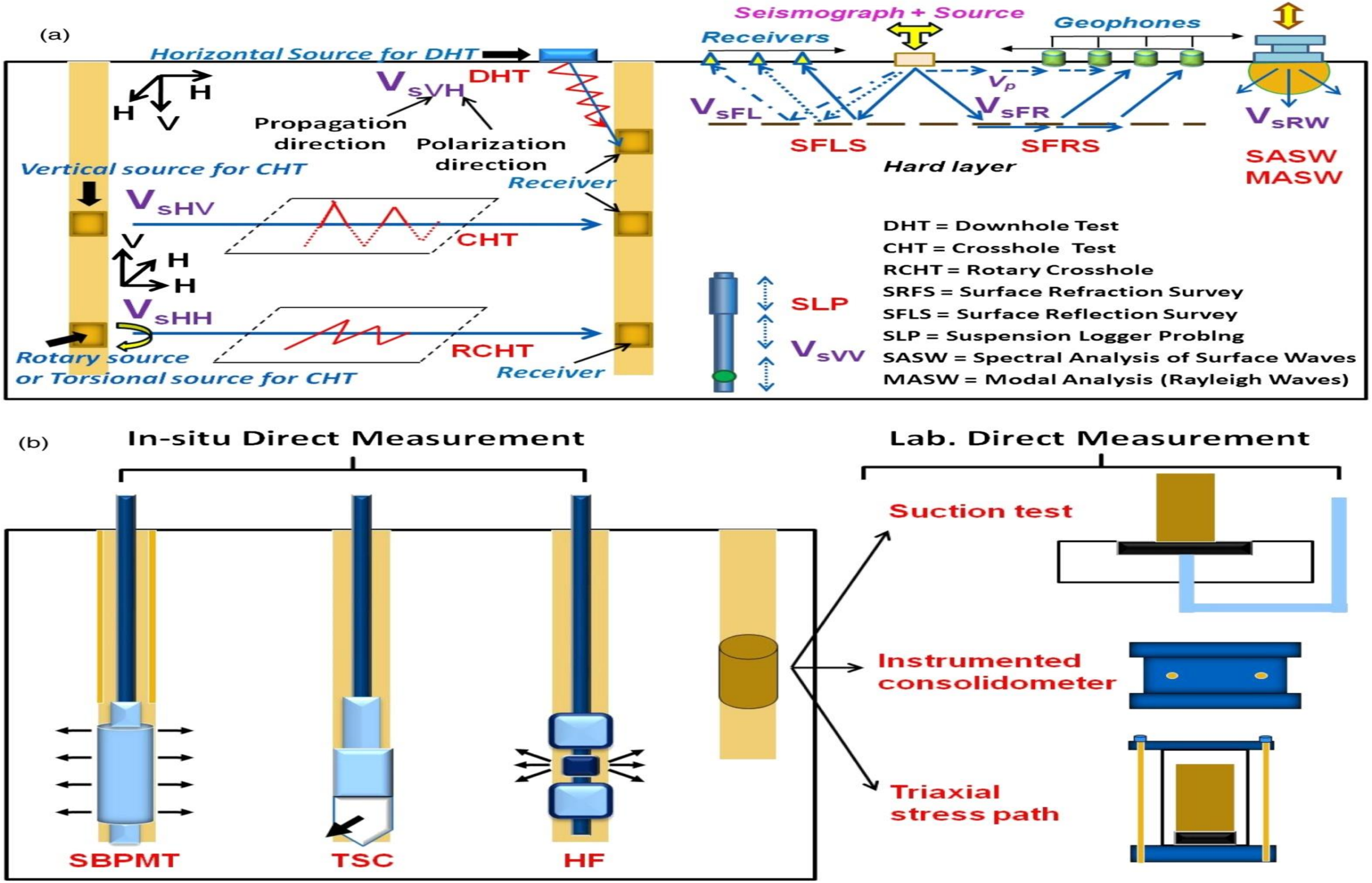
| SN | Initial reading (deg) | Final reading (deg) | Difference in reading (deg) | Spring constant (kg-cm) | Torque (kg-cm) | Average Shear strength (kg/cm$^2$) |
|---|---|---|---|---|---|---|
| 1 | 196 | 188 | 8 | 4.98 | 0.22 | 0.066 |
| 2 | 200 | 191 | 9 | 4.98 | 0.25 | |
| 3 | 195 | 186 | 9 | 4.98 | 0.25 | |
| 4 | 87 | 75 | 12 | 3.19 | 0.21 | 0.056 |
| 5 | 90 | 79 | 11 | 3.19 | 0.20 | |
| 6 | 88 | 77 | 11 | 3.19 | 0.20 | |


SPT
Standard Penetration Test
CPT
Cone Penetration Test
DMT
Flat Plate Dilatometer Test
PMT
Prebored Pressuremeter Test
VST
Vane Shear Test



Oscilloscope
Downhole Testing
Pump
Horizontal Plank with normal load
X
© Paul Mayne/GT
Δt
Hammer
$z_1$
$z_2$
packer
Test Depth Interval
Horizontal Velocity Transducers (Geophone Receivers)
Shear Wave Velocity:
$V_s = \Delta R/\Delta t$
$R_1^2 = z_1^2 + x^2$
$R_2^2 = z_2^2 + x^2$
Cased Borehole


Oscilloscope
Crosshole Testing
ASTM D 4428
Pump
Δt
Shear Wave Velocity:
$V_s = \Delta x / \Delta t$
Downhole Hammer (Source)
Test Depth
packer
Δx
Velocity Transducer (Geophone Receiver)
Slope Inclinometer
Slope Inclinometer
Note: Verticality of casing must be established by slope inclinometers to correct distances Δx with depth.
PVC-cased
PVC-cased


(a)
Horizontal Source for DHT
DHT
$V_{sVH}$
Propagation direction
Polarization direction
Vertical source for CHT
Receiver
$V_{sHV}$
CHT
$V_{sHH}$
RCHT
Rotary source or Torsional source for CHT
Receiver
Seismograph + Source
Receivers
Geophones
$V_p$
$V_{sFL}$
$V_{sFR}$
$V_{sRW}$
SFLS
SFRS
Hard layer
SASW
MASW
SLP
$V_{sVV}$
DHT = Downhole Test
CHT = Crosshole Test
RCHT = Rotary Crosshole
SRFS = Surface Refraction Survey
SFLS = Surface Reflection Survey
SLP = Suspension Logger Problng
SASW = Spectral Analysis of Surface Waves
MASW = Modal Analysis (Rayleigh Waves)
(b)
In-situ Direct Measurement
Lab. Direct Measurement
Suction test
Instrumented consolidometer
Triaxial stress path
SBPMT
TSC
HF

# Handling, preservation and transportation of samples

1. **Undisturbed samples in seamless tube:**
   - Ends cut and removed (atleast 2.5cm)→wax→ fill space with saw dust→ lid
2. **Undisturbed samples not in tube:**
   - Covered wholly with wax→ metal container→ tight lid→ adhesive tape
3. **Disturbed:**

   Immediately placed in glass jar→ airtight container

4. **Rocks:**

Label-reference no: directly on surface or tape wounded→ wrapped in paper→ box

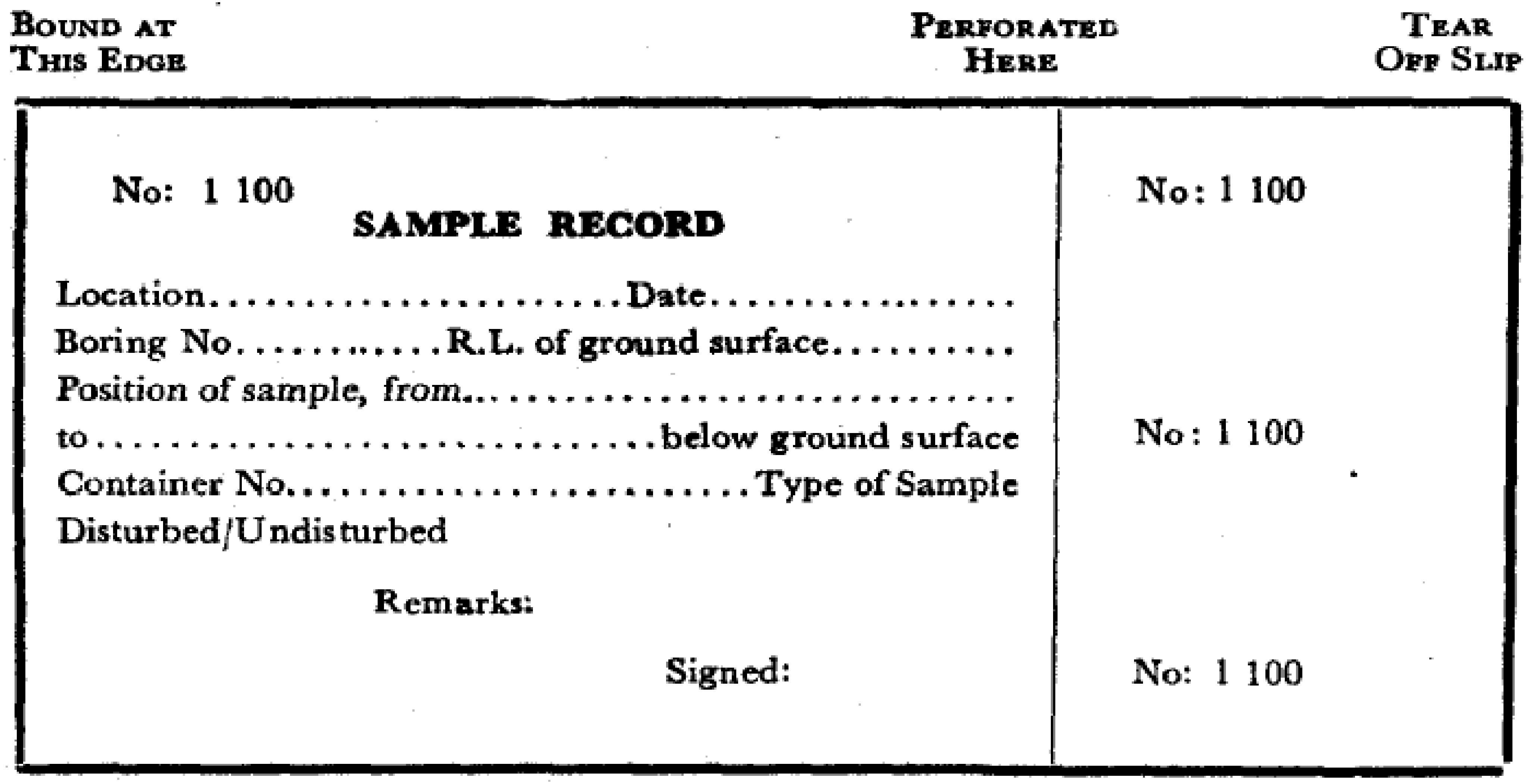
Rock core→ preserve whole core→ core box with separate compartments

- Labeling important

**Transportation:** Liner or containers placed in wooden box with separate partitions→ packed with fillers

- **Extrusion:**
  - Take out→ chip off wax
  - Piston extrusion( if properly oiled)→ disturbs soft clay
  - Support the sample
  - Extrude in one direction → from cutting edge to top
  - Store in cool humid place
  - Rock:  kept into box→ ensure no end to end turning


- **Labeling:** Label placed inside lid on top



BOUND AT THIS EDGE

PERFORATED HERE

TEAR OFF SLIP

No: 1 100

SAMPLE RECORD

Location........................Date..................

Boring No............R.L. of ground surface..........

Position of sample, from...............................

to.................................below ground surface

Container No.........................Type of Sample

Disturbed/Undisturbed

Remarks:

Signed:

No: 1 100

No: 1 100

No: 1 100

# SUBSOIL INVESTIGATION REPORT

- Last step in a soil investigation
- Borehole data, site observations and lab results
- Each bore hole-identified by code
- Mainly 4 parts: **Project details; Results; Analysis and possible solution; Recommendations** (Allowable soil pressure and expected settlements)
- Borelog → all details of the borehole → depth, strata variation obtained, properties of each strata, water table etc
- Subsurface profile → data obtained from a series of boreholes → vertical section through ground along line of exploration → Indicate boundaries of strata, the classification of soil type, and main properties

# Contents of subsoil investigation report

1. S**cope** of the investigation
2. **Proposed structure**
3. **Location descriptions** of the site → structures nearby, drainage conditions, vegetation and any other features unique to the site
4. **Geological setting** of the site
5. **Details of the field exploration**— number of borings, depths of borings, types of borings involved, and so on
6. A general description of the **subsoil conditions** -from lab and field tests
7. The **water-table conditions**
8. **Recommendations** regarding the foundation, the allowable hearing pressure, and any special construction procedure that may he needed;
9. **Conclusions and limitations** of the investigations

# Subsoil Exploration Report- Graphical presentations

The following graphical presentations should he attached to the report:

1. A site **location map**

2. A **plan view of the location of the borings** with respect to the proposed structures and those nearby

**3. Boring logs**

4. Laboratory **test results**

5. Other special graphical presentations

Testious Constructions

Testious Constructions

**BL-01**

**Type:** Borehole
**Start:** 6/6/2016
**End:** 7/1/2016

**Sample Project - 0001**

Investigation Borehole (ROCK)

**Equipment Type:** BOYLES 12

**Inspector:** B.K.

**Equipment** A.D.

**Drawn By:** N.L.

Geosysta Ltd

**Location:** Crete, Greece **X:** 25.62 **Y:** 35.01 **Z:** 11.80 **Inclination:** -90 **Azimuth:** 0

| Depth (m) | Casing (mm) | Core Bit | Returning Water | Sampling Type | Water Level | Description |
|---|---|---|---|---|---|---|
| 0–1.6 | 128.00/119.00 | T6S-D-116 | 75.0% | D | | blue-gray, blue-white, Limestone, Moderately weathered |
| 1.6–5.0 | | | 55.0% | | 9.30m | blue-gray, blue-white, Limestone, Slightly weathered |
| 5.0–10 | | | | | | Limestone, Intensely weathered |

| T.C.R. % | R.Q.D. % |
|---|---|
| 75% | 6% |
| 80% | 65% |
| 100% | 85% |
| 100% | 82% |
| 85% | 45% |
| 85% | 40% |
| 100% | 90% |

| Index Properties: Dry Unit Weight | Unit Weight |
|---|---|
| 25.2 | 25.6 |
| 25.1 | 25.3 |
| 25.9 | 26.2 |

| Dip Angle | Discontinuity Type | Discontinuity Spacing | Type of Infilling | Weathering |
|---|---|---|---|---|
| 20 | D | CS | II-III | III |
| 40 | D | CS | VII | II |
| 60 | D | MS | VII | II |
| 70 | J | CS | II-III | II |

| Compression Test (kPa) | () |
|---|---|
| 60 | 2 |
| 75 | 1.5 |

Permeability Test (DMT) (m/s): LUGEON 1.0e-4

Remarks: Zones of blocky limestone → 0-1.6m, 7.4-8.1m, 8.9-9.2m



Thank you…..