SOIL INVESTIGATION

Introduction

- The soil is the most important yet most neglected in a construction project.
- All structures, buildings, roads, bridges, dams and even life itself is based on the soil.
- The soil is the natural foundation that supports all structures and investment.
- Most clients see soil investigation as a waste of fund despite being the cheapest in the construction process, hardly is the cost of soil test up to one percent of the cost of construction.
- Some contractors to ignore the importance of proper soil investigation and analysis and base their design on assumed bearing capacity and rate of settlement.
- Soil test helps to determine varying physical and chemical characteristic of soil, which can vary from place to place and from layer to layer even within the limits of the proposed structure.
- Soil characteristics can change considerably within a small area.

Purpose of Soil Investigation

- The soil investigation helps to determine the following:
- Bearing capacity of the soil which determine the load sustenance capability of the soil,
- Rate of settlement of the soil which affect the rate at which any structure placed on it settles,
- To select a type and depth of foundation,
- To select suitable construction technique ,
- To predict and resolve probable foundation problems,
- To determine if the land can be subjected to subsidence and cause sinking of the building,
- To determine water table which affects humidity within the foundation and greatly affects the character of a soil which varies considerably with water content, mineral or chemical component of the soil that might affect the choice of construction materials.
- For example if the soil found to contain sulphur it can attack our foundation, therefore sulphur resisting cement must be used in the foundation in such soil.

Steps involved in Soil Investigation

- Soil investigation involves following steps
- Details planning for the sequence of operations.
- Collecting the samples of soil from the plot.
- Determining the soil characteristics by conducting field tests.
- Study the condition of ground water level.
- Collecting ground water sample for chemical analysis.
- Soil exploration.
- Testing all collected samples in the laboratory.
- Analysis the test results.
- Preparing report.

Factors Affecting Soil Investigation

- The amount of existing information available,
- The known uniformity or likely variability of the sub-soil in the area,
- The foundation loading and the type of structure,
- The general topography and likely groundwater conditions of the site.
- Subsidiary factors such as the amount of time and money available,
- The site access and other matters should not inhibit the planning of a thorough (and as reliable as is reasonably possible) investigation.

Phases Involved in Soil Investigation

- Prior to construction of a structure, soil investigation is done in order to get the idea of subsurface condition.
- The scope of a soils investigation is generally depends on many factor, such as
- Type, size & importance of the structure.
- The client.
- Engineer's familiarity with the soils at site.
- Local building code.
- Economy
- The 5 phases involved in any soil investigation work are as follows

1. Desk study
2. Preliminary reconnaissance
3. Field Investigation
4. Laboratory test
5. Report writing

Phases Involved in Soil Investigation

- **Desk Study**
- This is the phase where all the information that are available, are collected. The information which needs to be collected are as follows
- Site plan
- Type, size & importance of the structure
- Loading conditions
- Previous geo-technical reports
- Topographical maps
- Still photographs etc.
- Above ground obstructions e.g., transmission lines.
- Below ground obstructions e.g., sewerage.
- Water supply, telephone lines, subways or tunnels, etc.

Phases Involved in Soil Investigation

- **Sources of information for desk study**
- Ordnance survey (Survey of Pakistan)
- Geological survey and soil surveys maps and memoirs (Geological Survey of Pakistan)
- Hydrographic department
- Meteorological Department
- Seismological Department
- Aerial Photograph

Phases Involved in Soil Investigation

- **Preliminary reconnaissance**
- In this phase a site visit is made to get a general idea of the topography and geology of the site. You need to take with you all the information gathered in phase-1 to compare with current conditions of the site. Make a note of everything while visiting the site. You must note down the following things
- **Preparation for Visit:**
- Site plan, district maps, geological maps and aerial photographs should be made available before moving to the site.
- Make sure that permission to gain access has been obtained from both owner and occupier.
- Site and Ground Information:
- Set out location of proposed work on plans and record any changes and omissions like boundaries, buildings, roads, and transmission, telephone, gas, water, sewer lines and also ancient monuments etc.

Phases Involved in Soil Investigation

- Check access including the probable effects of Construction traffic on existing roads, bridges and services.
- Check and note water levels, direction and flow rate in river and canals and also flood levels and tidal and other fluctuations where relevant, also record positions of wells, springs and sinkholes.
- Observe and record adjacent property, its performance history, such as cracks, noticeable sags, sticking doors and windows and chances of its being affected by the proposed works.

Phases Involved in Soil Investigation

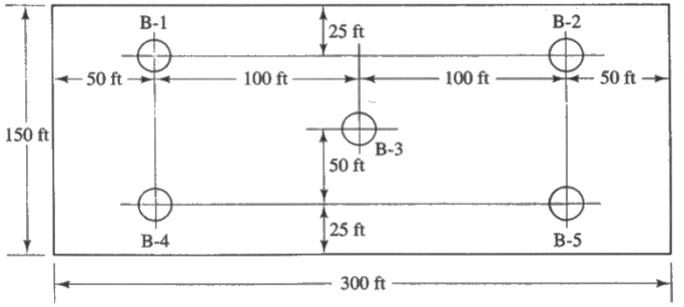
- **Field Investigation**
  - Preliminary Ground Investigation
  - Detailed Ground Investigation
- **Preliminary Ground Investigation**
- Few bores or test pits are made to know the subsoil, stratification, index and strength properties and the location of GWT.
- **SIGNIFICANCE :**
- For small projects this step may be final and sufficient to establish foundation criteria.
- For large extended sites, this step may be necessary for best planning for detailed investigation.

Phases Involved in Soil Investigation

- **Detailed Ground Investigation**
- Carried out for large projects or where the soil is of poor quality and/or non uniform soil.
- it verifies and expand information previously collected.
- **Laboratory Testing**
- The objectives of laboratory tests are
- To classify the soils
- To determine soil strength, failure stresses and strains, stress-strain response, permeability, compaction properties and settlement parameters.

Phases Involved in Soil Investigation

- **Report Writing**
- The report must contain a clear description of the soils at the site, methods of exploration, soil stratigraphy, in situ and laboratory test methods and results, and the location of the ground water, recommendation regarding construction operation.
- This includes
- The name of the client
- The site investigation
- The consultant firms
- The nature and purpose of investigation
- The name of project
- The time over which the work was carried out
- Method of Boring involved
- Result
- Borehole Layout



Methods of Investigation

- Soil Exploration methods may be divided in to following two groups, fro the point of view of the performance

1. Direct methods
2. Indirect Methods

- **Direct methods**
- In these methods soil samples are taken from the soil /rock strata by making actual excavation through Probing , Borings
- Sub soil characteristics are determined by field /laboratory testing performed on the samples recovered from site
- **Indirect methods**
- Theses methods establish boundaries between strata of different composition , by detecting changes in the electrical resistivity or wave velocity in the soil
- The indirect methods do not provide information regarding the characteristics of the sub soil and must be used in conjuction with direct methods

Methods of Investigation

- **Direct methods**

1. Test pits
2. Shafts and Adits
3. Displacement boring
4. Wash boring
5. Auger boring
6. Rotary drilling
7. Percussion drilling
8. Continuous sampling

- **Indirect methods**

1. SEISMIC Methods
2. High Resolution Reflection
3. Vibration
4. Electrical Methods (Resistivity)
5. Drop in Potential Methods

Methods of Investigation

- The methods to determine the sequence, thickness and lateral extent of t soil strata and, where appropriate the level of bedrock.
- The common methods include

1. Test pits
2. Shafts and Adits
3. Boring or drilling

- **Test Pits**
- Trial pits provide the best method of obtaining very detailed information on strength, stratification, pre-existing shear surfaces, and discontinuities in soil.
- Trial pits, trenches and shallow excavations are often used in site investigations, particularly during investigations for low- and medium-rise construction, because they provide an economical means of acquiring a very detailed record of the complex soil conditions which often exist near to the ground surface.
- Very high quality disturbed, undisturbed and block samples can only be taken from trial pits and the sides can be photographed for permanent record.

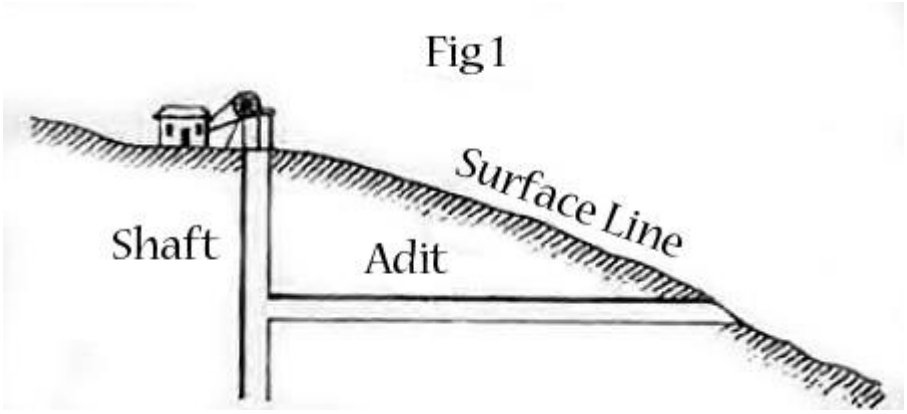
Methods of Investigation

- The excavation of test pits is a simple and reliable method.
- The depth is limited to 4-5m only.
- The in-situ conditions are examined visually
- It is easy to obtain disturbed and undisturbed samples
- Test pits permit a direct inspection of the soil strata in place, and taking of adequate disturbed and undisturbed soil samples.
- 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.

Methods of Investigation

- **Shafts and Adits**
- Shafts or deep pits and Adits or headings are very costly and their use is justified only in investigations for large projects, such as dams, if the ground conditions could not be ascertained adequately by other means.
- Shafts or headings are not usually excavated below the groundwater table.
- Shafts are usually advanced by hand excavation, the sides being supported by timbering.
- Headings or Adits are excavated laterally from the bottom of shafts or from the surface into hillsides, both the sides and roof being supported.

Fig 1



Methods of Investigation

- **Probing or Sounding**
- Probing is made by driving a steel rod of about 25 mm diameter in to the ground.
- The soil type and its properties are related to the driving resistance to the rod and from particles adhering to the rod when it is pulled out.
- Sometimes some small grooves are made along the rod to collect some traces of soils through which it passes during probing
- Merits
- Suitable to locate thickness of loose soil
- Relative cost is low
- May be used above or below GWT
- Demerit
- A boulder may be mistaken as for bedrock
- Nor suitable for rocks or soil with gravel and cobbles
- Suitable for depth about 10 to 20 m

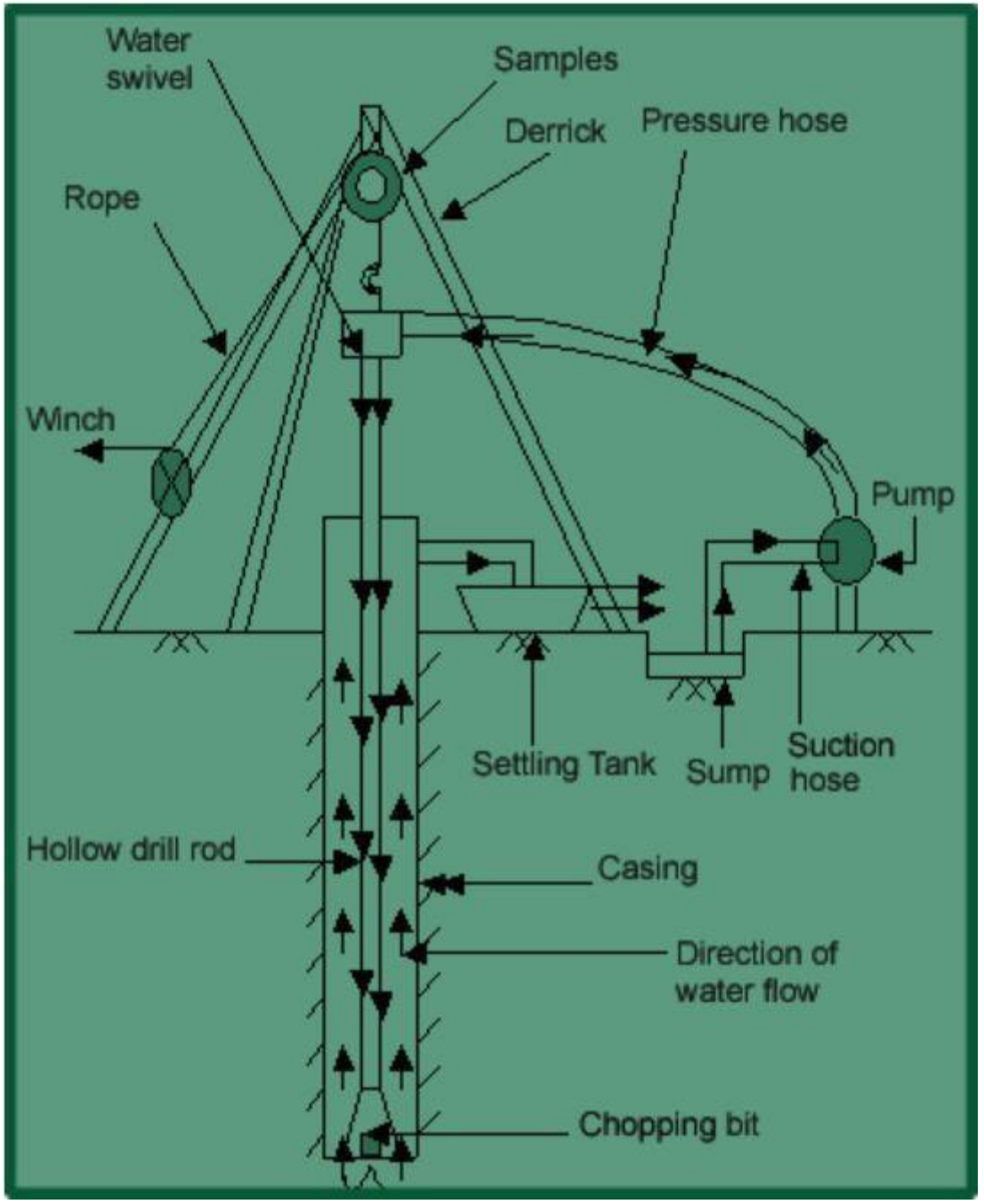
Methods of Investigation

- **BORING**
- Boring refers to advancing a hole in the ground.
- Boring is required for the following:
- 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.
- The different types of boring methods are:

1. Displacement boring
2. Wash boring
3. Auger boring
4. Rotary drilling
5. Percussion drilling
6. Continuous sampling

Methods of Investigation

- **Wash Boring**
- Water with high pressure pumped through hallow boring rods is released from narrow holes in a chisel attach to the lower end of the rods.
- The soil is loosened and broken by the water jet and the up-down moment of the chisel.
- The soil particles are carried in suspension to the surface between the rock and the borehole sites.
- The rods are raised and drop for chopping action of the chisel by means of winch.
- Wash boring can be used in most type of soil but the progress is slow in coarse gravel strata.
- The accurate identification of soil strata is difficult due to mixing of the material has they are carried to the surface.
- The method is unacceptable for obtaining soil samples.
- It is only used for advancing the borehole to enable tube sample to be taken are field test to be carried at the hole bottom.
- The advantage is that the soil immediately below the hole remains relatively un-disturbed



Wash Boring Rig

Wash Boring Rig

Methods of Investigation

- **Displacement Boring**
- It is combined method of sampling & boring operation. Closed bottom sampler, slit cup, or piston type is forced in to the ground up to the desired depth. Then the sampler is detached from soil below it, by rotating the piston, & finally the piston is released or withdrawn. The sampler is then again forced further down & sample is taken. After withdrawal of sampler & removal of sample from sampler, the sampler is kept in closed condition & again used for another depth.
- **Features**
- Simple and economic method if excessive caving does not occur. Therefore not suitable for loose sand.
- Major changes of soil character can be detected by means of penetration resistance.
- These are 25mm to 75mm holes.
- It requires fairly continuous sampling in stiff and dense soil, either to protect the sampler from damage or to avoid objectionably heavy construction pit.

Displacement Boring Sampler

Methods of Investigation

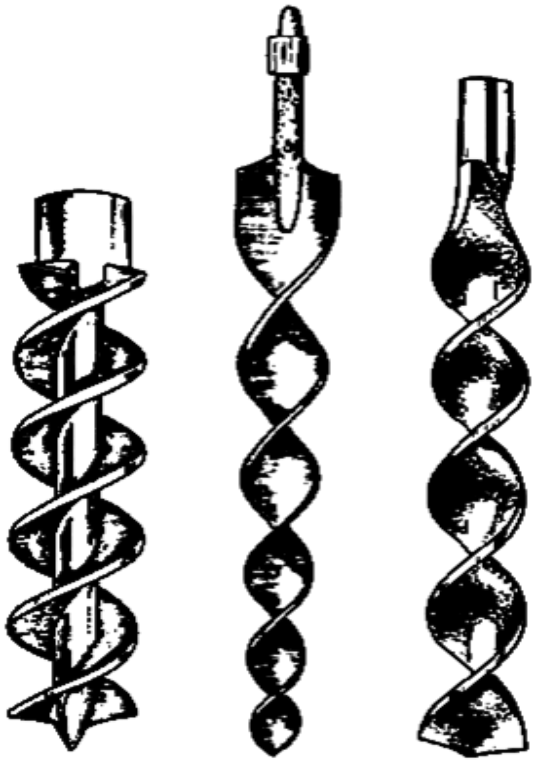
- **Auger Boring**
  - Hand Auger
  - Mechanical Auger
- **Hand Auger**
- It is the simplest method of boring used for small projects in soft cohesive soils.
- For hard soil and soil containing gravels boring with hand auger becomes difficult.
- Hand-auger holes can be made up to about 20m depth, although depth greater than about 8-10m is usually not practical.
- The length of the auger blade varies from 0.3-0.5m.
- 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.
- Repeated with drawl of auger for soil removal makes boring difficult below 8-10m depth.
- The soil samples collected in this manner are disturbed samples and can be used for classification test. Auger boring may not be possible in very soft clay or coarse sand because the hole tends to collapse when auger is removed

Hand Auger

Mechanical Auger

Methods of Investigation

- a. Helical (worm types) Augers
- b. Short flight Auger
- c. Ivan (posthole) Auger



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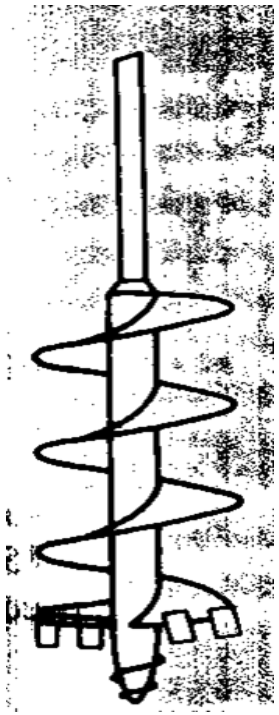

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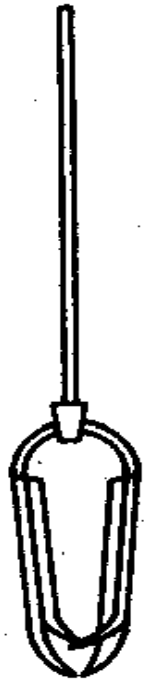
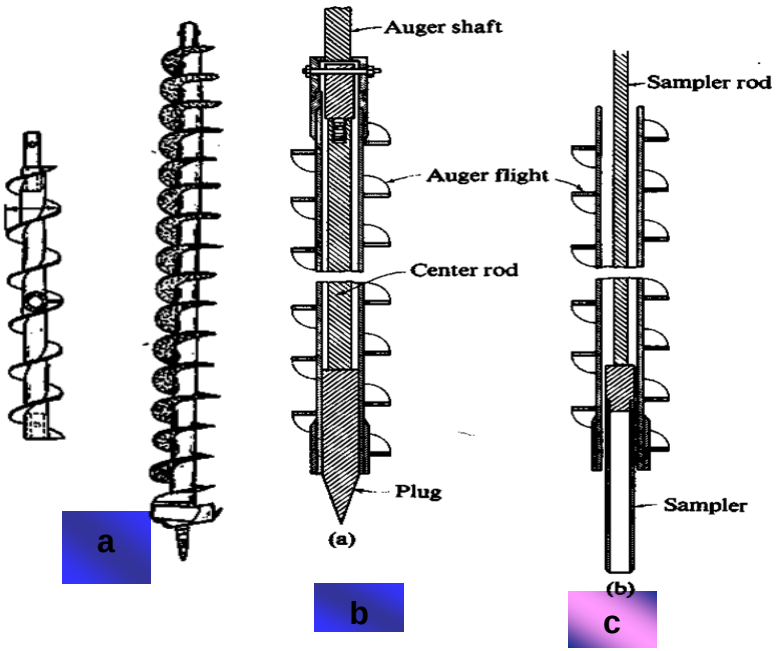


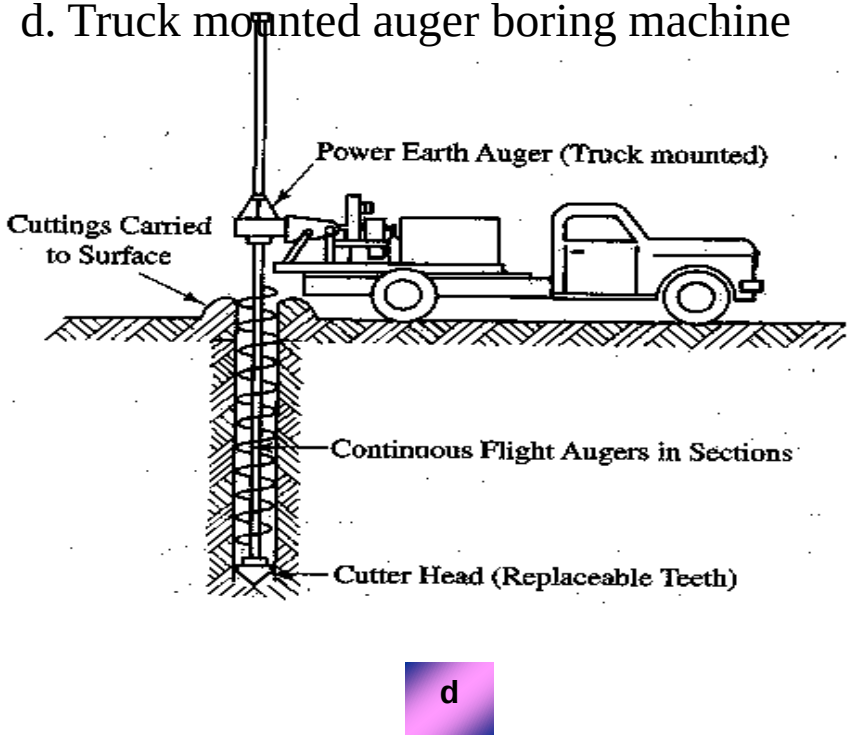
c

Methods of Investigation

- **Mechanical Auger**
- Mechanical Auger means power operated augers. The power required to rotate the auger depends on the type and size of auger and the type of soil.
- Downwards pressure can be applied hydraulically, mechanically or by dead weight

a. Continuous Flight Auger
b. Hallow-stem auger plugged during advancing bore
c. Plug removed and sampler inserted
d. Truck mounted auger boring machine





Methods of Investigation

- The diameter of the flight auger usually is between 75 to 300mm, althou diameters up to 1m and bucket augers up to2m are available.
- Borehole depths up to 50m are possible with continuous-flight augers.
- The most common method is to use continuous flight augers. Continuous flight augers can be solid stem or hollow stem with internal diameter of 75-150mm.
- Hollow stem augers are used when undisturbed samples are required. Plug is withdrawn and sampler is lowered down and driven in to the soil below the auger.
- If bed rock is reached drilling can also take place through the hollow stem.
- As the auger acts as a casing it can be used in sand below water table. The possibility of rising sand in to the stem by hydrostatic pressure can be avoided by filling the stem with water up to the water table
- The soil rises to the surface along the helical blades, obviating the necessity of withdrawal.

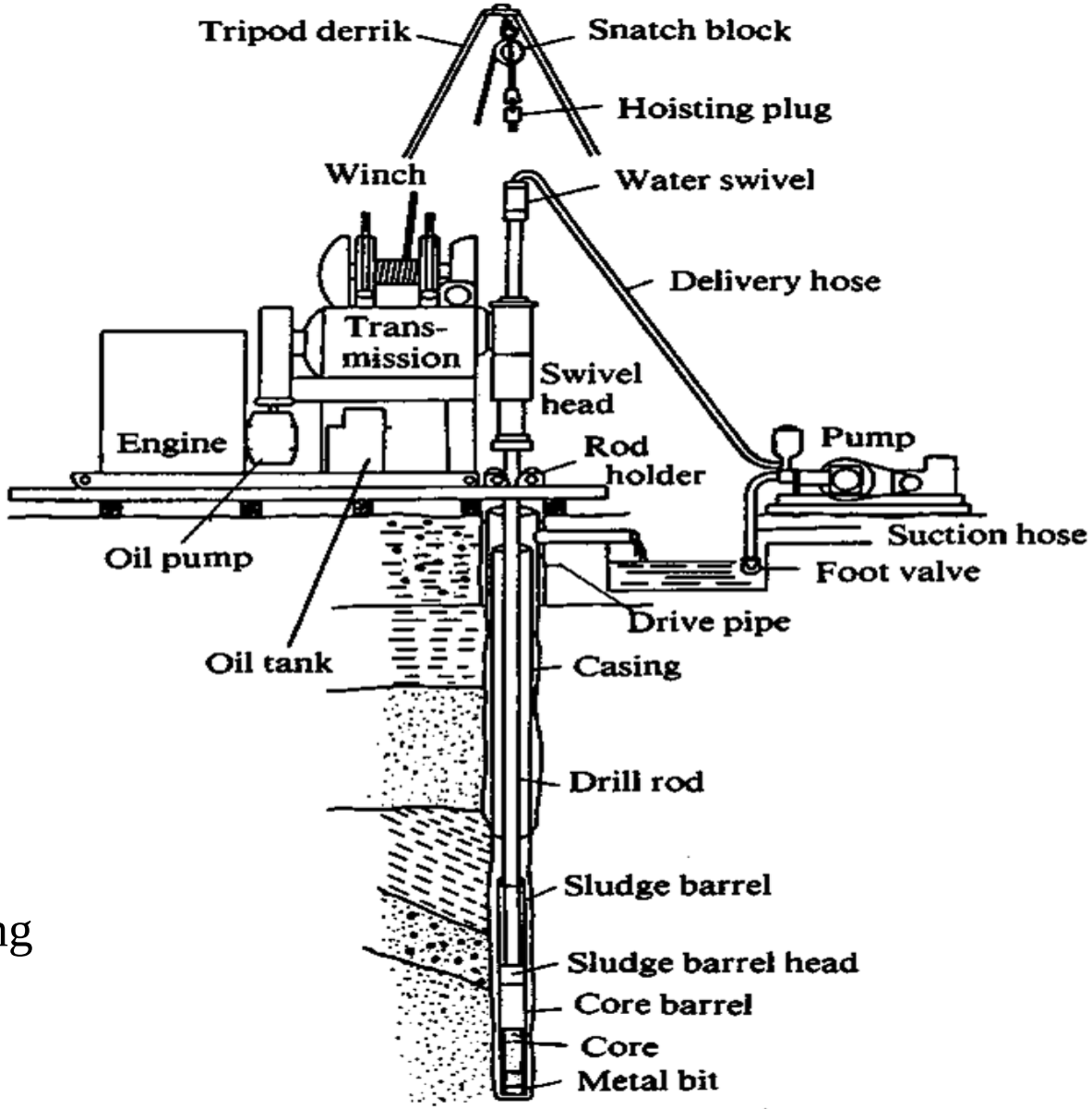
Methods of Investigation

- **ROTARY DRILLING**
- The rig consists of a derrick, power unit, winch, pump and a drill head to apply high-speed rotary drive and downward thrust to the drilling rods.
- Primarily intended for investigation in rock, but also used in soils.
- The drilling tool, (cutting bit or a coring bit) is attached to the lower end of hollow drilling rods
- The coring bit is fixed to the lower end of a core
- Water or drilling fluid is pumped down the hollow rods and passes under pressure through narrow holes in the bit or barrel
- The drilling fluid cools and lubricates the drilling tool and carries the loose debris to the surface between the rods and the side of the hole.
- The fluid (bentonite slurry) also provides some support to the sides of the hole if no casing is used
- There are two forms of rotary drilling, open-hole drilling and core drilling.

Methods of Investigation

- **Open- hole drilling,** which is generally used in soils and weak rock, ju 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.
- **In core drilling**, which is 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.
- **Advantages**
- The advantage of rotary drilling in soils is that progress is much faster than with other investigation methods 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

Methods of Investigation



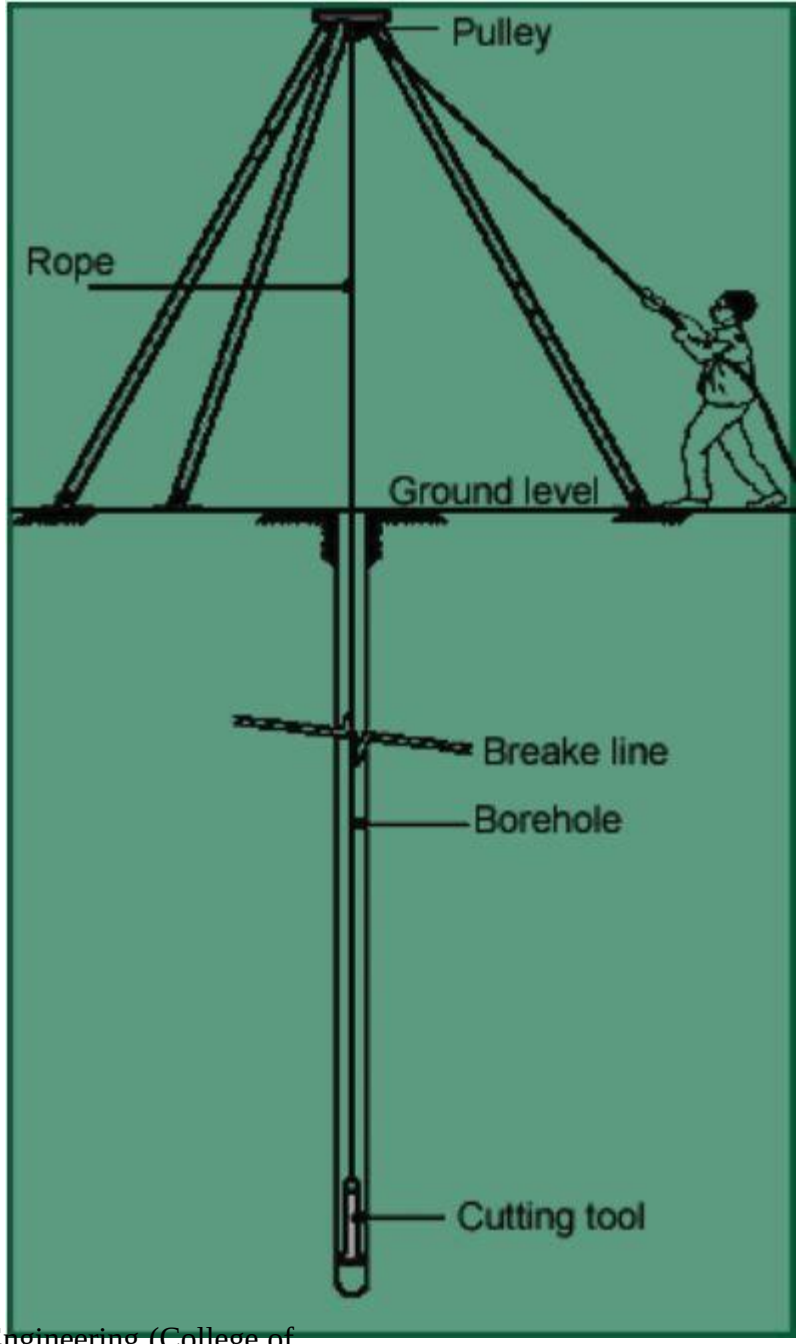
- Rotary Drilling

Methods of Investigation

- **Percussion Boring**
- In case of hard soils or soft rock, auger boring or wash boring cannot be employed.
- For such strata, percussion drilling is usually adopted.
- Here advancement of hole is done by alternatively lifting and dropping a heavy drilling bit which is attached to the lower end of the drilling bit which is attached to the cable.
- Addition of sand increases the cutting action of the drilling bit in clays.
- Whereas, when coarse cohesion less soil is encountered, clay might have to be added to increase the carrying capacity of slurry.
- In cohesion less soils casing must be used to prevent collapse borehole.
- The clay cutter, which is used in cohesive soils, is an open steel tube with a cutting shoe and a retaining ring at the lower end.
- The percussive action of the cutter cuts a plug of soil, which eventually fractures near its base due to the presence of the retaining ring.

Methods of Investigation

- When the cutter is full, it is raised to the surface to be emptied.
- Small boulders, cobbles and hard strata can be broken up by means of a chisel, aided by the additional weight of a sinker bar if necessary
- Borehole diameters can range from 150 to 300 mm.
- The maximum borehole depth is generally between 50 and 60 m
- **Limitations**
- However, there is generally some disturbance of the soil below the bottom of the borehole, from which samples are taken,
- It is extremely difficult to detect thin soil layers and minor geological features with this method.


Pulley
Rope
Ground level
Breake line
Borehole
Cutting tool

Methods of Investigation

- **Continuous sampling**
- The sampling operation advances the borehole and the boring is accomplished entirely by taking samples continuously.
- The casing is used to prevent the caving in soils. It provides more reliable and detail information on soil condition than the other methods.
- Therefore it is used extensively in detailed and special foundation exploration for important structures. It is slower method and more expensive than intermittent sampling.
- When modern rotary drilling rigs or power driven augers are not available, continuous sampling may be used to advantage for advancing larger diameter borings in stiff and tough strata of clay and mixed soil.

Methods of Investigation

- **Core drilling**
- Cored boreholes are generally 70-200mm in diameter.
- Cores are undisturbed samples of the ground. "Undisturbed" means they are representative of ground conditions in situ.
- Core logs give a cross section of ground lithology (The lithology is a description of its physical characteristics visible at outcrop, in hand or core samples).
- Cores are carefully packed and sent to the laboratory to investigate their physical properties (density,, moisture content, Atterberg limits, etc.), mechanical characteristics (unconfined crushing and triaxial strength, consolidation, etc.) and chemistry (mineral or organic composition).
- The number of cored boreholes that can be drilled at a site is limited because drilling is slow and costly.
- It is usually attractive to supplement them with quicker uncored boreholes and record the drilling parameters (penetration rate, torque, down pull, water losses, etc.).

Core Drilling

Methods of Investigation

- **Boring report:**

A boring report should contain:

1. Location plan of the project.
2. Location plan borings.
3. Description of borings
4. Surface drainage conditions.
5. Probable source of free water,
6. Groundwater conditions,
7. Goring log drawn to scale,
8. Information on difficulties met with during exploration.
9. Soil identification and classification tests results.

Soil Sampling

- A sample is said to be representative sample when it truly represents the characteristics of the stratum from which it is recovered
- There are two types of samples
- **Disturbed Samples**
- A samples is said to be disturbed when its natural conditions such as structure , texture, density, natural water content and stress conditions are disturbed during recovery .
- Disturbed sample can be recovered by using shovel, from auger cuttings etc.
- These samples used for identification/classification tests and chemical analysis
- **Undisturbed Samples**
- A sample that is taken without disturbing the structure, texture, moisture content and density of soil is termed as Undisturbed sample
- UDS is used to determine shear strength, compressibility and permeability characteristics of soil

Sampling Procedure

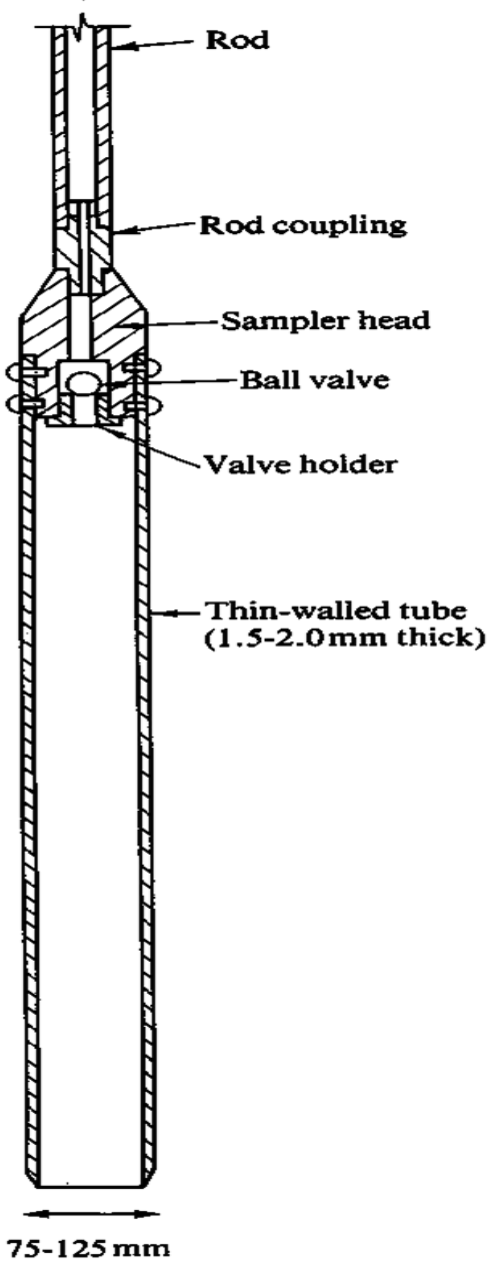
- The piston is secured at the bottom of the tube by a locking mechanis before lowering the sampler to the bottom of the drill hole
- When the sampler reaches the sampling depth, the piston is unlocked. Unlocking is achieved by rotating the drill rod clockwise 90 degrees.
- The thin-walled sampler permits easy and accurate determination of the total recovery ratio, and its piston acts in reducing pressure over the sample during withdrawal.
- Therefore, the thin-walled sampler with a free piston takes better samples than the thin-walled open-drive sampler.
- The operation of the sampler with the free piston is simpler than that of the other types of piston samplers and is nearly as easy as that of a thin-walled, open-drive sampler.

Thin-walled, Open-drive Sampler

- It is one of the simplest sampling devices.
- It consists of cold-drawn seamless steel, brass, or stainless steel tubing attached to a sampler head that contains a ball check valve and vents.
- Air and drilling mud in the tube can escape through the vents during lowering of the tube into the hole and during penetration.
- The ball check valve prevents entrance of air and drilling mud during withdrawal, and assists in creating a partial vacuum above the soil, which aids in retaining the sample in the tube
- The length of the sampling tube is variable, but is commonly about 1 m long.
- The- outside diameter of the tube is normally between 75 mm (3 in.) and 125mm (5 in).
- The lower end of the tube is sharpened to form a cutting edge.

Thin-walled, Open-drive Sampler

- The thin-walled open-drive sampler is applicable to all cohesive so unless they are too hard, cemented, or too gravelly for sampler penetration
- **Limitation**
- The sampler may be partially filled during uncontrolled lowering (by shaving the wall of the borehole and/or by penetrating soft/loose sediments on the bottom), and packing of the sampler may occur.
- The vacuum created by the ball check valve is not always enough to retain the sample. If the valve becomes ineffective due to clogging by soil particles and/or defects (e.g. scratches on the ball, etc.), the result is a frequent loss of the sample during withdrawal. Therefore, this sampler is not recommended for detailed investigations of soft cohesive soils.



Thin-walled, Open-drive Sampler

THANK YOU!