1.2 Method of soil exploration: Methods of drilling bore holes for subsurface investigations:

The following are the various methods used in soil exploration:

1. Test Pits or Trial Pits (for Shallow Depths)
2. Auger Boring (for Shallow or Large Depths).
3. Wash Boring.
4. Percussion Drilling.
5. Rotary Boring.

1. Tests Pits:

Trial pits are a simple and economical method of soil exploration to shallow depths. In this method of exploration, a square pit is excavated and soil samples are collected at required depths.

Method of Excavation:

Pits can be excavated manually with crowbars by local labor. Small tractor-mounted mechanical excavators can also be used, if locally available, which makes the exploration faster and economical.

Size of Pits:

The size of the excavation depends primarily on the space required for efficient excavation and sample collection and on economic limits. Test pits normally are square or circular in plan, of size 1.2-3 m. Test trenches usually are 1-2 m wide and may be extended to any length, as required, to reveal soil conditions along a specific line.

In general, test trenches are relatively shallow, whereas test pits may be deep. It is common to limit even test pit depths to a minimum, as the cost increases with depth. Deeper excavations are justified in countries where labor is inexpensive.

Stabilizing Side Walls:

Excavations to depths of approximately 1.5 m often do not require lateral support to side walls. Shallow test pits can be stabilized more economically by sloping the side walls. Deeper excavations are generally more economical if sheeted.

Excavation for test pits below GWT requires proper dewatering arrangements to ensure stability of the side-walls, to prevent the bottom of the pit from heaving, and to keep the test pit dry to facilitate collection of undis-turbed soil sample.

Collection of Soil Samples:

After excavating the test pit up to the required depth, the soil sample can be collected from the bottom of the test pit. An undisturbed soil sample is collected by driving the thin-wall soil sampler into the bottom of the test pit. This is done by placing the sampling tube vertically on the bottom of the test pit, after making the surface level and horizontal.

A flat metal plate is placed on the top of the sampler and the sampler is driven by smooth blows of a hammer on the flat plate up to the required depth. The soil surrounding the sampler outside is removed and then the sampling tube, along with the soil inside, is carefully lifted from the ground.

Any loose soil on both ends of the sampling tube is removed and the surfaces are made level. Molten wax is poured on the surface of the soil in the sampling tube on either ends to prevent evaporation of water from the soil sample. The sampling tube is properly labeled with sample number, depth, test pit number, and project or site number. The sample is then carefully transported to the laboratory for testing.

After collecting the undisturbed soil sample, the loose soil at the bottom of the pit is taken in sufficient quantity and collected into a bag. The bag is properly labeled and transported to the laboratory along with other samples.

Advantages of Test Pits:

Following are the advantages of test pits:

i. The method is simple and fast.

ii. Test pits are one of the most economical means of soil exploration to shallow depths.

iii. Undisturbed samples can be collected with minimum disturbance.

iv. It is possible to directly observe the soil profile and its variation in the vertical or lateral direction by observing the walls of the test pit.

v. The presence of any lenses or pockets of weaker material can be readily identified.

vi. Test pits are particularly valuable in investigating the nature of fill material, where voids, loosely deposited layers, or deleterious material can be readily recognized.

vii. Test pits or trenches are the only reliable means of obtaining adequate information on a filled ground or very variable natural deposits.

Method # 2. Auger Boring:

Auger boring is a cheap and simple means of soil exploration.

Method:

In auger boring, vertical holes are advanced by rotating the cross arm of the auger and pushing the auger into the ground. When the auger is filled with the soil, it is withdrawn. The soil is removed from the auger and examined. The auger is then inserted into the borehole, pushed into the bottom soil by rotation of the cross arm, and the process is repeated.

Helical augers, when used with casing, facilitate collection of undisturbed soil samples by fixing the sampler to the bottom of the drill rod. Field tests such as SPT may also be done by attaching the standard spilt-spoon sampler to the bottom of the drill rod after removing the helical screw.

Types of Augers:

Following are the two types of augers:

i. Spiral or helical augers.

ii. Post-hole augers.

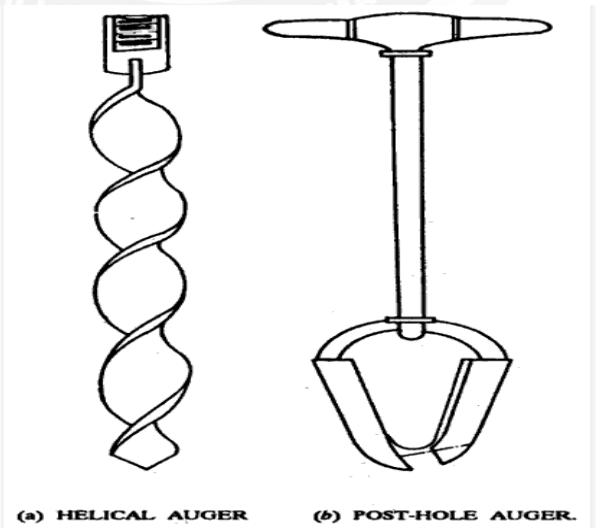

Fig1 Auger Boring

[Fig1http://www.abuildersengineer.com/2012/10/boring-methods-siteexploration .html]

Augers may be operated manually by labor or may be power driven. Hand augers (generally post-hole type) are usually suitable for depths up to 5-7 m in soft-to-firm

clays or sands with some cohesion. Mechanical augers are suitable for depths up to 12 m and additional rods may be used for extension to greater depths.

Suitability:

Augers are suitable under the following conditions:

i. Auger boring is generally suitable in soils where the walls of the borehole can stand without casing or stabilization with a drilling fluid above the GWT.

ii. Augers are found to be particularly suitable for highway, railway, or airfield projects, where low cost, rapid drilling, and high mobility of the equipment make them ideally suited for such projects.

Disadvantages:

Following are the disadvantages of auger boring:

i. The main disadvantage with auger boring is that the samples are highly disturbed and mixed.

ii. Work may be held up and auger boring is not suitable if large cobbles, boulders, or other obstructions are present at any depth.

iii. It is generally difficult, if not impossible, to locate the exact changes in the soil strata.

Method # 3. Wash Boring:

Wash boring is one of the most commonly used economical method for advancing boreholes in medium soft-to-firm clays and dense sands for soil exploration.

Procedure:

The wash boring method of soil exploration is done in the following steps:

i. A casing is first driven into the ground to a depth of 1.5-3 m. A hollow drill rod, with a chisel-shaped chopping bit at its bottom, is inserted inside the casing.

ii. Water is pumped down into the drill rod that emerges as a strong jet through the small openings of the bit at the bottom of the drill rod.

iii. The jet disintegrates the soil in the borehole and carries the broken fragments upward through the annular space between the casing and the drill rod.

iv. This return water, carrying soil fragments, known as cuttings, is collected in a sump tank through a T-shaped pipe fixed at the top of the casing.

v. The hole is further advanced by alternately raising and dropping the chopping bit by a winch. The drill rod is supported through a swivel joint, wire rope, and a pulley by a triangular or equivalent frame. The swivel joint facilitates turning of the drill rod.

vi. The process of raising, dropping, and turning of the drill rod is continued even below the bottom of the casing until the borehole begins to collapse.

vii. At this stage, the casing is further driven into the borehole and extended at the top by providing additional pieces.

viii. Soil samples can be collected by attaching soil samplers to the bottom of the drill rod, after removing the chop-ping bit. The soil sampler is pushed into the bottom of the borehole vertically after cleaning and then withdrawn. The undisturbed soil sample is brought along with the soil sampler.

ix. Bentonite slurry (5% bentonite mixed in water as solution) may be generally used instead of water as the drilling fluid, which stabilizes the walls of the borehole.

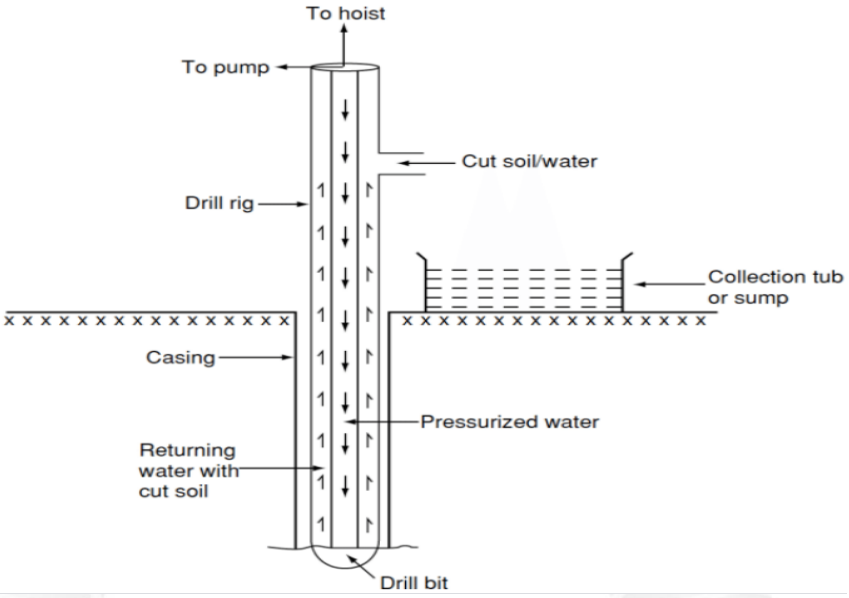

Fig 2 Wash Boring

[*Fig2*https://www.researchgate.net/figure/Schematic-diagram-of-a-wash-boring-drill-rig-after-Gunaratne-2006_fig5_323256947]

Changes in the soil profile are indicated by:

i. The rate of progress of drilling.

ii. Color of the drilling fluid.

iii. Examination of the soil cuttings.

Applicability:

The soil cuttings are not representative of the soil in situ, due to breakdown of particles, loss of fines during trans-port to ground level, and segregation in the sump tank. However, the wash boring method today is primarily useful as a means of advancing a borehole in the interval between the collections of soil samples at different levels in the borehole.

Advantages:

Following are the advantages of wash boring method of soil exploration:

i. Wash boring method is one of the simplest and fastest methods of soil exploration in soft- to medium-stiff cohesive soils and in sand or gravels without boulders.

ii. The equipment used for this method is light and inexpensive.

iii. It can also be adopted in inaccessible locations, such as on water, in swamps, or in between buildings.

iv. Undisturbed soil sampling or field testing, such as SPT or vane shear test, can be readily done in this method.

Disadvantages:

Some of the disadvantages of wash boring are:

i. The method is slow in the stiffer and coarse-grained soils and is not efficient in materials such as hard or cemented soils, rock, and soils that contain boulders.

ii. The method is not suitable for collecting undisturbed soil samples above GWT since the drilling fluid enters the soil mass and may increase its water content.

Method # 4. Percussion Drilling:

The percussion drilling method of advancing boreholes is of common use in drilling water wells; it is also known as cable tool drilling or churn drilling.

Method of Drilling Borehole:

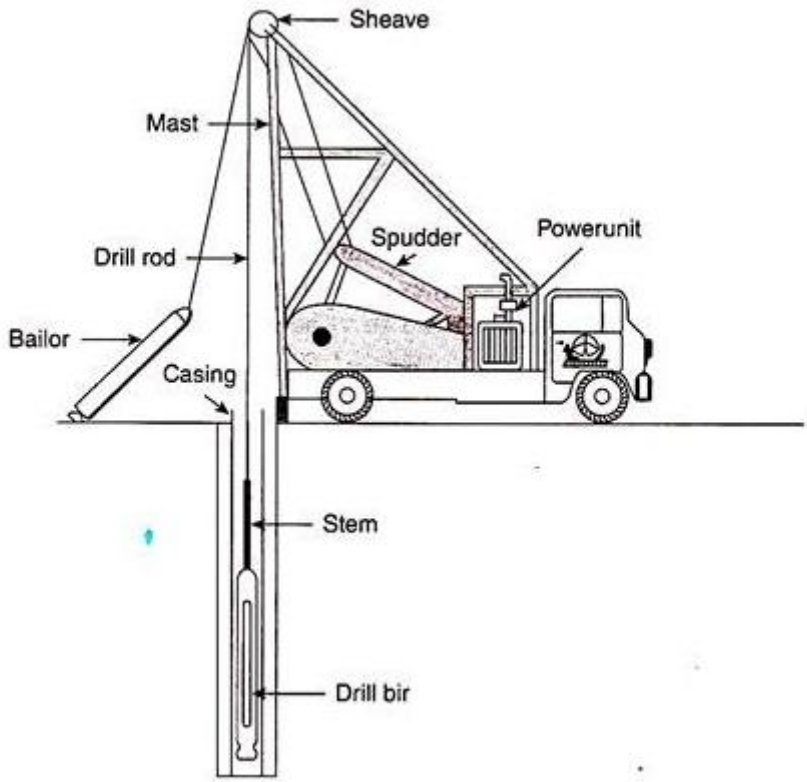

Fig 3 Percussion Boring

[Figure3https://www.soilmanagementindia.com/soil-exploration/top-5-methods-used-in-soil-exploration-soil-engineering/13877]

Figure3shows the schematic diagram of percussion drilling equipment.

Advance of the borehole in this method is made by the following procedure:

i. Alternately raising and dropping a combination of heavy drilling tools to break down the material at the bottom and to form slurry of the material.

ii. The combination of drilling tools consists of a drill rod with a chisel-shaped chopping bit at its lower end. The chopping bit has beveled edges for cutting the material at the bottom of the borehole.

iii. Periodically removing the slurry using bailers.

iv. The amount of water introduced into the hole in this method is kept to the minimum required to form the slurry. In soft soils and cohesionless material below GWT, no water is generally used in this method.

v. Changes in the soil profile are indicated by the rate of progress of drilling, color of the slurry, and examination of the contents of the slurry.

Removal of Soil Slurry:

Bailers or sand pumps are used for removal of the slurry from the bottom of the borehole. A bailer consists of a pipe having a one-way valve at its lower end and a bail at its upper end. When the bailer is pushed into the bottom of the borehole, the valve opens and the slurry enters the bailer. When the bailer is lifted, the valve closes and the slurry is retained in the bailer.

The process is repeated several times to collect the entire slurry into the bailer. The bailer is then lifted to ground level and tipped upside down to remove the slurry from the bailer. There are two types of bailers.

They are:

i. Flat-valve bailer.

ii. Dart-valve bailer.

The flat-valve bailer requires more time for emptying than the dart-valve bailer. A sand pump is costlier than a bailer. The dart-valve bailer is, therefore, more commonly used than the other.

Advantages:

Main advantages of using percussion drilling are as follows:

i. The main advantage of percussion drilling is that it can be used in all types of soil or rock and particularly useful for soils containing boulders and rock.

ii. It may also be useful to probe cavities and weakness in rock, by observing changes in the drill rate.

Disadvantages:

The disadvantages of percussion drilling are as follows:

i. The main disadvantage of percussion drilling is that the blows of the chisel disturb the soil at the bottom of the borehole heavily.

ii. It is also not economical for boreholes of diameter less than 100 mm.

iii. It is difficult to trace thin layers or slight changes in soil strata when this method is used.

Metho5. Rotary Boring or Drilling:

Rotary boring or drilling is a very fast method of advancing holes in rocks and soils.

Method of Drilling Borehole:

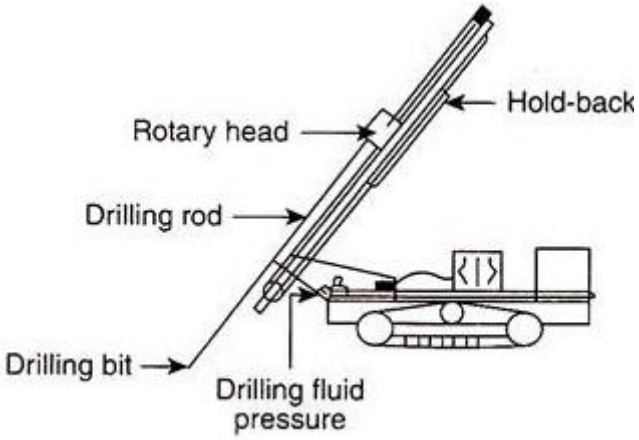

Fig 4 Rotary boring

[Figure4https://www.soilmanagementindia.com/wp-content/uploads/2018/02/clip_image004-40.jpg]

Figure 4shows the schematic diagram of rotary boring equipment. In this method, the borehole is advanced by rotating a hollow drill rod, which has a cutting bit at its lower end. The drill rod is rotated by a drill head, provided at the top of the drill rod. The drill head consists of a rotary drive mechanism and an arrangement for applying downward pressure.

As the drill rod is rotated, the cutting bit shears of chips of the material penetrated. A drilling mud, usually a water solution of bentonite with or without other admixtures, is continuously forced down the hollow drill rod.

The drilling fluid serves the following three functions:

i. It carries the cuttings of the material penetrated from the bottom of the borehole to the ground surface, through the annular space between the drill rod and the walls of the borehole.

ii. It also cools the cutting bit.

iii. It supports the walls of the borehole in uncased boreholes. Casing is usually not required except near ground surface.

Sample Collection:

When sampling is required, the drill rod is raised and the cutting bit is replaced by a soil sampler. When the rotary boring is done through rock and when it is required to collect rock core samples, a coring bit is used at the bottom of the drill rod, instead of the cutting bit.

The coring bit cuts an annular hole around an intact core that enters the barrel and is recovered. Thus, the core barrel is used primarily in bedrock, which is usually cored continuously up to the required depth.

Types of Rotary Boring:

There are following two methods of rotary boring:

i. Straight rotary method.

ii. Reverse rotary method.

In the reverse rotary method, the drilling fluid is supplied through the annular space between the drill rod and walls of the bore-hole, while the soil cuttings are collected through the central hollow portion of the drill rod. The reverse rotary method is best suited to holes 30 cm and larger in diameter.

Advantages:

Rotary boring is superior to all other methods of soil exploration.

Following are the advantages:

i. It is more rapid, in general, than the other methods of boring.

ii. It also causes less disturbance to the soil during sampling. Due to this reason, its applications are increasing day by day.

Disadvantages:

Following are the disadvantages of rotary boring:

i. The equipment is bulky and expensive.

ii. The method is not suitable for inaccessible locations.

iii. If the soil contains large gravel, it will rotate beneath the drill bits and cannot be easily broken. Thus, a nest of gravel will continually remain at the bottom of the borehole, preventing or delaying the progress of advancing the borehole.