TWO MARKS
UNIT I
SITE INVESTIGATION AND SELECTION OF FOUNDATION

1. What is soil exploration? (April/May 2004)
   The field and laboratory investigations required to obtain the necessary data for the soils for the purpose of proper design and successful construction are collectively called as soil exploration.

2. Define Area ratio. (April/May 2004)
   Area Ratio, $A_r = \frac{D_2^2 - D_1^2}{D_1^2} \times 100\%$
   Where, D_1 - Inner diameter of cutting edge
   D_2 - Outer diameter of cutting edge

3. How will you reduce the area ratio of a sampler? (Nov/Dec 2005)
   Generally samples will area ratio less than 15% are said to be undisturbed. So area ratio is reduced by reducing the thickness of the cutting shoe.

4. When thin walled sampler is used for sampling? (Nov/Dec 2005)
   Thin walled sampler is used for those soils which are very sensitive to disturbances such as soft clays and plastic silts.

5. Define Chunk samples. (May/June 2009)
   Chunk samples are the hand carved samples obtained from the exposed portion of test pit, shafts and tunnels.

6. Explain Representative and Non-Representative Samples. (May/June 2009)
   Representative samples – Natural moisture content and the proportion of the mineral constituents are preserved even though the structure is disturbed.
   Non-Representative samples – In addition to alteration in the original soil structure, soils from the other layers gets mixed up or the mineral constituents gets altered.

7. What is significant depth? (Nov/Dec 2009)
   Exploration in general should be carried out to a depth up to which the increase in pressure due to structural loading is likely to cause perceptible settlement or shear failure. Such a depth is known as significant depth.

8. What is detailed Exploration? (Nov/Dec 2009), (Nov/Dec 2012)
   A detailed Exploration is meant to furnish information about soil properties such as Shear strength, Compressibility, Density index and Permeability. Detailed Exploration is

followed by the general exploration in case of large engineering works, heavy loads, and complex and costly foundations are involved.

9. What are the factors affecting quality of a sample? (Nov/Dec 2010)
   The following are the factors affecting quality of the sample.
   1. Cutting edge
   2. Inside clearance
   3. Outside clearance
   4. Inside wall friction
   5. Non-return valves

10. How is the depth of exploration decided? (Nov/Dec 2010)
    The depth of exploration required, depends on the type of proposed structure, its total weight, the size, shape and disposition of the loaded areas, soil profile and the physical properties of the soil that constitutes each individual stratum.

11. What are the various methods of site investigation? (Nov/Dec 2010)
    1. Open Excavation
    2. Borings
    3. Sub- Surface soundings
    4. Geophysical method

12. What are the tests used to determine the bearing capacity of soil? (Nov/Dec 2010)
13. List the field tests used in subsurface investigations. (Nov/Dec 2013)
    1. Standard Penetration Test.
    2. Static Cone Penetration test
    3. Dynamic Cone Penetration test
14. Write the uses of bore log report. (Nov/Dec 2012)
    1. Used to record the change of layers depth
    2. Used to record the water level
    3. Used to record the water quality in deeper level

15. What is meant by inside and outside clearance? What is its use? (Nov/Dec 2013)
    Inside clearance, $C_i = \frac{D_3 - D_1}{D_1} \times 100\%$

Where, D_1 - Inner diameter of cutting edge

D_3 - Inner diameter of sample tube

The inside clearance is given to reduce the friction between the tube, by allowing for the elastic expansion of the soil.

Outside clearance, $C_o = \frac{D_2 - D_4}{D_4} \times 100\%$

Where, D_4 - Outer diameter of cutting edge

D_2 - Outer diameter of sample tube

The outside clearance will help in reducing the friction while the sampler is being driven and when it is being withdrawn after the collection of the sample.

16. What are the limitations of hand augers in soil exploration? (May/June 2012)
    1. Hand augers are not suitable for sands and gravels above the water table.
    2. The sample is disturbed and suitable for identification purpose only.

17. What are the guidelines in terms of inside and outside clearance for obtaining undisturbed sample? (May/June 2012)
    An undisturbed sample is that in which the natural structure and properties remain preserved. The inside clearance should lie between 1 to 3% and the outside clearance 0 to 2%. The walls of the sampler should be smooth and should be kept properly oiled.
18. What is site reconnaissance? (May/June 2013)
    Site reconnaissance is defined as the inspection of the site and study of topographical features, the soil and ground water conditions and in deciding the future programme of exploration.

19. What is the objective of site investigation? (May/June 2013)
    The objective of site investigation is to provide reliable, specific and detailed information about the soil and ground water conditions of the site, economic design and execution of the engineering works.

20. The internal diameter of a sampler is40mm and the external diameter is 42mm. Will you consider the sample obtained from the sampler as disturbed or undisturbed?
    Given data: $D_1 = 40$mm,
    $D_2 = 42$mm

Area Ratio , $A_r = \frac{D_o^2 - D_i^2}{D_i^2} \times 100\%$

$= \frac{42^2 - 40^2}{40^2} \times 100\%$

$= 10.25\% < 15\%$

The sample is undisturbed one

21. A standard Penetration test was conducted on saturated fine sand below the ground water table. The SPT value was found to be 32. Does the value represent true SPT value? Explain.

Given Data: N =32

Corrected N value $N_c = 15 + \frac{1}{2}(N-15) = 15 + \frac{1}{2}(32-15)$

$N_c = 23.5$

Since it needs dilatancy correction for under water table as per the formula it does not represent the true value.

22. What is Standard Penetration Number (N)?

The Standard Penetration Number (N) is equal to the number of blows required for 300mm of penetration beyond a seating drive of 150mm.

23. What is sub surface profile?

A Sub surface profile is a vertical section through the ground along the line of exploration which indicates the boundaries of different strata, along with their classification.

24. Define Sub soil investigation Report or Boring Log.

Information on subsurface conditions obtained from the boring operation is typically prevented in the form of a boring record commonly called as Boring log or Sub soil investigation Report.

UNIT II

SHALLOW FOUNDATIONS

1. What is ultimate bearing capacity? (April/May 2004), (May/June 2013)

   The ultimate bearing capacity is defined as the minimum gross pressure intensity at the base of the foundation at which the soil fails in shear.

2. What is consolidation settlement? (April/May 2004)

   The consolidation settlement is the long term settlement taking place over a long period of time due to the gradual expulsion of water without replacing it by air from the soil pores.

3. List the various components of settlement. (Nov/Dec 2005), (April/May 2010)

Foundation design is based on providing a means of transmitting the loads from a structure to the underlying soil without

- A soil shear failure, shear failure means that, it is a plastic flow and/ or a lateral expulsion of soil from beneath the foundation.
- Causing excessive settlements of the soil under the imposed loads.

22. What is the effect of rise of water table on the bearing capacity and the settlement of a footing on sand? (Nov/Dec 2013)
The pressure of water affects the unit weight of soil. Hence bearing capacity is affected due to the effect of water table. For practical purpose it is more sensitive when the water table rises above depth 13 m from footing.

23. Define allowable bearing pressure.
The maximum allowable net loading intensity on the soil at which the soil neither fails in shear nor undergoes excessive or intolerable settlement, detrimental to the structure.

24. Define settlement and its types.
The term settlement indicates the sinking of the structure due to compression and deformation of the underlying soil.
Types:
1. Uniform settlement 2. Non uniform or differential settlement

SIXTEEN MARKS

UNIT I

SITE INVESTIGATION AND SELECTION OF FOUNDATION

1. What are the objectives of soil exploration? (April/May 2004) (6)

Objectives of soil exploration:

1. Determination of the nature of the deposits of soil.
2. Determination of the depth and thickness of various soil strata and their extent in horizontal direction.
3. Location of ground water and fluctuations in ground water level.
4. Obtaining soil and rock samples from the various strata.

5. Determination of engineering properties of soil and rock strata that affects the performance of the structure.
6. Determination of in-situ properties by performing field tests.

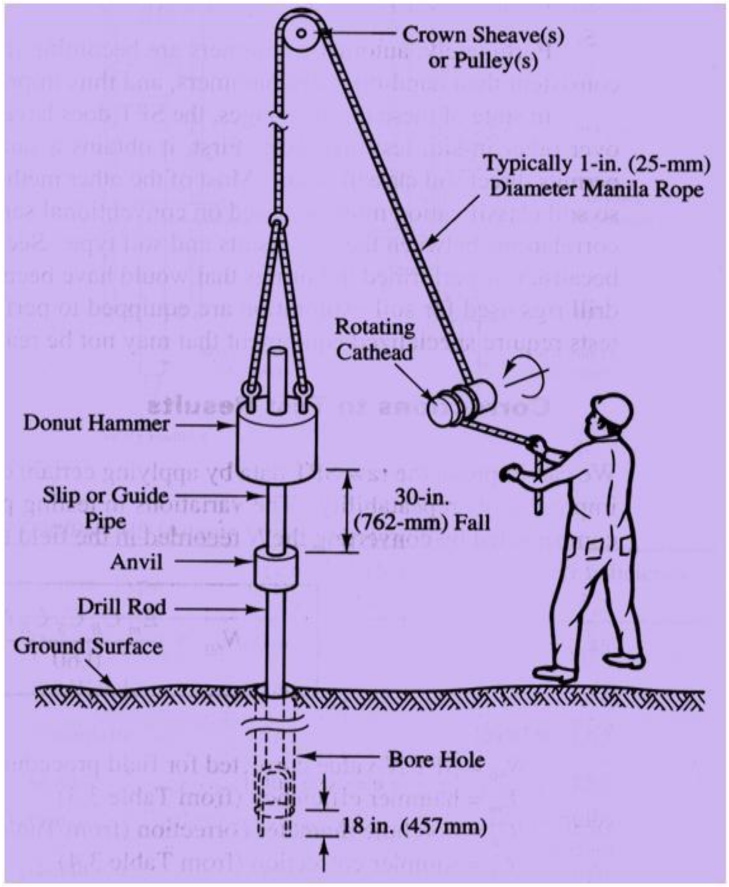
2. Briefly explain with neat sketch Standard Penetration Test and the correction to be applied to find 'N' value. (April/May 2004), (May/June 2009) , (Nov/Dec 2011), (April/May 2004), (May /June 2012), (Nov/Dec 2013) (10 or 8 or 16)

Standard Penetration Test.:

The standard Penetration Test is the most commonly used in –site test, especially for cohesion less soils which cannot be easily sampled, the test is extremely useful for determining the relative density and the angle to determine the UCC strength of the cohesive soil.

The standard penetration test is conducted in a bore hole using a standard split spoon sampler, when the bore hole has been drilled to the desired depth, the drilling tools are removed and the sampler is lowered to the bottom of the hole. The sampler is driven into the soil by a drop hammer of 63.5kg mass falling through a height of 750mm at the rate of 30blows per minutes.

The number of hammer blows required to drive 150mm of the sample is counted. The sampler is further driven by 150mm and the number of blows recorded. Likewise the sampler is once again further driven by 150mm and the number of blows recorded. The number of blows recorded for the first 150mm is disregarded. The plumber of blows recorded for the last two 150mm intervals are added to give the standard Penetration Number (N). In other words, the standard Penetration number is equal to the number of blows required for 300mm of penetration beyond a seating drive of 150mm.



If the number of blows for 150mm drive exceeds 50, it is taken as refusal and the test is discontinued. The standard Penetration number is corrected for decadency correction and our burden correction.

(a) Dilatancy Correction.

Silty fine sands and fine sands below the water table develop pore pressure which is not easily dissipated. The pore pressure increases the resistance of the soil and hence the Penetration number (N). Terzaghi and peck recommend the following correction when the observed N value exceeds 15. The corrected Penetration Number,

$$N_c = 15 + ½ [N_R – 15]$$

Where, N_c – corrected value

N_R – Recorded Value

If $N_R \leq 15$, then $N_c = N_R$

(b) Over burden Pressure Correction:

In granular soils, the overburden pressure affects the penetration resistance. Generally, the soil with high confining pressure gives higher penetration number. As the confining pressure in cohesion soil increases with depth, the penetration number for the soils at shallow depths is under estimated and that at greater depths is over estimated for uniformity, the N values obtained from field tests under different effective overburden pressure are corrected to a standard effective overburden pressure.

For dry or moist clean sand, (Gibbs and Holtz)

$$N_c = N_R \times \frac{350}{\bar{\sigma}_0 + 70}$$

Where, N_c - corrected value

N_R - Recorded Value

$\bar{\sigma}_0$ - effective over burden pressure

It is applicable for $\bar{\sigma} \leq 280 kN/m^2$. Usually the overburden correction is applied first and then dilatancy correction is applied first and then dilatancy correction is applied.

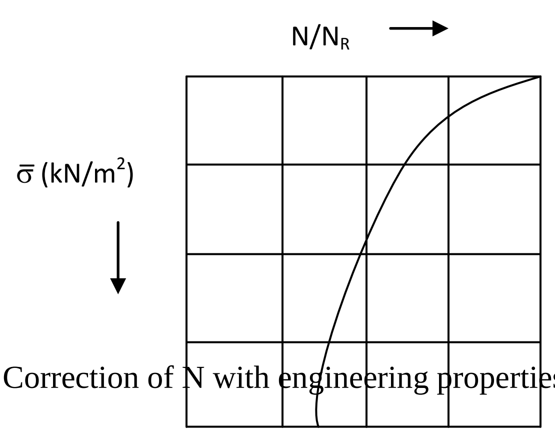
The correction given by Bazara & peck is

$$N = \frac{4N_R}{1 + 0.0418\bar{\sigma}_0} \quad \text{if } \bar{\sigma}_0 < 71.8 \text{ kN/m}^2$$

$$N = \frac{4N_R}{3.25 + 0.0104\bar{\sigma}_0} \quad \text{if } \bar{\sigma}_0 > 71.8 \text{ kN/m}^2$$

$$N = N_R \quad \text{if } \bar{\sigma}_0 = 71.8 \text{ kN/m}^2$$

Overburden pressure correction diagram



Correction of N with engineering properties:

The value of standard Penetration number N depends upon the relative density of the cohesionless soil and the unconfined compressive strength of the cohesive soil. If the soil is compact or stiff, the penetration number is high.

The angle of sheaing resistance (ϕ) of the cohesionless soil depends upon the number N. In general, greater the N-value greater the ϕ value. The consistency &UCC strength of cohesive soils can be approximately determined from SPT, N-value.

Correction between N, Dr, ϕ

N	Condition	Relative density, Dr	Angle of internal friction, ϕ
0-4	Very Loose	0-15%	<28°
4-10	Loose	15-35%	28°-30°
10-30	Medium	35-65%	30°-36°
30-50	Dense	65-85%	36°-42°
>50	Very Dense	>85%	42° & greater

For Clays the following data are given.

Correlation between N and q_u

N	Consistency	q_u(kN/m2)
0-2	Very soft	<25
2-4	Soft	25-50
4-8	Medium	50-100
8-15	Stiff	100-200
15-30	Very stiff	200-400
>30	Hard	>400

3. What are the steps involved in soil exploration? (8)

Steps involved in soil exploration:

1. Planning of a program for soil exploration.
2. Collection of disturbed and undisturbed soil or rock samples from holes drilled in the field. The number and depth of holes depend upon the project.
3. Conducting all the necessary in-situ tests for obtaining the strength and compressibility characteristics of the soil or rock directly or indirectly.
4. Study of ground water conditions and collection of water samples for chemical analysis.

5. Geophysical exploration, if required.
6. Conducting all the necessary tests on the samples of soil, rock and water collected.
7. Preparation of drawings, charts etc.
8. Analysis of the data collected
9. Preparation of reports.

The in-situ field tests for a project may consist of any one or more of the following tests:

1. Standard penetration tests in bore holes
2. Static cone penetration tests
3. Vane shear test
4. Plate load test
5. Permeability.

4. Explain the (i) Seismic refraction method and (ii) Electrical resistivity method of soil exploration. (May/June 2009), (Nov/Dec 2005), (or)
   Explain in detail the geophysical methods of soil explorations with neat sketch. (Nov/Dec 2012), (Nov/Dec 2013), (May /June 2013)
   (16)

(i) SESMIC REFRACTION METHOD

General

This method is based on the fact that seismic waves have different velocities in different types of soils and besides the wave refract when they cross boundaries between different types of soils. In this method an artificial impulse are produced either by detonation of explosive or mechanical blow with a heavy hammer at ground surface or at the shadow depth within a hole.

These shocks generate three types of waves.

- Longitudinal or compressive wave or primary (p) wave
- Transverse or shear waves or secondary (s) waves
- Surface waves

It is primarily the velocity of longitudinal or the compression waves which is utilized in this method. The equation on the p-waves (V_c) and s-waves (V_s) is given as

$$V_c = \sqrt{\frac{E(1-\mu)}{(1+\mu)(1-2\mu)\rho}}$$

$$V_s = \sqrt{\frac{E}{2\rho(1+\mu)}}$$

Where E is the dynamic modulus of the soil

μ is the Poisson's ratio

ρ is density

G is the dynamic shear modulus

These waves are classified as direct, reflected and refracted waves. The direct waves 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. The time required for the impulse to travel from the shot point to various points on the ground surface is determined by means of geophones which transform the vibrations into electrical currents and transmit them to a recording unit or oscillograph, with a timing mechanism.

Assumptions

The various assumptions involved are

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

i_1 is the angle of incidence

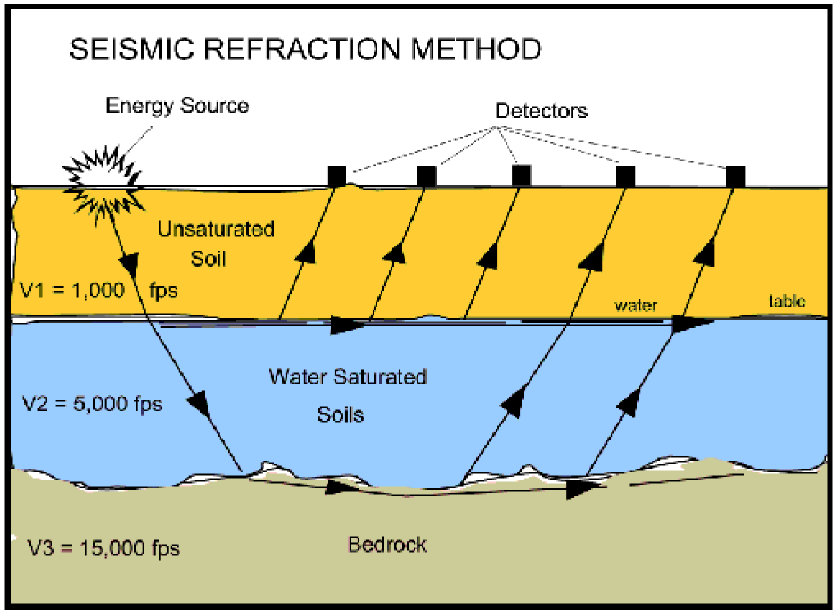
i_2 is the angle of refraction

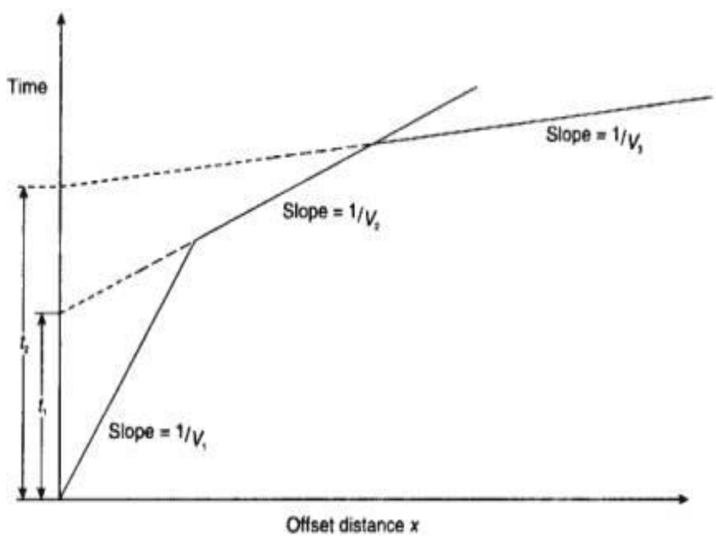
v_1 and v_2 are velocity in two different mediums

Procedure

The detectors are generally placed at varying distance from the shot point but along the straight line. The arrival time of the first impulse at each geophone is utilized. If the successfully deeper strata transmit the waves with increasingly greater velocities the path travelled by the first impulse will be similar to those. Those recorded by the nearest recorders pass entirely through the overburden, whereas those first reaching the after detectors travel downward through the lower velocity material, horizontally within the higher velocity stratum and return to the surface.

(A T_1 and A T_2) as the function of the distances between the geophones and the shot points (L_1 and L_2). A curve obtained which indicates the wave velocity in each stratum and which may be used to determine the depths to the boundaries between the strata.





$$H_1 = \frac{l_1 V_1}{2\cos\alpha} = \frac{L_1}{2}\sqrt{\frac{V_2 - V_1}{V_2 + V_1}}$$

$$H_2 = \frac{l_2 V_2}{2\cos\beta} = 0.85 H_1 + \frac{L_2 - L_1}{2}\sqrt{\frac{V_3 - V_2}{V_3 + V_2}}$$

Where H_1 and H_2 are the depths of the strata

$$l_1 = AB_1$$

$$l_2 = AC_1 - AB_1$$

$$\sin\alpha = (V_1 - V_2)$$

$$\sin\beta = (V_2/V_3)$$

Applications

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

Advantages

- Complete picture of stratification of layer up to 10 m depth.
- Refraction observations generally employ fewer source and receiver location and thus relatively cheap to acquire.
- Little processing is done on refraction observations with the exception of trace scaling or filtering to help in the process of picking the arrival times of the initial ground motion.
- Because such a small portion of the recorded ground motion is used developing models and interpretations is no more difficult than our previous efforts with other geophysical surveys.
- Provides seismic velocity information for estimating material properties.
- Provides greater vertical resolution than electrical, magnetic or gravity methods.
- Data acquisition requires very limited intrusive activity is non- destructive.

Disadvantages

- Blind zone effect: If $v_2 < v_1$, then wave refracts more towards normal then the thickness of the strata is neglected.
- Error also introduced due to some dissipation of the velocity as longer the path of travel, geophone receives the erroneous readings.
- Error lies in all assumptions.

(ii) ELECTRICAL RESISTIVITY METHOD

Electrical resistivity method is based on the difference in the electrical conductivity or electrical resistivity of different soils. Resistivity is defined as the resistance in ohms between opposite phases of a unit cube of a material.

$$\rho = (RA)/L$$

ρ is resistivity in ohm-cm

R is resistance in ohms

A is the cross sectional area (cm^2)

L is the length of the conduction (cm)

Procedure:

In this method the electrodes and driven approximately 20 cms in to the ground and a dc or a very low frequency ac current of known magnitude is passed between the outer electrodes thereby producing within the soil an electrical field and the boundary conditions. The electrical potential at point C is V_c and at the point D is V_d which is measured by means of the inner electrodes respectively.

$$V_c = \frac{I\rho}{2\pi}\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

$$V_D = \frac{I\rho}{2\pi}\left(\frac{1}{r_3} - \frac{1}{r_4}\right)$$

Where ρ is resistivity

I is current

r_1, r_2, r3 and r_4 are the distances between the various electrodes

Potential difference between C and D = V_{CD}

$$= V_c - V_D = \frac{I\rho}{2\pi}\left[\left(\frac{1}{r_r} - \frac{1}{r_2}\right) - \left(\frac{1}{r_3} - \frac{1}{r_4}\right)\right]$$

$$\rho = \frac{2\pi V_{CD}}{I}\left[\frac{1}{\left(\frac{1}{r_1} - \frac{1}{r_2}\right) - \left(\frac{1}{r_3} - \frac{1}{r_4}\right)}\right]$$

If r_1=r_4= (r_2/2)= (r_3/2)Then the resistivity is given as

$$\rho = \frac{2\pi R r_1}{I}$$

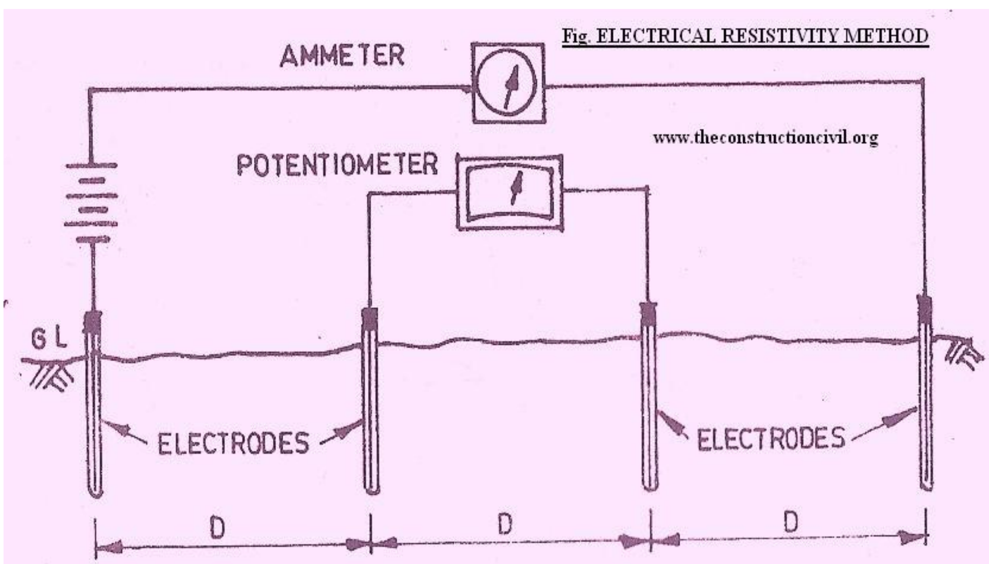
Where,

Resistances R= V_{CD}/I

Thus the apparent resistivity of the soil to the depth approximately equal to the spacing r_1 of the electrode can be computed. The resistivity unit is often so designed that the apparent resistivity can be read directly on the potentiometer.

In resistivity mapping or transverse profiling the electrodes are moved from place to place without changing their spacing and the apparent resistivity and any anomalies within a depth a depth equal to the spacing of the electrodes can thereby be determined for a number of points.

In resistivity sounding or depth profiling the center point of the set up is stationary whereas the spacing of the electrode is varied. A detailed evaluation of the results of the resistivity sounding is rather complicated, but preliminary indications of the subsurface conditions may be obtained by plotting the apparent resistivity as a function of electrode spacing. When the electrode spacing reaches a value equal to the depth to a deposit with a resistivity materially different from that of overlying strata, the resultant diagram will generally show a more or less pronounced break in the strata depth beyond A_2 .



I practice many several different arrays are used. For simple sounding a Wenner array is used. Then the resistivity is given as

$$\rho = \frac{2\pi Ra}{I}$$

Where a is the spacing between the electrodes.

The Schlumberger array is used for profiling and sounding. In sounding configuration the current electrodes separated by AB are symmetric about the potential electrodes MN. The current electrodes are then expanded and the resistivity is given as

$$\rho = \frac{\pi\left(s^2 - a^2/4\right)}{a}R$$

Applications

- Characterize subsurface hydrogeology.
- Determine depth to bedrock /over burden thickness.
- Determine depth to ground water.
- Map stratigraphy.
- Map clay aquitards.
- Map salt water intrusion.
- Map vertical extent of certain types of soil and ground water contamination.

Resistivity profiling

- Map faults.
- Map lateral extent of conductive contaminant process.
- Locate voids.
- Map heavy metals soil contamination.
- Delineate disposal areas.
- Map paleochannels.
- Explore for sand and gravels.
- Map archaeological sites.

Advantages of this method are

- It is very rapid and economical method.
- It is good up to 30 m 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.
- Data acquisition can be slow compared to other geophysical methods, although that difference is disappearing with the very latest techniques.

5. Describe the various methods of drilling bore holes for sub surface investigations.(April/May 2011)

(16)

When the depth of exploration is large, borings are used for exploration. A vertical bore hole is drilled in the ground to get the information about the subsoil strata samples are taken from the bore hole and tested in the laboratory. The bore hole may be used for conducting in-situ tests and for locating the water table.

Extensometers or pressure meter may also be installed in the bore hole for the measurement of deformation in the sub-strata. Depending upon the type of soil and the purpose of boring, the following methods are used for drilling the holds.

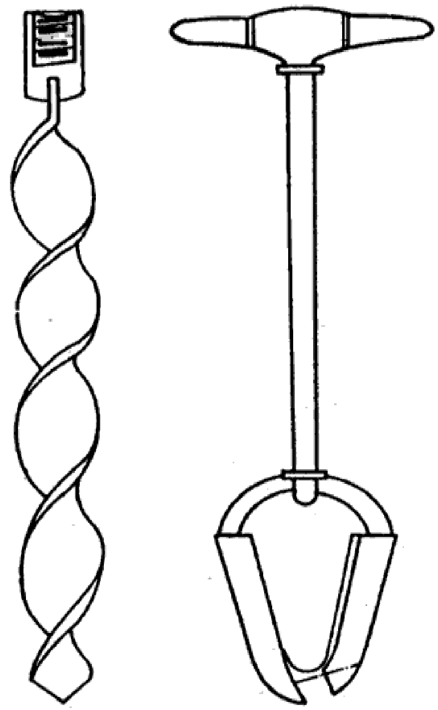
1. Auger Boring
2. Auger and shell boring
3. Wash Boring
4. Rotary Drilling
5. Percussion drilling
6. Core Boring

1. **Auger Boring:**

Augers are used in cohesive and other soft soils above water table. Hands augers are used for depth up to 6m. Mechanically operated augers are used for greater depths and they can also be used in gravelly soils. Samples recovered from the soil brought up by augers are badly disturbed nature of soil sample; it becomes difficult to locate the exact changes in the soil strata.

Augers consist of a shank with a cross-wise handle for turning and having central tapered feed screw. It can be operated manually or mechanically. Mechanical augers are driven by power. These are used for making holes in hard strata to a great depth. Even mechanical augers become inconvenient for depth greater than 12m and other methods of boring are used.

The hand augers used in boring are about 15to 20cm in diameter. It is attached to the lower end of the pipe of about 18mm diameter. The pipe is provided with cross arm at top. The hole is advanced by turning the cross arm manually and at the same time applying thrust in the downward direction. When the auger is filled with soil, it is taken out. If the hole is already driven, another type of auger known as post hole auger is used for taking soil samples.



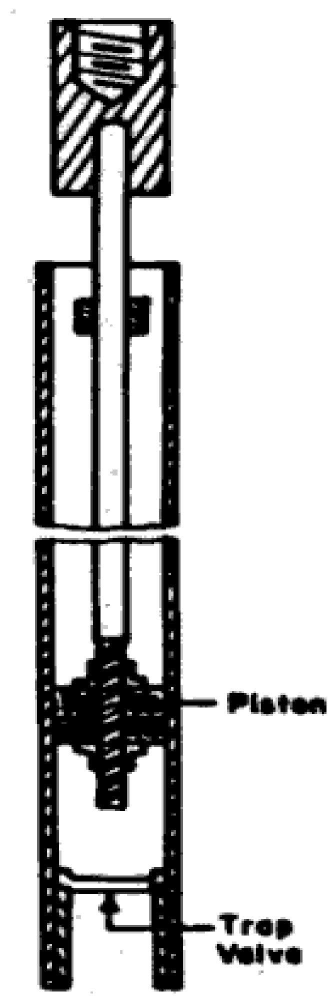
(a) HELICAL AUGER (b) POST-HOLE AUGER.

Clays, silts and partially saturated sands can stand unsupported. For soils cannot stand unsupported, especially for sandy soil below water table, a casing is normally required. For such soils, the method of auger boring becomes slow and expensive. Auger boring cannot be used when there are large cobbles, boulders or other obstructions which prevent drilling of the hole.

Auger boring is fairly satisfactory for highways, railways, airfield exploration at shallow depth. The sub-surface explorations are done quite rapidly and economically by auger boring.

Augers and shell Boring:

Cylindrical augers and shell with cutting edge on teeth at the lower end can be used for making deep borings. Hand operated rings are used for depth up to 2.m and the mechanical ring up to 50m. Augers are suitable for soft to stiff clays, shells for very stiff and hard clays and shells or sand pumps for sandy soils. Small boulders, thin soft strata or rock or cemented gravel can be broken by chisel bits attached to drill rods. The hole usually requires a casing.



Wash Boring:

In wash boring, the hole is drilled by first driving a casing about 2 to 3m long and then inserted into a hollow drill rod with a chisel shaped chopping bit at its lower end. Water is pumped down the hollow drill rod, which is known as wash pipe.

Water emerges as a strong jet through a small opening of the chopping bit. The hole is advanced by a combination of chopping action and the jetting action as the drilling bit and the accompanying water jet disintegrates the soil.

The water and chopped soil particles rise upward through the annular space between the drill rod and the casing. The return water also known as wash water which is collected in a tub through a T-shaped pipe fixed at the top of the casing.

The hole is further advanced by alternately raising and dropping the chopping by a winch. The swivel joint provided at the top of the drill rod facilitates the turning and twisting of the rod. The process is continued even below the costing till the hole begins to cave in. At that stage the bottom of the casing can be extended by providing additional pieces at the top.

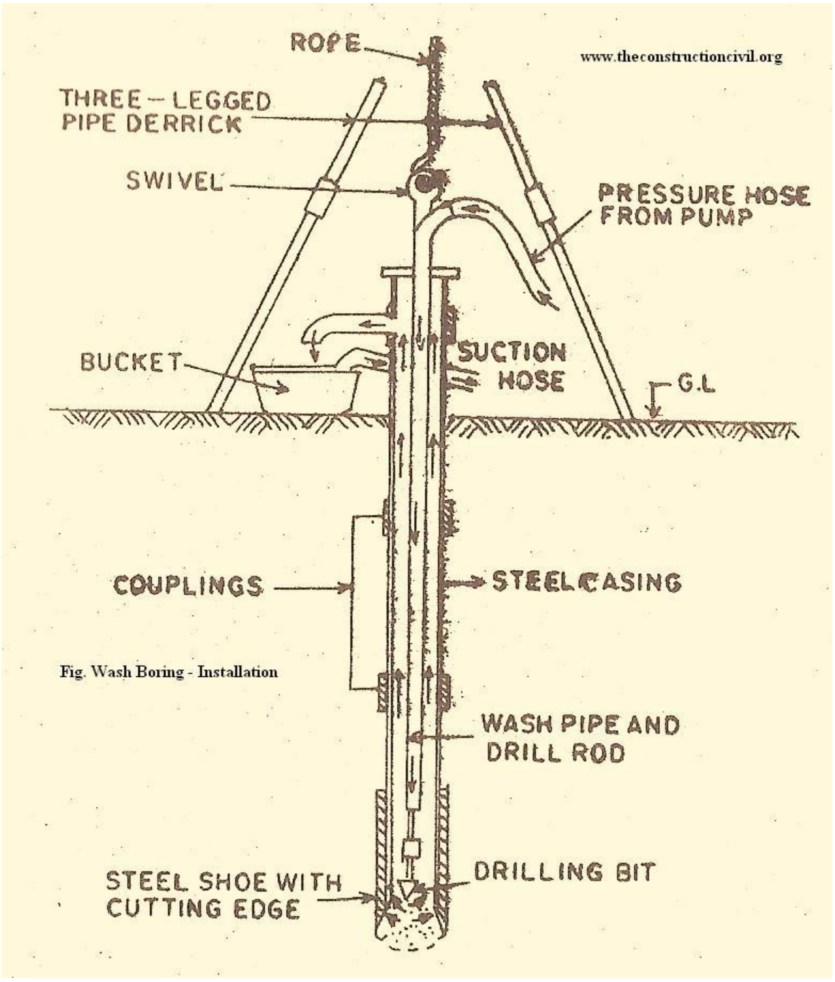


Fig. Wash Boring - Installation

However in stable, cohesive soils the casing is required only in the top portion. Sometimes instead of casing, special drilling fluids made of suspension or emulsion of fat clays or bentonit combined with some special additives are used for supporting walls of the hole.

The change in strata is provided by the reaction of the chopping bit as the hole is advanced. It is also indicated by a change in colour of the wash water. The wash boring is mainly used for advancing a hole in the ground. Once the hole has been drilled, a sampler is inserted to obtain soil samples for testing in the laboratory.

The equipment used in wash boring is relatively light and inexpensive. The main disadvantage of the method is that it is slow in stiff soils and coarse grained soils. It cannot be used efficiently in hard soils, rocks and the soil containing boulders.

The method is not suitable for taking good quality undisturbed samples above ground water table, as the wash water enters the strata below the bottom of the hole and causes an increase in its water content.

Percussion Drilling:

The percussion drilling method is used for making holes in rocks, boulders and other hard strata. In this method a heavy chisel is alternately lifted and dropped in a vertical hole. The material gets pulverized. If the point where chisel strikes is above the water table, water is added to the hole. The water forms slurry with the pulverised material which is removed b a sand pipe. Percussion drilling may require a casing. It is also used for drilling tube wells.

The main advantage of the percussion drilling method is that it can be used for all types of materials. It is particularly useful for drilling holes in is glacial tills containing boulders. One of the major disadvantages is that the material at the bottom of the hole is disturbed by heavy blows of the chisel. It is not possible to get good quality undisturbed samples. This method is generally more expensive.

Rotary Drilling:

Rotary boring or drilling is a very fast method of advancing hole in the both rocks and soils. A drill bit, fixed to the lower end of the drill rods, is rotated by a suitable chunk and is always kept in firm contact with the bottom of the hole. A drilling mud, usually a water solution of bentonite with or without other admixtures is continuously forced down the hollow drill rods. The mud entering upwards brings the cuttings to the surface. This method is also known as ‘MUD ROTARY DRILLING ‘and the hole usually requires no casing.

When the soil sample is required to be taken the drilling rod is raised and the drilling bit is replaced by the samples. Rotary drilling can be used in clay, sand and rocks. Bore holes of diameter 50mm to 200mm can be easily made by this method.

Core Drilling:

The core drilling method is used for drilling holes and for obtaining rock cores. In this method a core barrel fitted with a drilling bit is fixed to a hollow drilling rod. As the drilling rod is rotated, the bit advances and cuts an annular hole an intact hole. The core is then removed from its bottom and is retained by a core –lifter and brought to the ground surface.

The core drilling may be done using either a diamond studded bit or cutting edge consists of chilled shot. The diamond driller is superior to the other type of drilling, but it is costlier

Water is pumped continuously into the drilling rod to keep the drilling bit cool and to carry the disintegrated materials to the ground surface.

6. Discuss the features of bore log report in detail. (Nov/Dec 2010), (May/June 2012) (10 or 8)

Information on subsurface conditions obtained from the boring operation is typically presented in the form of a boring record commonly known as 'boring log'. It is also known as sub-soil investigation report which should contain the data obtained from bore holes, site recommendations about the suitable type of foundation, soil pressure and expected settlements.

It is essential to give a complete and accurate record of data collected. All relevant data for the bore bole is recorded in a boring log. A boring log gives the description or classification of various strata encountered at different depths. Any additional information that is obtained in the field soil consistency, UCC strength, standard Penetration test, Cone penetration Test is also indicated on the boring log. It should also show the water table.

The data obtained from a series of bore holes is presented in the form of a vertical section through the ground along the line of exploration. It indicates the boundaries of different strata, along with their classification. It is important to remember that conditions between bore holes are estimated by interpolation, which may not be correct. Obviously, larger the number of holes, the more accurate the subsurface profile.

Sample Bore Log

Record of boring [IS 1892-1979]

TEST PIT LOG

Report Date: 6/15/99	**Pit No.:** 001
Company Name: ACME ENVIRONMENTAL LTD	**Surface Elevation:** 425 ft msl
Site Name: Texeron Service Station	**Total Depth:** 10.4 ft
Location: Section 22, T7S, R8W N425789, E259874 Gibson County IN	**Start:** 01/01/2000 at 7:00am
Logged By: C. Dana Chicago IL	**Finish:** 01/01/2000 at 7:00pm
Contractor: Magmun Drilling Evansville, IN	**Equipment Type:** Cat 442
Conditions: Cold and Clear	**Pit Dimensions:** 30ft x 20ft x 10.4
Comments: 1500 gallon diesel UST removal	**Sampling Methods:** grab

Graphical Log	Top Depth (ft)	Thick. (ft)	Bt.Elev. (ft)	Strata Code	Material Description	Sample No.	Sampling Method	Remarks
	0.0	1.5	423.5		Topsoil			
	1.5	4.0	419.5		Brown, silt with minor sand, root structures, moist	001	grab	sample at 3.0 ft bls, slight petroleum odor, HNU reading 200
	5.5	1.0	418.5		Brown finegrained sand, wet	002	grab	sample at 6.0 ft, strong petroeum odor, HNU reading 1125
	6.5	2.7	415.8		brown slightly sandy clay, moist	003, 004		sample at 7.0 ft, slight pretroleum odor, HNU reading 300 sample at 8 ft, no petroeum odor, HNU reading 0.
	9.2	1.2	414.6		dark brown clayey silt with trace of gravel	005		sample at 10 ft, no petroleum odor, HNU reading 0.

10.4 ft T.D.

EASYSOLVE SOFTWARE LLC
1531 East 10th Street, Craig, Colorado 81625
www.easysolve.com (970) 824-0113

Page 1 of 1

A soil exploration report generally consists of the following:

1. Introduction, which gives the scope of the investigation.
2. Description of the proposed structure, the location and the geological conditions at the site.
3. Details of the field exploration programme, indicating the number of borings, their location and depths.
4. Details of the method of exploration.
5. General description of the sub- soil conditions as obtained from in-sites tests, such as standard penetration Test, cone test.
6. Details of the laboratory test conducted on the soil samples obtained and the results obtained.
7. Depth of ground water table and the change in water levels.
8. Discussion of the results.
9. Recommendation about the allowable bearing pressure, the type of foundation or structure.
10. Conclusion: The main findings of the bore hole investigations should be clearly stated.

7. Explain in detail the cone penetration test with sketches. (16)

Cone Penetration Test

The cone test was developed by the dutch government, soil mechanics laboratory at Defit and is therefore also known as Dutch cone test. The test is conducted either by the Static method or by dynamic method.

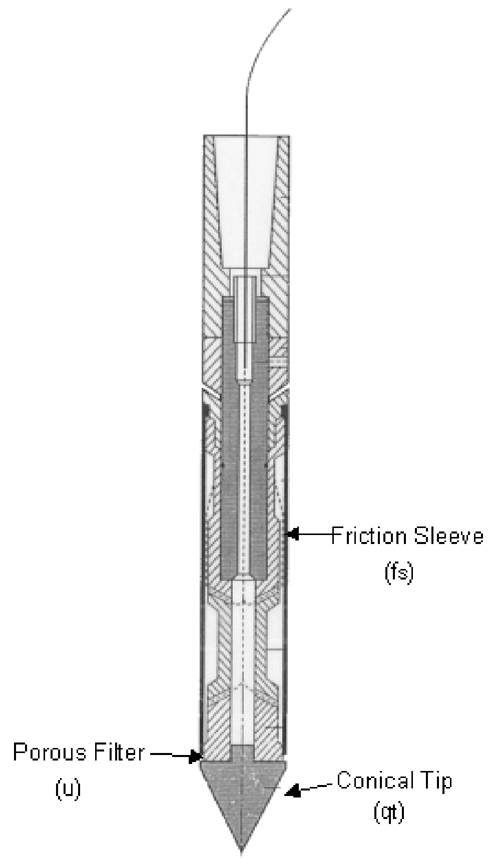
Static Cone Penetration Test.:

The Dutch cone has an apex angle of 60 and an overall diagram of 35.7mm giving an overall diagram of 35.7mm giving an end area of 10cm2. For obtaining the cone resistance, the cone is pushed downward at a steady rate of 10mm/sec through a depth of 35mm each time. The cone is pushed by applying thrust and not by driving.

After the cone resistance has been determined the cone is withdrawn. The sleeve is pushed onto the cone both are driven together into the soil and the combined resistance is also determined. The resistance of the sleeve alone is obtained by subtracting the cone resistance from the combined resistance.

A modification of the dutch cone pentrometers is the refined dutch cone. It has got a friction sleeve of limited length above the cone point. It is used for obtaining the point resistance of the cone and the frictional resistance of the soil above cone point.

For effective use of the cone penetration test, some reliable calibration is required. This consists of comparing the results with those dutch cone obtained from conventional tests conducted on undisturbed sample in a laboratory. It is also convenient to compare the cone test results with SPT results, are related to the SPT number N, indirect correlations are obtained between the cone tests and the engineering properties of the soil.



Typical 15cm² CPT probe showing the relative location of each component

The following relation holds approximately good between the point resistance of the cone (9c) and the standard penetration Number (N)

i)	Gravels 9c	=	800N to 1000N
ii)	Sands 9c	=	500N to 600N
iii)	Silly sands 9c	=	300N to 400N
iv)	Sills & clayey 9c	=	200N where 9c is in KN/m2 silts

b. Dynamic Cone Penetration Test.

The test is conducted by driving the cone by blows of a hammer. The number of blows for driving the cone through a specified distance is a measure of dynamic cone resistance.

It is performed either by using a 50mm cone without bentonite slurry or by using a 65mm cone with bentonite slurry (IS 4968 – part I &II 1976) The driving energy is given by 65kg hammer falling through a height of 75cm. The number of blows required for 30cm of penetration is taken as the dynamic cone resistance (N_{cbr}). If the skin friction is to be eliminated, the test is conducted in a cased bore hole.

When a 65mm cone with bentonite slurry is used, the set up should have arrangement for circulating slurry so that the friction on the driving rod is eliminated. The dynamic cone resistance (N_{cbr}) is correlated with the SPT number N. the following approximate relations may be used when a 50mm diameter cone is used.

N_{cbr}	Depth
1.5N	<3m
1.75N	3-6m
2.0N	>6m

The central building research Institute, Roorkee has developed the following correlation between the dynamic cone resistance (N_{bcr}) of SPT Number N. It is applicable for medium to fine sand.

Ncbr	Depth
1.5N	<4m
1.75N	4-9m
2.0N	>9m

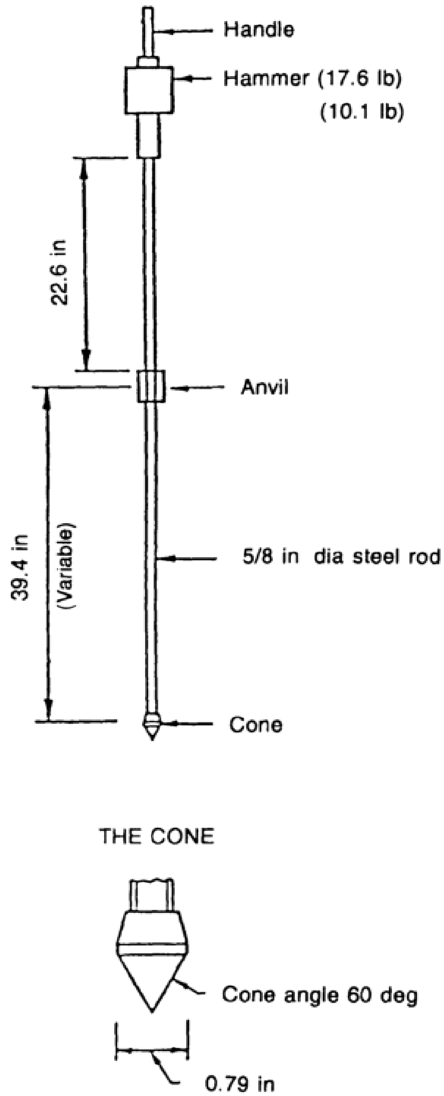


Figure J-1. Dual-mass DCP

8. Explain in detail the various types of samplers with sketches. (16)

OPEN DRIVER SAMPLER:

Open driver sampler can be of the thick wall type as well as of the thin wall type. The head of the sampler is provided with values to permit water and air to escape during driving. The check valve helps to retain the sample when the sampler is lifted. The tube may be seamless. If the tube splits in two parts which is called as split tube or split spoon sampler.

SPLIT SPOON SAMPLER:

The most commonly used sampler for obtaining disturbed sample of soil is the standard split spoon sampler. It consists mainly of three parts

i) Driving shoe, made of tool steel, about 75mm long
ii) Steel tube abut 450mm long, split longitudinal in two halves and
iii) Coupling at the top of the tube about 150mm long.

The inside diameter of the split tube is 38mm and the outside diameter is 50mm. The coupling head may be provided with a check valve and 4 venting ports of 10mm diameter to improve sample recovery. This sampler is also used in conducting standard penetration test.

After the bore hole has been made, the sampler is attached to the drilling rod and lowered into the hole. The sample is collected by jacking or forcing the sampler into the soil by repeated blows of a drop hammer. The sampler is then withdrawn. The split tube is separated after removing the shoe and the coupling and the sampler is taken out. It is then paced in a container, sealed and transported to the laboratory.

If the soil encountered in the bore hole is fine sand and it lies below the water table, the sample is recovery becomes difficult. For such soil, a spring core catcher device is used to aid recovery. As the sampler is lifted springs close and form a dome and retain the sample.

While taking samples, care should be taken to ensure that the water level in the hole is maintained slightly higher than the piezometric level at the bottom of the hole. It is necessary to prevent quick sand conditions.

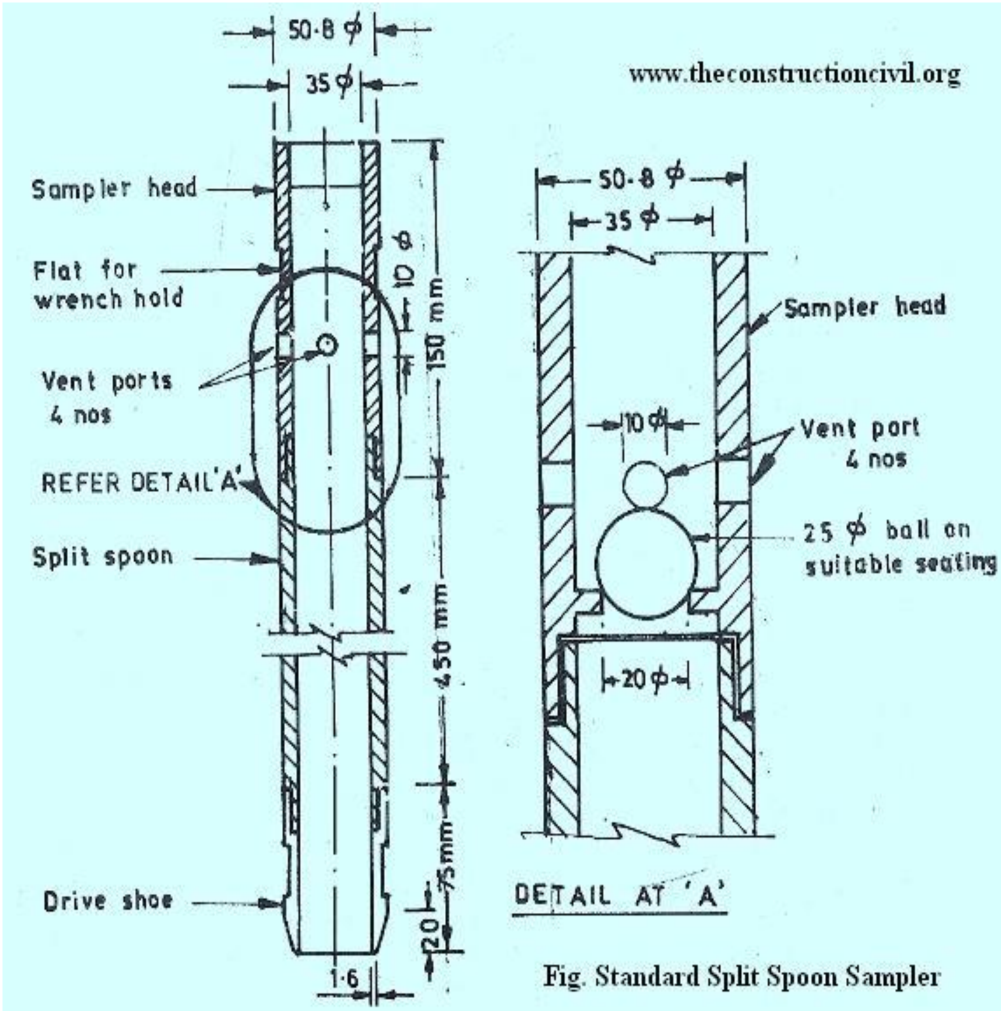


Fig. Standard Split Spoon Sampler

The split tube may be provided with a thin metal or plastic tube liner to protect the sample and to hold it together. After the sample has been collected, the liner and the sample it contains are removed from the tube and ends are sealed.

STATIONARY PISTON SAMPLER:

Stationary piston sampler consists of a sampler with a piston attached to a long piston rod extending up to the ground surface through the drill rods. The lower end of the sampler is kept closed with piston while the sampler is lowered through the bore hole.

When the desired elevation reached, the piston rod is clamped; thereby keeping the piston stationary and the sampler tube is advanced further into the soil. The sampler is then lifted and the piston rod clamped in position. The piston prevents the entry of water and soil into the tube, when it is being lowered and also helps to retain the sample during the process of lifting the tube.

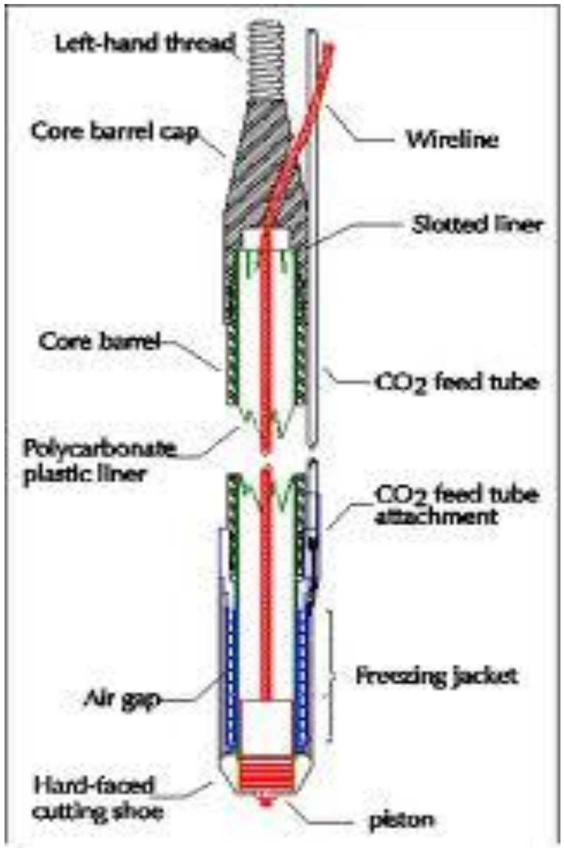


Figure 1. A cross-sectional view of the sample-freezing drive shoe attached to the Solinst core barrel. The scale is broken; the sampler is about 6.5 ft (2 m) long and 3 in. (75 mm) in diameter.

The sampler is therefore very much being suited for sampling in soft soils and saturated sands.

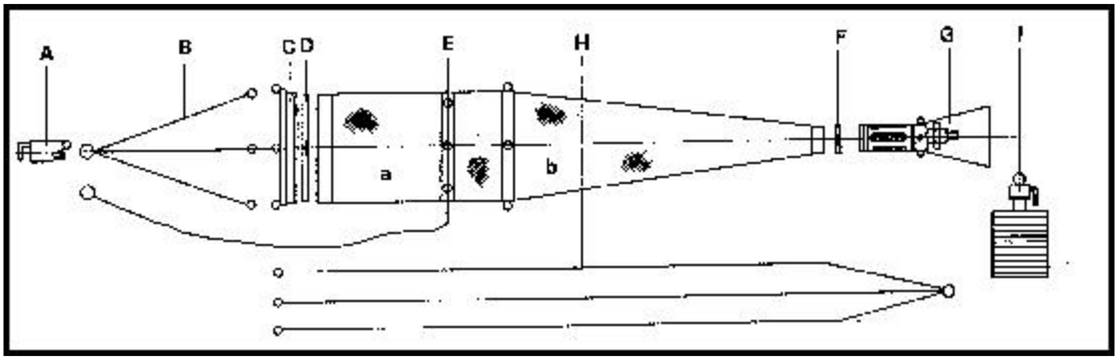
ROTARY SAMPLERS:

Rotary samplers are core barrel type with an outer tube provided with cutting teeth and a removable thin liner inside. It is used for sampling in stiff cohesive soils.

SCRAPER BUCKET SAMPLER:

If a sandy deposit contains pebbles it is not possible to obtain samples by standard split spoon sampler by standard split spoon sampler or split spoon fitted with a spring core catcher. The pebbles come in between the springs and prevent their closure. For such deposits, a scraper bucket sampler can be used.

A scraper bucket sampler can also be used for obtaining the samples of cohesion less soils below the water table.



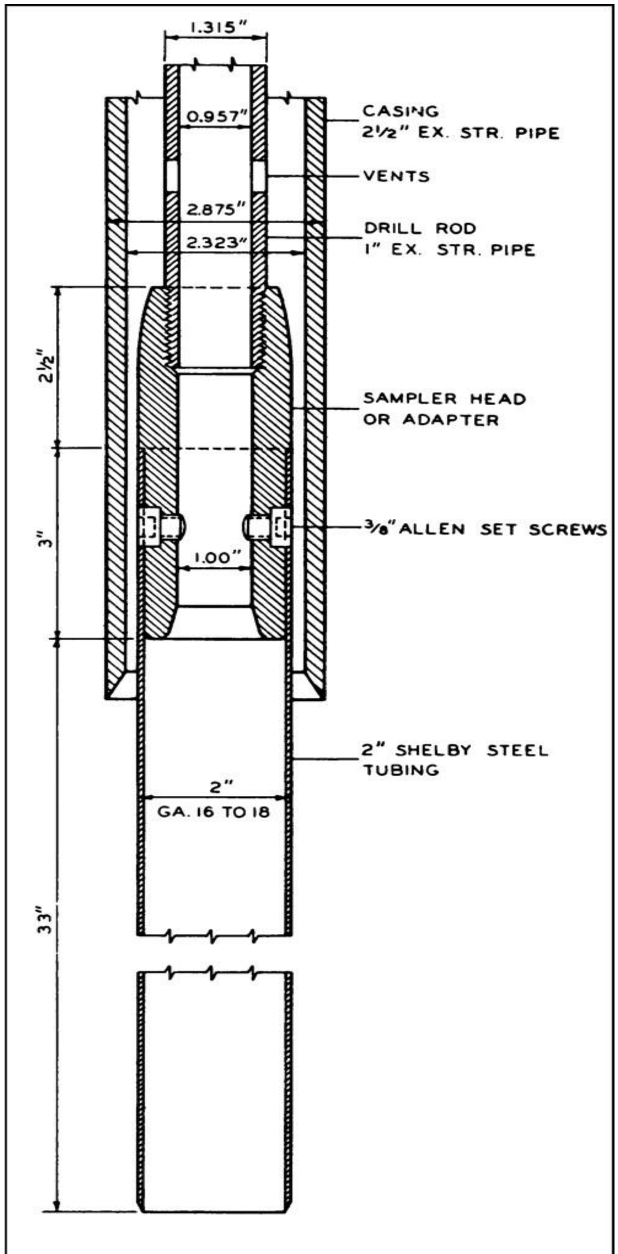
SHELBY TUBES AND THIN WALLED SAMPLERS:

Shelby tubes are thin wall tube samplers made of seamless steel. The outside diameter of the tube may be between 40 to 125mm. The area ratio is less than 15% and the inside clearance is between 0.5 to 3%.

The length of the tube is 5 to 10 times the diameter for sandy soils and 10 to 15 times the diameter for clayey soils. The diameter generally varies between 40 and 125mm and thickness varies from 1.25 to 3.15mm.

The sampler tube is attached to the drilling rod and lowered to the bottom of the bore hole. It is then pushed into the soil. Care should be taken to push the tube into the soil by a continuous rapid motion without impact or twisting. The tube should be pushed to the length provided for the sample.

At least 5 minutes after pushing the tube into its final position, the tube is turned revolutions to shear the sample off at the bottom before it is withdrawn. The tube is taken out and its ends are sealed before transportation. Shelby tubes are used for obtaining undisturbed samples of clay.

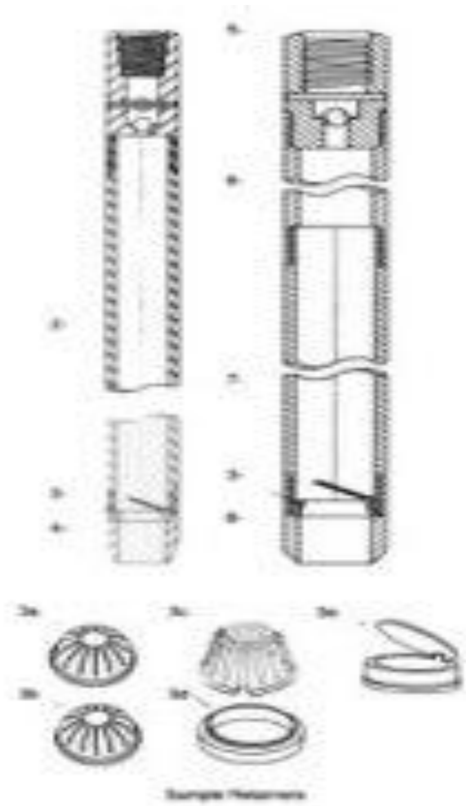


SHELBY TUBING SAMPLER BY H. A. MOHR

DENISON SAMPLER:

The Denison sampler is a double walled sampler. The outer barrel rotates and cuts into the soil. The sample is obtained in the inner barrel. The inner barrel is provided with a liner. It may also be provided with a basket type core retainer.

The Denison sampler is mainly used for obtaining samples of stiff to hard cohesive soils and slightly cohesive sands. However, it cannot be used for gravelly soils, loose cohesion less sands and silts below ground water table and very soft cohesive soils.



HAND-CURVED SAMPLES:

Hand curved samples can be obtained if the soil is exposed, as in a test pit, shaft or tunnel. Hand curved samples are also known as chunk samples. The soil should have at least a trace of cohesion so that it can stand unsupported for sometimes.

To obtain a sample, a column of soil is isolated in the pit. The soil is carefully removed from around the soil column and it is properly trimmed. An open ended box is then placed over the soil column. The space between the box and the soil column is fitted with paraffin. A spade or a plate with sharp edges is inserted below the box and the sample is cut at its base.

The box filled with the soil sample is removed. It is turned over and the soil surface in the box is trimmed and any depression is filled with paraffin. A chunk sample may be obtained without using the box if the soil is cohesive. A column of soil is isolated. The block of soil is carefully removed from the soil column with sharp knife.

The chunk sample is then coated with paraffin wax to prevent loss of moisture. Samples from open pits can also be obtained by pressing a sampling tube provided with a cutting edge. The soil surrounding the outside of the tube is carefully removed while the tube is being pushed into the soil. Hand – curved samples are undisturbed.

9. Describe in detail the scope of site investigation and stages of site investigation. (16)

Planning of site investigation:

Site investigation refers to the procedure of determining surface and sub surface conditions in the area of proposed construction.

Site investigation consists of determining the profile of the natural soil deposits at the site, taking the soil samples and determining the engineering properties of the soils. It also includes in-situ testing of the soils. Site investigations are generally done to obtain the information that is useful for one or more of the following purposes.

1. To select the type and depth of foundation for a given structure.
2. To determine the bearing capacity of the soil
3. To estimate the probable maximum and differential settlement.
4. To estimate the GWL and to determine the properties of water.
5. To predict and to solve potential foundation problems.
6. To select suitable construction techniques.
7. To predict the lateral earth.
8. To ascertain the suitability of the soil as a construction material.
9. To investigate the safety of the existing structures and to suggest remedial measures.

Stages in site investigation:

Site investigation or sub surface exploration is carried out in three stages.

1. **Reconnaissance**

   Site reconnaissance is the first step in an investigation process. It includes a visit to the site and to study the maps and other relevant records. It helps in deciding future programme of site investigations, scope of work, methods of exploration to be adapted, types of samples to be taken and the laboratory testing and in-situ testing.
2. **Preliminary exploration**
   - The aim of a preliminary exploration is to determine the depth, thickness, extent and composition of each soil stratum at the site.
   - The depth of bed rock and ground water table is also determined.
   - The preliminary explorations are generally in the form of a few boring or test pits. Tests are conducted with cone penetrometers and sounding rods to obtain information about the strength and compressibility of soils.
   - Geophysical methods are also used in preliminary explorations for locating the boundaries of different strata.
3. **Detailed explorations:**

- The purpose of the detailed explorations is to determine the engineering properties of the soils in different strata. It includes an extensive boring programme, sampling and testing of the samples in the laboratory.
- Field tests such as vane shear tests, plate load tests, permeability tests are conducted to determine the properties of the soils in the natural of state. The tests for the determination of dynamic properties are also carried out, if required.
- For complex projects involving heavy structures such as bridges, dams, multi-storey buildings it is essential to have detailed explorations. However for smaller projects, especially at sites where the strata are uniform, detailed investigation may not be required. The design of such projects is generally based on the data collected during reconnaissance and preliminary explorations.

Reconnaissance:
The geotechnical engineer makes a visit to the site for careful visual inspection in reconnaissance. The information about following features is obtained in reconnaissance.

1. The general topography of the site, the existence of drainage ditches and dumps of debris and sanitary fills.

2. Existence of settlement cracks in the structure already built near the site.

3. The evidence of landslides, creep of slopes and the shrinkage cracks.

4. The stratification of soils as observed from deep cuts near the site.

5. The location of high food marks on the nearby building and bridges.

6. The depth of ground water table as observed in the wells.

7. Existence of springs, swamps etc at the site.

8. The drainage pattern existing at the site.

9. Type of vegetation existing at the site.

10. Existence of underground water mains, power conduits etc at the site.

In addition to making site visits, the geotechnical engineer should study geological maps, aerial photographs, toposheet, and soil maps, blue prints of the existing buildings. These give a lot of information about the geologic character of the area.

The geotechnical engineer should also get information about the type of structure to be built and its proposed use. In the case of a multi- storeyed building, the information about the column loads and their approximate locations should be obtained. In the case of bridges span length and the load carried by the piers and abutments should be ascertained.

In the case of a dam, the geotechnical engineer should get information about the type of dam, its height, base width and other salient features or characteristics.

Study of maps:

- Topographical maps called toposheets – survey of India and geological survey of India
- Soil conservation maps may also be available.
- Faults, folds, cracks, fissures, dikes, skills and caves and such other defects in rock and soil strata may be indicated.
- Maps showing the earthquake zones of different zones of different degree of vulnerability are available.
- Seismic potential is a major factor in structural design especially in the construction of major structures such as dams and nuclear power plants.