30.1 Introduction

The field and laboratory investigations required to obtain the necessary data of soils for proper design and successful construction of any structure are called soil exploration. The choice of the appropriate foundation and its depth depend on the bearing capacity, settlement of the foundation soil under the working loads. The bearing capacity and settlement depend on the various engineering properties of the foundation soils. The main objectives of the soil exploration are: determination of the nature of the soil deposits, depth and thickness of the different soil strata, location of the ground water table, collection of soil and rock samples for testing, determination of engineering properties of the soil and rock strata by laboratory or field tests that affect the performance of the structure placed on it. The soil index properties (like water content, Atterberg limits, etc.) and strength & compressibility characteristics (like cohesion, angle of internal friction, coefficient of consolidation, compression index) are very important parameters those are to be determined by testing. In the first stage of soil exploration, the aerial photographs, topographical maps, existing site investigation report (for nearby sites) are to be collected.

30.2 Different Methods

The methods available for soil exploration are:

1. Direct methods (like Test pits,trial pits or trenches)
2. Semi-direct methods (like Borings)
3. Indirect methods (like penetration test and geophysical methods)

30.2.1. Direct Methods

Test pits or trenches are open type or accessible exploratory methods where soils can be inspected in their natural condition. The necessary soils samples may be obtained by sampling techniques. The obtained soil samples can be used for finding strength and other engineering properties through laboratory tests. Test pits are considered suitable only for small depths - up to 3m. The cost of the soil exploration increases rapidly with depth. For greater depths, lateral supports or bracing of the excavations will be necessary. Test pits are usually made only for supplementing other methods or for minor structures.

30.2.2. Semi Direct Methods-Boring

Making or drilling bore holes into the ground for obtaining soil or rock samples from specific depths is called boring. The different types of borings are:

(i) Auger boring

(ii) Wash boring

(iii) Rotary drilling

(iv) Percussion drilling

The auger is useful for advancing a bore hole into the ground. It may be hand-operated or power-driven. The hand-driven augers are used for relatively small depths (less than 3 to 5 m), while the power-driven augers are used for greater depths (upto 60 to 70 m). The soil auger is advanced by rotating it while pressing it into the soil. As soon as the auger gets filled with soil, it is taken out and the soil sample collected. The soil samples obtained from this type of borings are highly disturbed. The Augur boring is suitable

for partially saturated sands, silts and medium to stiff cohesive soils.Wash boring is commonly used for exploration below ground water table for which the auger method is not suitable. This method may be used in all kinds of soils except those mixed with gravel and boulders. A casing pipe is pushed in and driven with a drop weight. A hollow drill bit is screwed to a hollow drill rod connected to a rope passing over a pulley and supported by a tripod. Water jet under pressure is forced through the rod and the bit into the hole. This loosens the soil at the lower end and forces the soil-water suspension upwards along the annular surface between the rod and the side of the hole. This suspension is led to a settling tank where the soil particles settle while the water overflows into a sump. The water collected in the sump is used for circulation again. The soil particles collected are very disturbed sample and is not very useful for the evaluation of the engineering properties. Wash borings are primarily used for advancing bore holes; whenever a soil sample is required, the chopping bit is to be replaced by a sampler. The change of the rate of progress and change of color of wash water indicate changes in soil strata.

Rotary drilling can be used in sand, clay and rocks. A drill bit, fixed to the lower end of a drill rod, is rotated by power while being kept in firm contact with the hole. Drilling fluid or bentonite slurry is forced under pressure through the drill rod and it comes up bringing the cuttings to the surface. Even rock cores may be obtained by using suitable diamond drill bits. When soil samples are required, the drilling rod is raised and drilling bit is replaced by a sampler.

In case of Percussion drilling, a heavy drill bit is suspended from a drill rod or a cable and is driven by repeated blows. The water is added to facilitate the breaking of stiff soil or rock. The slurry of the pulverized material is bailed out at intervals. The method cannot be used in loose sand and is slow in plastic clay. The formation gets badly disturbed by impact.

The soil samples taken out of natural deposits for testing may be classified as:

(i) Disturbed sample

(ii) Undisturbed sample

A disturbed sample is that in which the natural structure of the soil gets modified partly or fully during sampling. An undisturbed sample is that in which the natural structure and other physical properties remain preserved. Disturbed but representative samples can generally be used for determination of the following purposes:

(i) Grain-size analysis

(ii) Determination of liquid and plastic limits

(iii) Determination of specific gravity of soil solids

(iv) Organic content determination

(v) Soil classification

The Undisturbed samples must be used for

(i) Consolidation test

(ii) Hydraulic conductivity test

(iii) Shear strength test (to determine the cohesion and angle of friction)

For collecting good quality undisturbed soil samples the area ratio [$A_r = (O.D^2 - I.D^2)/I.D^2 \times 100$ (%), where O.D and I.D are the outside and inside diameter of the sample tube] of the sample tube should be less than 10%. Thicker the wall, greater is the disturbance. Proper care has to be taken for transport and handling of the soil samples. The soil samplers are classified as:

(i) Thick wall samplers (Split spoon sampler)

(ii) Thin wall samplers (Shelby tubes)

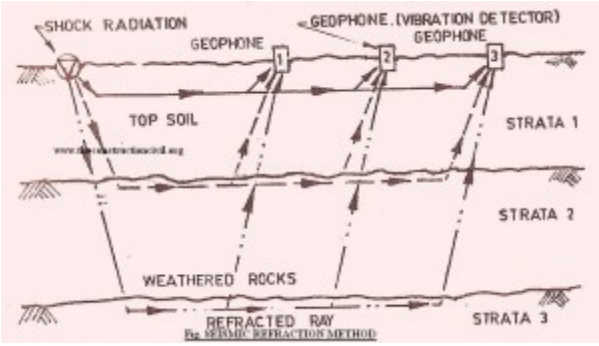
The standard size of the spoon sampler is of 35 mm internal and 50.8 mm external diameter. Thus, the area ratio is 112% and the obtained samples are highly disturbed sample. The sampler is lowered to the bottom of the bore hole by attaching it to the drill rod. The sampler is then driven by forcing it into the soil by blows from a hammer. The assembly of the sampler is then extracted from the hole and the cutting edge and coupling at the top are unscrewed. The two halves of the barrel are separated and the sample is thus exposed. Samples are generally taken at intervals of about 1.53 m (5 ft). When the material encountered in the filed is sand (particularly fine sand below the water table), a spring core catcher is placed inside the split spoon. Shelby tubes are commonly used to obtain undisturbed clayey samples. The Shelby tube has outside diameter: 50.8 mm (2 in) and 76.3 mm (3 in).

Geo-Physical Method of Soil Exploration

Geo-physical methods are used when soil exploration is to be carried out over large area and where speed is of prime importance. These soil exploration methods are based on principle that physical properties like electrical conductivity, elasticity or seismicity, magnetic susceptibility, density etc. vary for different types of soils. There are four soil exploration methods of geo physical survey,namely, *(1)* Seismic refraction method *(it)* Electrical resistivity method, *(iit* Magnetic method and *(ivy* Gravitational method. However, out of these only two methods *namely* ***(1)*** **Seismic refraction method and *(ii)* Electrical resistivity method** are widely used.

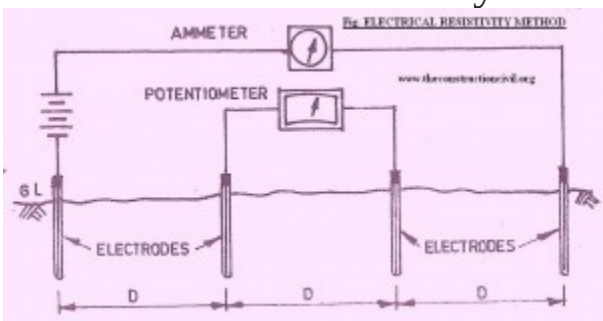
(i) Seismic Refraction Method: This soil exploration method is based on the principle that sound waves travel faster in rock than in soil. This is on account of the fact that velocity of sound waves is different in different media. In this method shock waves (or sound waves of vibration) are created into the soil at ground level or at a certain depth below it, either by striking a plate on the soil with the hammer or by exploding small charge in the soil. The shock waves so produced travel down in the sub-soil strata and get refracted after striking a hard rock surface below. The refracted or radiated shock waves are picked up by the vibration detector (also known as geophone) where the time of travel of the shock waves gets recorded. Knowing the time of travel of the primary and refracted waves at various geophones, tune and distance graphs are drawn based on which it is possible to evaluate the depth of various strata in the sub-soil. Different materials such as clay, gravel, silt

rock, hard rock etc. have characteristics seismic velocities and hence it is possible to establish their identity in the sub-soil based on time distance graph.



Seismic Refraction Method

(ii) Electrical Resistivity Method: This soil exploration method is based on the principle that each soil has different electrical resistivity, depending upon the type of soil, its water content, compaction and composition. Thus saturated soil has lower electrical resistivity as compared to loose dry gravel or solid rock. In this method 4 electrodes are driven in the ground at equal distance apart and in a straight line. The distance between two electrodes being the depth of exploration or depth up to which the ground resistance is to he measured. A current is passed between the two outer electrodes and the potential drop between the inner electrodes is measured by use of potentiometer.



Electrical Resistivity Method

The mean resistivity is calculated by the following formula:-

$P = 2 \pi D (E/I)$

Where,

P =mean resistivity (ohm.cm)
D = distance between electrodes (cm)
E =potential drop between inner electrodes (volts)
I = current flowing between outer electrodes *(amperes)*
Average value of resistivity for various types of soils have already been established based on tests. Thus on knowing the values of change in mean resistivity of sub-soil strata at site, it is possible to establish the nature and distribution of different type of soils in the formation.