# Exploration Methods

**A. Direct method** **B. Indirect Method**

**Direct Methods:** which involve direct penetration/excavation of ground

**1) Probing/Sounding Methods:**

- **These methods have been developed for determining the consistency of cohesive soils or relative density of cohesionless deposits. In this method a rod encased in a sleeve is forced into the soil and the resistance to penetration or with drawl is observed. Variations in the resistance shows dissimilar soil layers and the numerical values of the resistance permits an estimate of some of the physical properties of the strata.**
- **The advantages and limitations of soil sounding methods are as follows.**
  - **Soundings are generally considerably faster and cheaper than boring.**
  - **In boring a thin weak soil strata may pass unnoticed but sounding indicates its presence.**
  - **In erratic soil conditions soundings can be used between two borings.**
  - **Sounding gives an idea about the consistency of cohesive soils and degree of compactness of cohesionless soils. Hence where undisturbed sample is difficult to collect or is expensive sounding may be used as a substitute.**
  - **Bearing capacity of soil can be estimated by sounding.**
  - **Soundings alone cannot provide sufficient data for the final design of important or unusual foundations and earth structures.**
  - **Sounding gives no idea about the settlement characteristics of the soil in question.**
  - **Sounding gives misleading results when soil contains stones/boulders etc.**
- **As a general rule, dynamic penetration tests are performed in cohesionless soils and static tests in cohesive materials.**

# DIRECT METHODS OF SI:

**1-A: DYNAMIC PENETRATION OF RODS.**

- **The oldest and simplest form of soils sounding consists in driving a rod into the ground by repeated blows of a hammer.**
- **The penetration of the rod for a given number of blows with a hammer of constant weight and drop is recorded or the number of blows required per foot penetration of the rod is noted. These information's are used as an index of the penetration foundation experience.**
- **Skin friction is also acting on the rod and is cumulative with depth, hence the penetration resistance does not directly represent the strength or density of the strata encountered.**
- **{SKIN FRICTION = Perimeter x Length x Average shear resistance per unit area developed between the soil and the rod**

# DIRECT METHODS:

## 1-B: PENETRATION BY ROTATION [SWEDISH METHODS]

- A sounding rod is forced into the soil partly by static load and partly by rotation of the rod.
- The rod is provided with a screw point with a diameter about 50 percent greater than that of the rod. The penetration is first recorded for successive static loads of 5,15,25,75 and 100 kg. The rod with a final static load of 100 kg is then rotated and the penetration is observed for each 25 half turns. A diagram of the variation of this penetration with depth is then plotted and compared with similar diagrams obtained for the same soil for which the bearing capacity has been determined by other means.
- This method is relatively fast and inexpensive, even when compared with other sounding methods, but it is not suitable for exploration of coarse and gravelly soils or very compact or hard soils. Neither does the method furnish adequate details on the soil profile when soils are so soft that they are penetrated by the sounding rod without rotating it but simply by placing the above mentioned static loads on the self-locking clamp.

# DIRECT METHODS:

## 1-C: CONE PENETROMETER

- A cone penetrometer is used for shallow explorations in relatively soft deposits and determination of the capacity of such deposits to sustain various types of loads and traffic. At depths at which it is desired to determine the penetration resistance, the pressure on the handle is slowly increased until there is a perceptible but very slow and uniform downward movement of the cone. The corresponding pressure is measured by means of the proving ring.

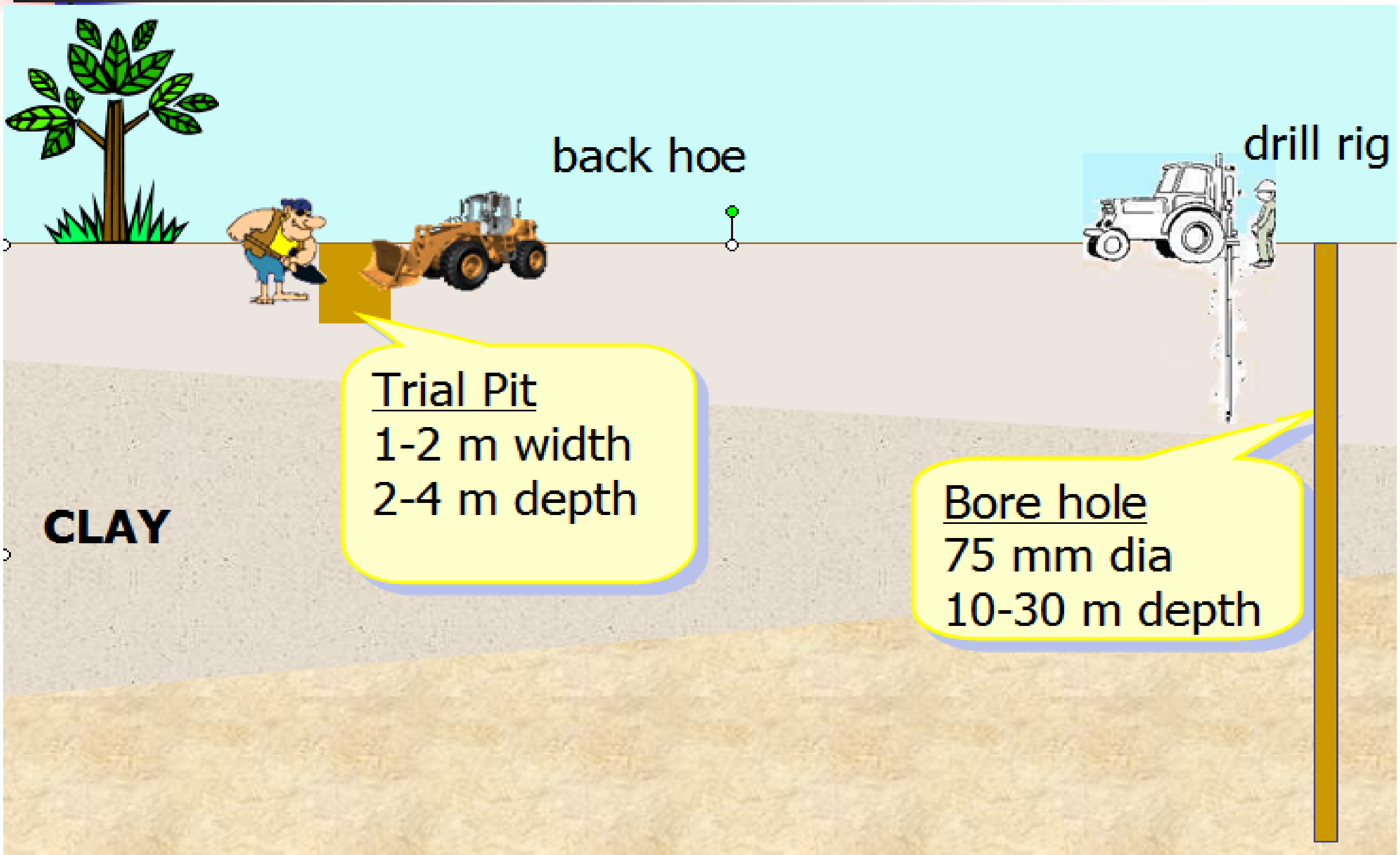
# DIRECT METHODS:

## 2. Test Pits/Trenches (Open pit exploration):

**Test pits permit a direct inspection of the soil strata in place, and taking of adequate disturbed and undisturbed soil samples.**

- **Test pits are the most satisfactory method of disclosing the soil strata conditions. Also it is possible to take even undisturbed samples of sands by this method. The cost of test pit increases rapidly with depth; they are uneconomical beyond a depth of 12 ft. They are practically impractical when groundwater is to be handled.**

# SOIL BORING


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

## TRIAL PITS

Trial pits are used for shallow visual investigations and to obtain samples from the top few metres of soil. They are a very economical means of obtaining information rapidly.

Trial pits are used to obtain detailed information of the top layers of soil, determine rock head if it is near the surface and obtain class 1 samples.

They are normally 1 to 3m deep but can extend to 6m. The depth is limited because of the method of excavation which is either by hand or machine. In exceptional circumstances deeper pits are dug.

The depth is also limited because of possible collapse especially in water bearing sands and gravels.

No one should enter a trial pit unless they can guarantee that the pit will not collapse. It may be necessary to use some form of retaining structure.

There is no limit to the size of the pit but the excavated soil will be disturbed when replaced hence the ground would be unsuitable for constructing shallow foundations. The size should be limited. On occasions trenches rather than pits are dug so that sub surface features such as karst can be identified.

# Merits & Demerits of Test Pits

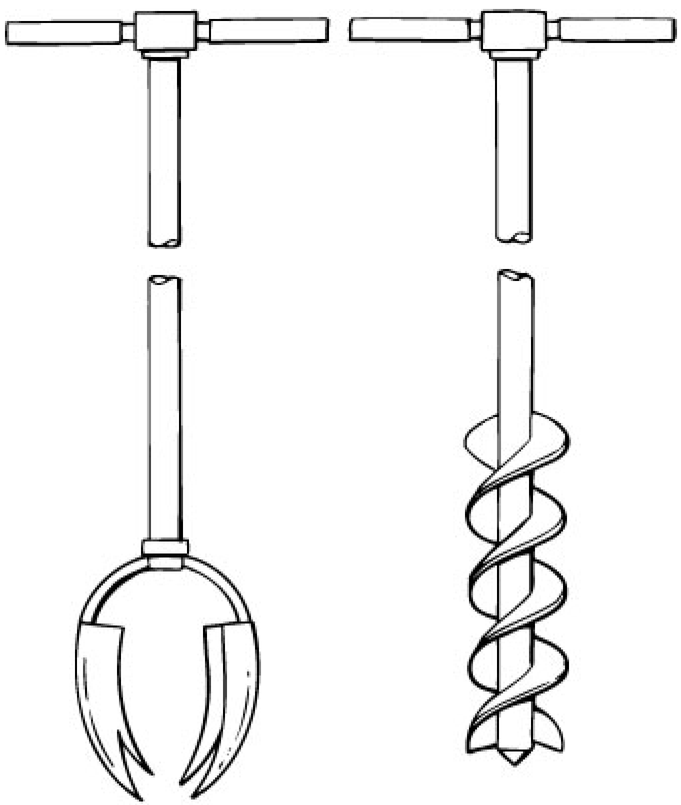
| Merits | Demerits |
|---|---|
| • Visual inspection of stratification | • Limited to a depth of about 3 m as the cost beyond this depth increases rapidly |
| • Suitable for best quality disturbed and undisturbed sampling. Bulk samples may also be recovered. | • Suitable for exploration only above GWT |
| • In-situ tests such as plate load test or in-place density test may be performed. | • Backfilling and compaction may be required |
| • Difficulties of excavating can be assessed. | • Limited to shallow exploration only. |

# DIRECT METHODS:

**3. Auger Borings:** Auger borings are very efficient soil exploration methods. These are made in cohesive soil or in non-cohesive soils above groundwater table. The soil samples so obtained by auger borings are badly disturbed. However, the auger may also be used for advancing the hole down to the point where undisturbed soil samples are to be taken. Different types of augers are used for auger boring as shown in fig. (helical auger, post-hole auger etc.). Hand-operated augers can be used to reach depth up to 20 ft. to 30 ft. For greater depths motor-driven auger can be used. The size of boring varies from 2 in. to 12 in.

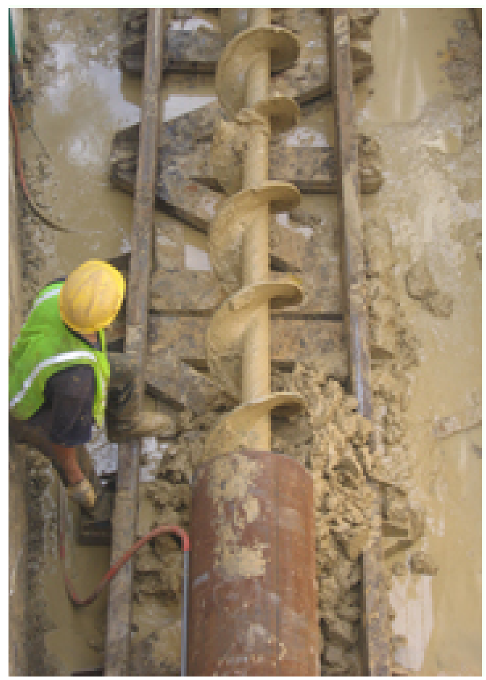
# Boring tools

Hand tools



posthole auger helical auger

Auger boring



Power drills

# Merits & Demerits of Auger Boring

| Merits | Demerits |
| --- | --- |
| • Hand augers are economical to advance holes upto about 10 m. For deeper depths, power augers may be used. | • Suitable only above GWT |
| • Quality disturbed or undisturbed samples can be recovered from the bottom of the bore using samplers | • Auger samples are badly mixed and may be utilized only for identification tests. |
| • Rapid means of advancing boreholes | • Only limited quantity of samples can be recovered. Bulk sampling in small size holes is not possible. From large diameter bore, however, bulk samples can be obtained |
| • Hollow stem augers are best suited to soils susceptible to caving-in problems. | • Boreholes caving in may cause problems and casing may be required or switch over to hollow stem auger. |

# DIRECT METHODS:

## 4. Percussion Boring

- Also known as cable tool drilling either manual or powered

- a. Light percussion (by labor)

- b. Heavy percussion (by machine)

## LIGHT PERCUSSION RIG (SOFT GROUND RIG, CABLE TOOL RIG, SHELL AND AUGER)

This is the main method of carrying out site investigation in the UK. It is used to drill holes in all soils and weak rocks. It is usually operated by a two man crew. The rig is towed by a cross country vehicle.

150 mm to 300 mm diameter boreholes can be drilled from 1 to 80m in soils though the most common depths are between 1 and 30m. It used in investigations for shallow and deep foundations in soils.

**Purpose**

The rig is used to create boreholes for in situ tests, take samples (disturbed and undisturbed) and install instruments.

**Equipment**

An A frame is erected over the borehole. A wire rope connected to a motorised winch passes over a pulley at the top of the A frame and is connected to a boring tool used to advance the hole.

Boring tools include shells (to retrieve clay soils and dry sands), balers (to remove water and wet soils), clay cutters (to remove clay) and chisels ( to drill through rocks and boulders)

**Operation**

The hole is advanced by repeatedly raising and dropping the boring tool. The tool is removed from the hole repeatedly to remove the soil. The boring tool penetrates the ground because of the weight of the tool and the drop height. Additional weights can be added in the form of sinker bars.

Casing is usually required in unstable soils and deep holes. It ensures hole stability, reduces friction between the tool and borehole sides and tends to keep the hole vertical. There must be sufficient clearance between the boring tool and casing to prevent suction developing below the boring tool.

# Merits & Demerits of Percussion Boring

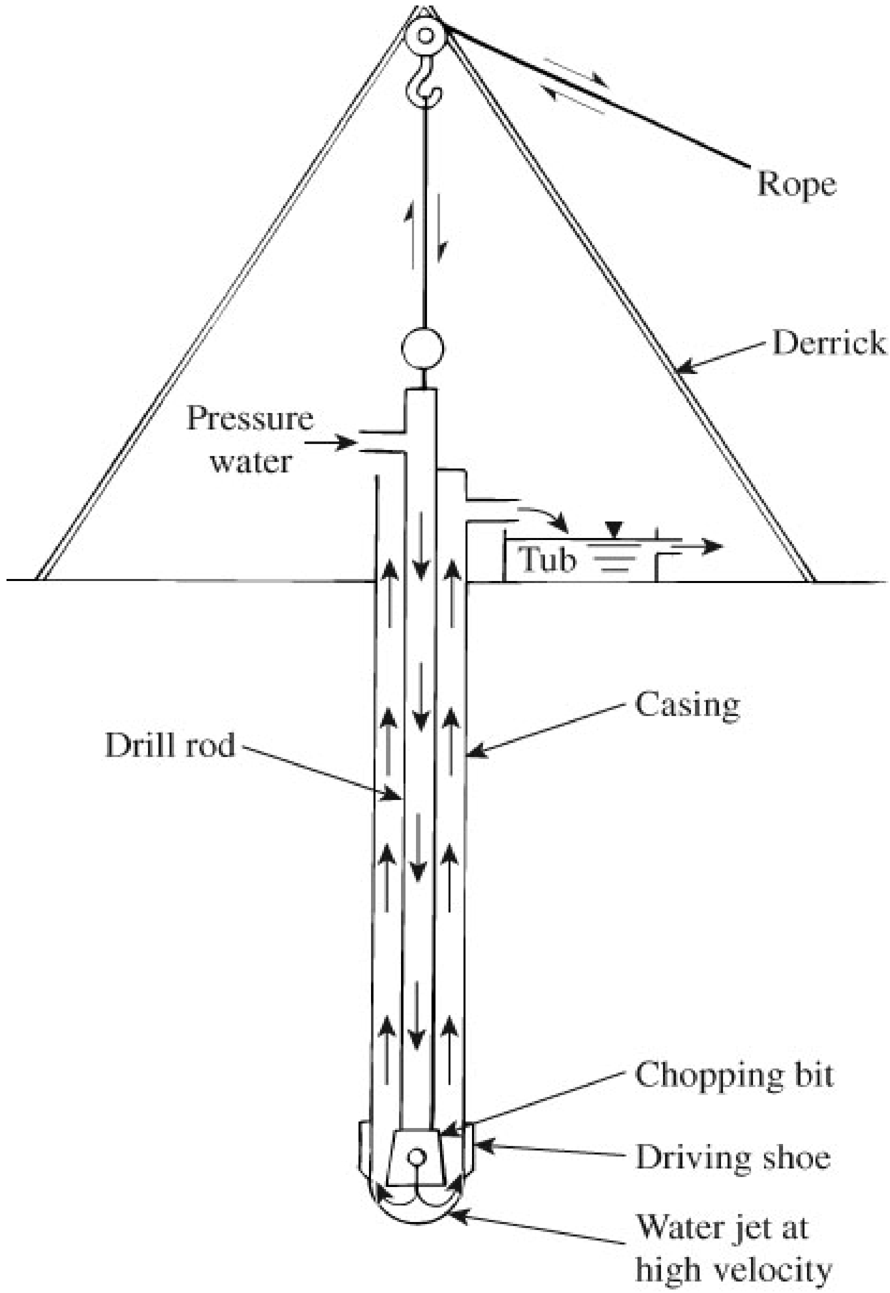
| Merits | Demerits |
| --- | --- |
| • Suits to a wide variety of soils | • Samples recovered are badly disturbed |
| • Faster in clayey soils and can be used both above and below GWT | • Soils below the bottom of the hole are also disturbed to an appreciable depth due to the impact of the falling bit or chisel |
| • Suitable and relatively faster for boulders/gravely formation | • Not suitable for loose sand formations. |

# DIRECT METHODS:

## 5. Wash Boring:

**Wash boring is one of the most common methods of advancing a hole into the ground. In this method a hole is started by driving a casing to a depth of 5 ft. to 10 ft. casing is simply a pipe, which supports the hole, preventing it from caving in. The casing is cleaned out by means of a chopping bit fastened to the lower end of the drilling rod, if water is pumped through the drilling rod and exists at high velocity through holes in the bit. The water rises between the casing and drill rod, carrying suspended soil particles, and overflows at the top of the casing through "T" connection into a container, from which the effluent is reticulated back through the drill rod. The hole is advanced by raising, rotating, and dropping the bit on to the soil at the bottom of the hole. Drill rods, and if necessary casing are added as the depth of the boring increases. This method is quite rapid for advancing holes in all soil except the very hard soil strata.**

# Wash Boring



Rope
Derrick
Pressure water
Tub
Drill rod
Casing
Chopping bit
Driving shoe
Water jet at high velocity

# Merits and Demerits of Wash Boring

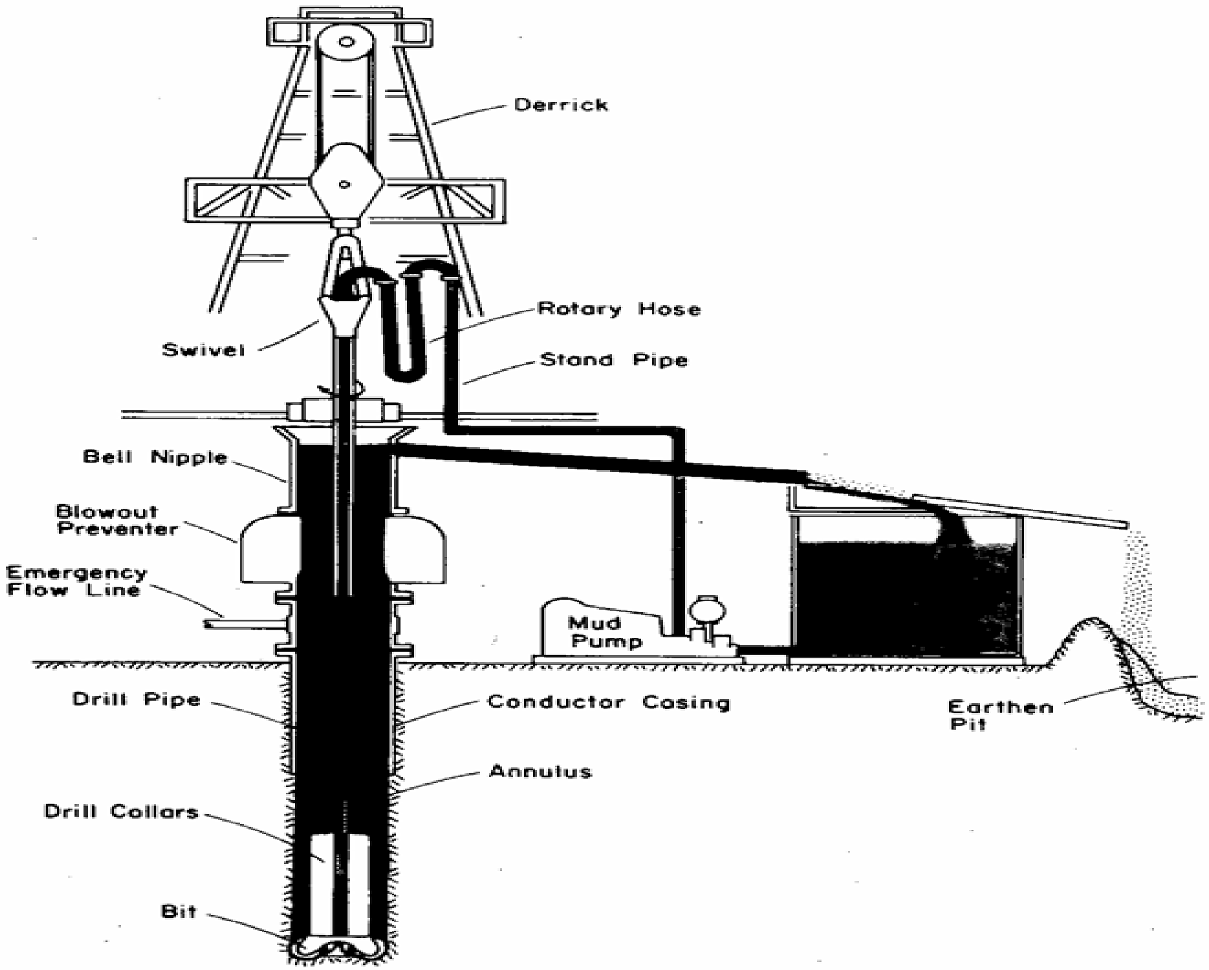
| Merits | Demerits |
|---|---|
| • The method is cheap and rapid for cohesionless soils | • For clays, boulders or gravels, and rock formations, the holes cannot be advanced using this method |
| • In cohesionless soils, the method offers minimum disturbance to soils | • Soil samples recovered from *wash boring* are badly disturbed and intermixed, often loosing the appreciable quantity of fines and as such are of no use even for identification purposes |
| • Boring can be advanced using this technique but dry sampling can be done at the bottom using samplers | • For collapsible soils, this method is not suitable |
| • Method can be used both above and below GWT | • For good results, a highly trained and experienced driller is required. |

# DIRECT METHODS:

## 6. ROTARY DRILL:

**Rotary drill is another method of advancing test holes. This method uses rotation of the drill bit with the simultaneous application of pressure to advance the hole. Rotary drilling is the most rapid method of advancing holes in the rock unless it is badly fissured; however, it can also be used for any other type of soil. If this is applied in soils when the sides of the hole tend to cave in, a drilling mud may be used. The drilling mud is usually a water solution of a thixotropic clay (Bentonite), with or without other admixtures, which is forced into the sides of the hole by the rotary drill. This provides sufficient strength to the soil so that it maintains the hole. The mud also tends to seal off the water flow into the hole from the permeable water bearing strata.**

# Schematic Sketch of Rotary Boring



# Merits & Demerits of Rotary Boring

| Merits | Demerits |
|---|---|
| • Most advanced drilling techniques suitable to a wide variety of soils and rock | • Relatively expensive and progress is slow in gravely stratum |
| • Suitable for rock coring | • When cavities are present fluid loss may cause difficulties in the progress and sometimes the bit is damaged. |
| • Casing may be avoided using drilling mud | • Highly trained and experienced driller is required. |

## General Considerations in Selecting Method of SI

- Two main considerations
- 1. Site Considerations

Related to site conditions

- 2. Subsurface ground considerations

Related to type of soil at the site

# 1. Site Considerations

- The topography, the nature of the ground surface, surface water, and the existence of buildings or other structures may cause problems of access to the location of boreholes, e.g.
- for soft ground, a light equipment can be used or access roads for heavy machinery will be required.
- On steep slopes, difficult to carry the heavy equipment.
- On sites that are obstructed by buildings or other structures either to demolish the walls or lift the equipment over the obstruction.
- Gaining access to site covered by water presents special problems.
- Certain methods of boring require a supply of water. There may be legal restriction on obtaining water or water may not be easily available.
- In build-up areas, seismic survey with explosives may be prohibited. Surface obstruction and buried services may interfere with other method.
- The electrical resistivity method is more difficult to apply in saline ground water condition or where there are buried metals.
- Difficulty in storage of spoil may restrict the use of pits and trenches.

# 2. Effect of Subsurface Ground Condition

- **(a) Non-Cohesive soils containing boulders, cobbles and gravels**
- Within the limit of cost, the best method of investigation of this type of ground is dry excavation i.e by

**shallow pits and deep pits**.

- If below GWT, dewatering will be required for dry excavation.

- **Advantages**: Good quality samples, field tools measure strength and deformation may be performed.

***For Boring***, there may be difficulty in advancing the borehole and obtaining samples of adequate quality.

- Boring can be advanced by light cable percussion with casing to stable the walls.
- Large pieces to be broken by chisel which often slow down the process.
- To reduce the use of chisel, larger size of boring equipment may be useful. 200 to 250 mm size for gravel and 300 mm to 450 mm in cobble, this may require the use of high-powered machines.
- In such ground, undisturbed samples are almost impossible. Only class 5 samples can be obtained.
- Gradation is disturbed by breaking action and washing out of fines.
- SPT with 60 degree cone replaced by the cutting shoe which give some indication of Dr.
- Due to cobbles and boulder, high strength may be estimated
- Borehole permeability may give reasonable indication of permeability and the results can also be used to give a guide to fine proportion in the soil.
- Dutch cone has limitation in this type of ground, static-dynamic may be useful but gravel and cobble may interface. PMT may be useful in such soil.

# 2. Effect of Subsurface Ground Condition

- **b) Sand:**
- Bore holes in sand are usually made by the light percussion, auger and wash boring.
- For dry conditions, water needs to be added in the borehole which affect the natural moisture content of the soil.
- Below GWT, some sand tends to blow up the boreholes. So loosening the ground below the bottom of the boreholes. K
- Keeping the borehole full of water and use of under size shell can reduce the tendency to blow but may not completely eliminate it.
- Class 5 samples may be obtained by shell as sample is deficient of fine due to water.
- However, SPT sampler can provide class 4 samples.
- Pitcher Samplers can be used to recover class 3 or 2 samples.
- SPT-N value can provide a fair indication of soil strength, density.
- PMT is useful in such soil.
- Under dry conditions, a more direct approach is PLT performed in the pits and trenches

# 2. Effect of Subsurface Ground Condition

- **Silt:**
- Silt is difficult material to sample, it is necessary to distinguish b/w fine silt and coarse silt approaching sand.
- Bore holes can be sunk, by auger (above w/t), percussion and wash boring below w/t.
- Due to low permeability, samples show usually representative moisture content.
- With the help of 100 mm open tube sampling equipment class 2 or 3 samples may be recovered.
- SPT can give indication of relative density.
- More reliable results for undrained strength can be obtained by Dutch cone, the vane Shear.

# 2. Effect of Subsurface Ground Condition

- **Clays:**

***For NCC***

- BH may be advanced by ***auger and light percussion technique***.
- DS may be obtained by auger cuttings of class 3 or 4.
- UDS may be obtained by thin walled and thick walled samplers, usually of class 1 or 2.
- Disturbance depends upon the sensitivity of clay to remoulding and depth of sampling.
- Sensitivity=qu(undisturbed/qu(remolded)
- St<2 not sensitive, St=2-4 low sensitivity, St= 4-8 medium sensitive,
- St=8-16 High sensitive, St>16 Quick clays
- Vane Shear tests for measuring undrained shear strength of soil.

***For OCC***

- BH may be advanced by ***auger and light percussion technique***.
- Samples are taken by thick wall samplers
- Firm to stiff ------------------------ Class 1
- Very Stiff to hard ------------------ class 2 or 3

Clay with Gravel or Cobbles,

- better is Open excavation.
- Boring with light percussion but frequent use of chisel and shell will be required.
- Boring with heavy percussion using large sized bailer or shell to avoid chiseling

# 2. Effect of Subsurface Ground Condition

- **Rocks.**
- Better is core drilling. Rotary core drilling with diamond or tungsten carbide bits are normally used in rocks.
- The use of periscope, cameras may identify the orientation of discontinuities.
- Water pressure or Lugeon test is performed at regular intervals to determine

  -Permeability of Rocks

  -Quality of rocks

  -To determine the grout intake.