UNIT-I

SOIL EXPLORATION

Introduction:

Although information on the soil exposed at the ground surface is very valuable, geotechnical engineers also need to evaluate the sub-surface conditions by taking samples by boring or by digging exploratory pits. These activities are called subsurface exploration.

The extent of exploration depends on the importance of the structure, the complexity of the soil conditions and the budget available for exploration. A detail soil exploration programme involves deep boring, field tests and laboratory tests for determination of different properties of soils required for the design of any structure.

Purpose and Scope

Purpose of soil exploration is:

(i) To determine the basic properties of soil which affect the design and safety of structure i.e., compressibility, strength and hydrological conditions.

(ii) To determine the extent and properties of the material to be used for construction.

(iii) To determine the condition of groundwater.

(iv) To analyze the causes of failure of existing works.

The nature and extent of soil exploration depends upon the ultimate use to which the results of the investigation will be applied. For example, for structures which transmit heavy load on the soil, the aim of soil exploration is to provide data which will help in the selection of proper types of foundation, its location and design of foundations.

Planning of Subsurface Investigation:

To obtain the most useful information at minimum cost and effort, proper planning of subsurface investigation programme is essential.

For planning of the programme, the soil engineer-in-charge of the programme should include the following steps:

(i) Completely familiar with the kind of information required from the investigation.

(ii) Knowledge of type, size and importance of the project.

(iii) Preparation of layout plan of the project,

(iv) Preparation of borehole layout plan which includes number and spacing of boreholes, depth and frequency of sampling.

(v) Selection of proper drilling and sampling equipment.

(vi) Selection of personnel to supervise the field investigation.

(vii) Marking on the layout plan any additional types of soil investigation.

(viii)Preparation of guidelines for laboratory testing of collected samples.

Stage of Subsoil Investigation:

Different stages of sub-soil investigation of a major civil Engineering project are mentioned below:

(i) Reconnaissance study:

(a) Geological data

(b) Serial photographs

(C) Pedological data

(ii) Detailed investigation:

(a) Boring
(b) Sampling
(c) Testing
(i) Lab test
(ii) Field test
(d) Aerial photographs
(e) Geophysical methods

(iii) Performance study

(a) Further testing
(b) Instrumentation
(c) Performance evaluation

Reconnaissance Study:

It involves the preliminary feasibility study that is undertaken before any detailed planning is done. The main objective of this phase of exploration is to obtain rough idea about the soil type in the area. This study is aimed to get a rough soil profile and representative sampling of the major soil strata and groundwater condition which will be helpful in deciding the future programme of explorations. This study is to be done at minimum cost and no large scale exploratory work is usually undertaken at this stage.

Detailed Soil Investigation:

In detailed soil investigation, boring, sampling and testing is done to obtain the engineering properties of soil.

Trial Pits:

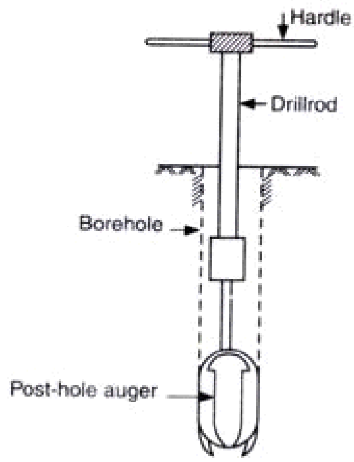
Trial pits can be used for all types of soils. It is the cheapest way of site exploration and do not require any specialized equipment. In this method a pit is manually excavated and soil is inspected in the natural condition. Both disturbed and undisturbed sample can be conveniently taken. Trial pits are suitable for exploration of shallow depth only.

Boring Method:

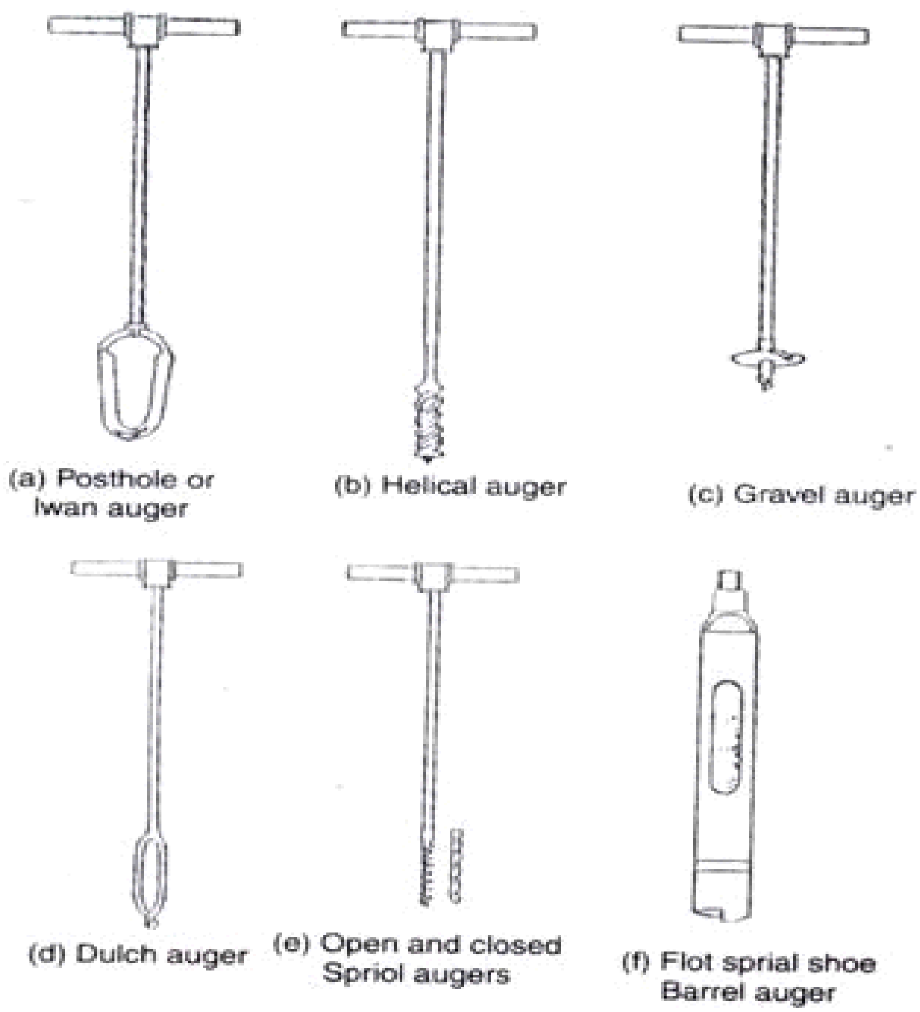
The methods of boring are of following types:
(i) Auger boring
(ii) Wash boring
(iii) Rotary boring
(iv) Percussion boring

(i) Auger boring:

Soil auger is a device that helps in advancing a bore-hole into the ground. These are used is cohesive and other soft soil above water table. Hand operated augers are used up-to a maximum depth of 10 m and power driven augers are used for greater depths.



Auger boring

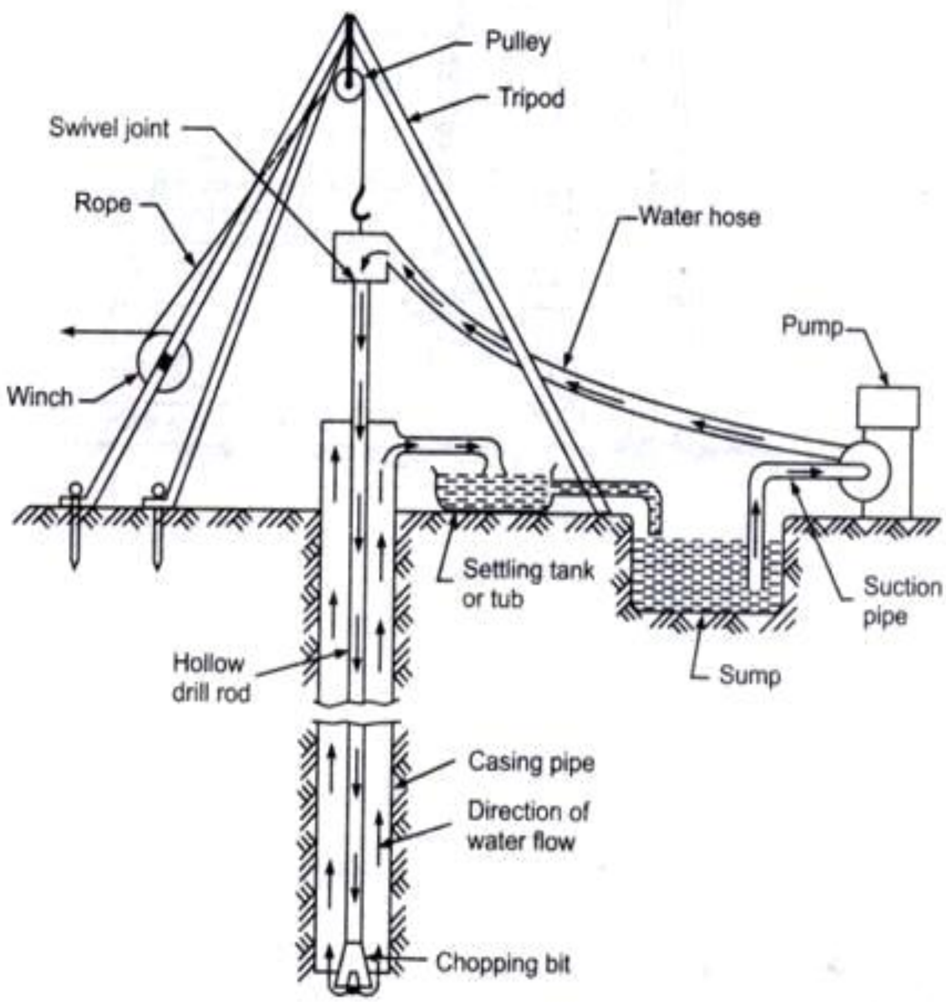


Boring is done by pressing the auger into the ground and rotating it with the handle at the top. As soon as the auger is filled with soil, it is taken out and soil is removed from the blades. Samples obtained are disturbed samples.

(ii) Wash boring:

Figure shows the arrangement for wash boring. It is a fast and simple method for advancing holes in soils. In wash boring the hole is advanced to a short depth by auger and then a casing pipe is driven in the ground to prevent the sides of the bore hole from caving in. Boring is continued by using chopping bit fixed at the end of a hollow drill rod. Water is forced under pressure through the drill rod which is alternatively raised and dropped, and also rotated.

Due to its jetting and chopping action soil is loosened. The loosened soil is forced up-to the ground surface in the form of soil water slurry through the annular space between the drill rod and the casing. The soil in suspension settles down in the tub and the water flows in the sump which is reused for circulation. The change of soil stratification can be guessed from the rate of progress and colour of wash water.



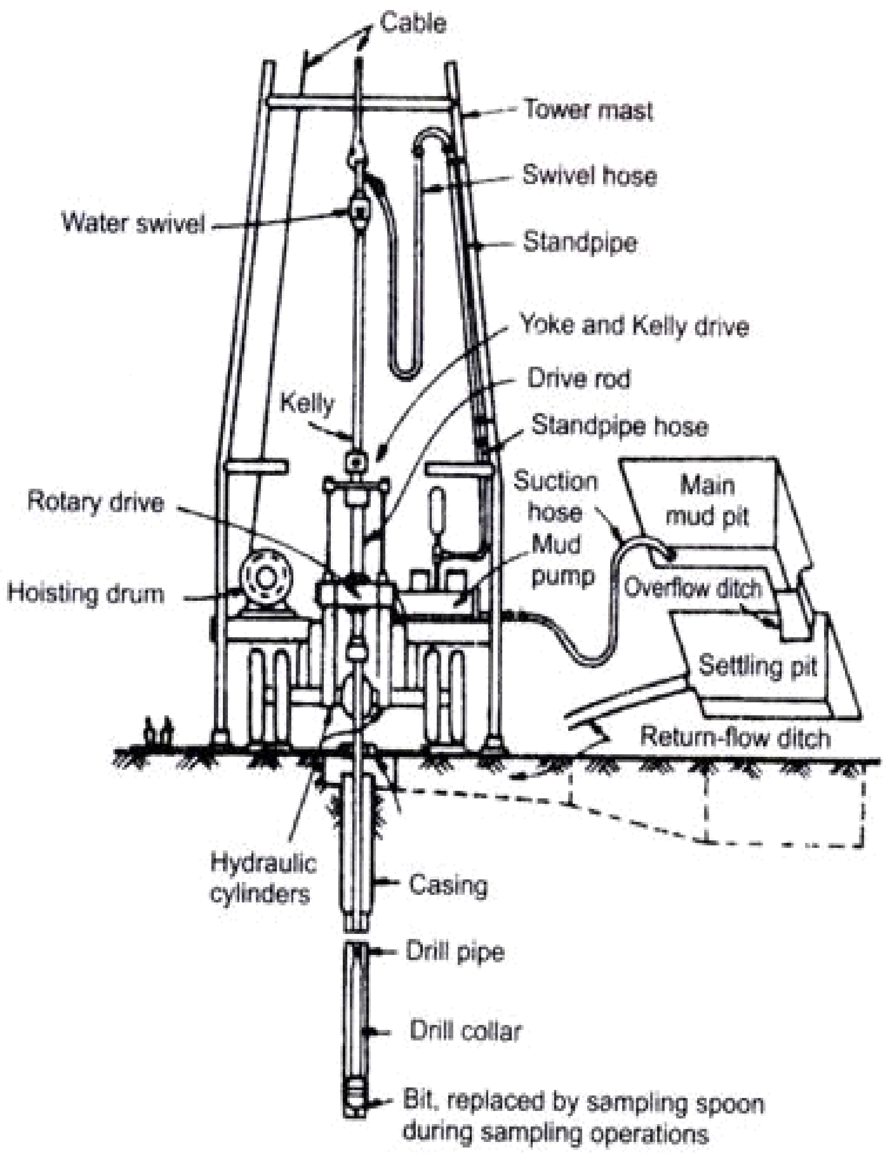
Wash Boring

(iii) Rotary boring:

Rotary boring is used for soil exploration work only when deep bore holes are required in difficult formations with boulders and fractured rock or water logged sand. In this method a cutter bit or a core barrel with a coring bit attached to the lower end of drill rods is rotated by a power rig. The bit cuts, chips and grinds the material into small pieces. The material is then taken out by pumping water or drilling mud through the hollow drilling rod. If drilling mud is used then no casing is required for the hole. Figure 10.3 shows rotary boring setup.

(iv) Percussion boring:

In this method, soil is lessened by repeated blows of a heavy drilling bit. The bit is called the churn bit. The bit is attached to the end of a drilling rod and is raised and dropped alternately in the bore hole. Water is added to facilitate the breaking of the soil. The slurry formed at the bottom of the hole is removed by means of bailers or sand pumps. This method is suitable for boring in rocks and hard soil.



Sampling:

1. Disturbed sampling
2. Undisturbed sampling

Samples which can be taken out from trial pits or boreholes are mainly of two type:

(i) Disturbed sample:

Disturbed sample is a sample in which soil structure is significantly or completely disturbed and the moisture content may also differ from in-situ value. The particle size distribution of in-situ soil is preserved. These samples are required for identification and classification tests.

(ii) Undisturbed sample:

Undisturbed sample is a sample which retains as closely as practicable, the true in-situ structure and moisture content of soil. These samples are required for shear strength, permeability and consolidation tests.

Sampling from Trial Pits:

Block samples are obtained from trial pits. Block samples are hand cut samples and are obtained from clay soil. A block sample is carefully trimmed and a wooden box is kept around the protruding sample. The sample is then cut at the bottom with Knife and turned upside down with the wooden box. The sample is then covered with lid and is sealed with wax or grease.

Sampling in Boreholes:

Undisturbed samples are obtained from bore holes by using thin wall samplers.

The two types of thin walled samplers in use are:

(a) Open drive samplers

(b) Piston samplers

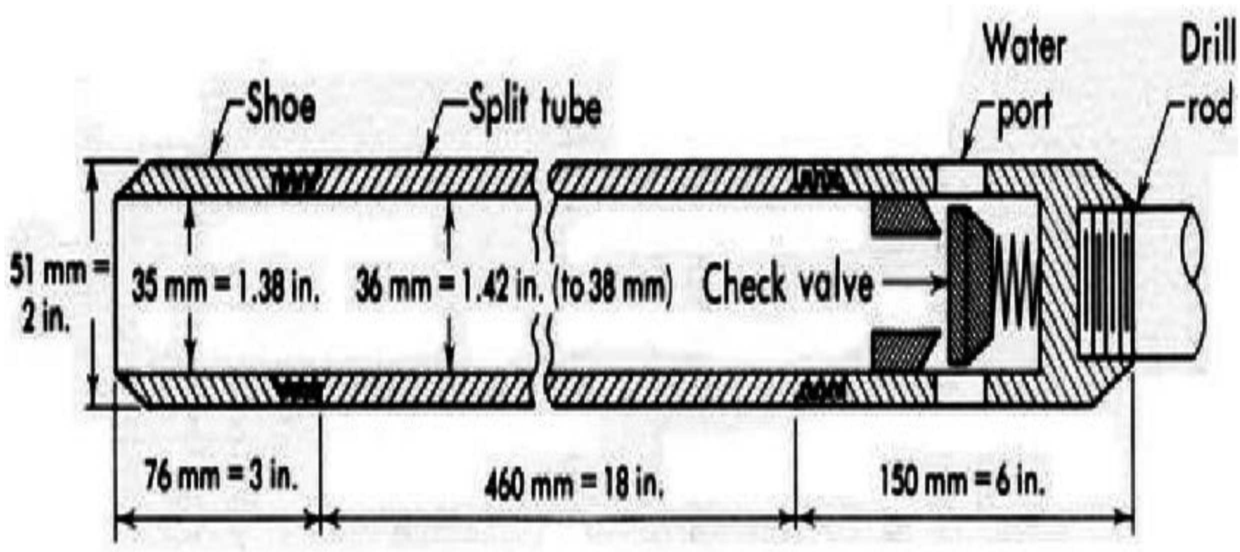
(a) Open drive sampler:

An open drive sampler consists of thin walled tube with a hard cutting edge and connected to a sampler head. The sampler head consists of a ball valve and ports which permits the easy escape of water or air from the sample tube. These samples are pushed or driven into the soil up to the required depth and then sheared off by giving twist to the drill rod. The sampler along with the sample inside is removed from the hole and the tube is taken out of the sampler head. The two ends of the tube is then sealed with grease or molten wax.

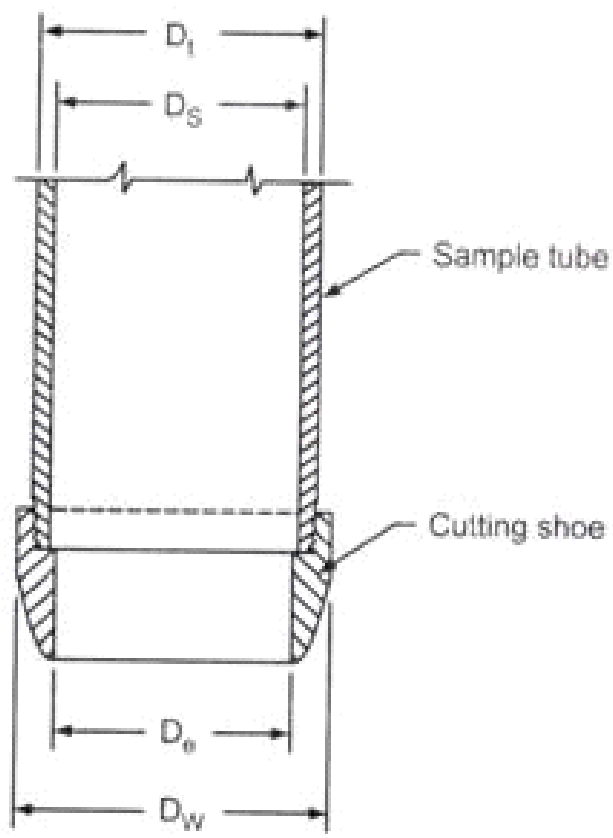
(b) Piston sampler:

Piston samplers are used to get good quality undisturbed samples from soft clays, silts and silty sands with some cohesion. It consists of thin walled tube fitted with a piston that closes the end of sampling tube until the apparatus is lowered to the bottom of the borehole. The piston prevents the soft soil from squeezing rapidly into the tube and thus eliminating the distortion of the sample.

During lowering of sampler in the hole, the piston is kept closer to the lower end of the sampler. After reaching the desired depth, the piston rod is clamped and the sampler tube is advanced down into the soil. The sampler is then withdrawn from the hole, with piston rod in clamped position. During withdraw! Of the sampler, the piston prevents water pressure from acting of the top of the sample and thereby increasing the chances of recovery.



Split Spoon Sampler



Details of Cutting Edge

(a) Inside Clearance

$C_i = D_s - D_e / D_e$

C_i = 1-3%

The inner diameter of the cutting shoe should be kept slightly smaller than that of the sampling tube. This helps for elastic expansion of the soil as it enters the sampling tube and reduces frictional drag on the sample from the wall of the tube.

(b) Outside clearance,

$C_0 = D_W - D_t / D_t$ = 2-3%

The outside diameter of cutting shoe should be slightly larger than the outside diameter of the sampling tube. This clearance is provided to reduce the driving force. This also facilitates the withdraw of the sampler from the ground

(c) Area ratio

$Ar = D^2{}_w - D^2{}_e / D^2{}_e$ 100 %

This represents the amount of soil that is displaced when a sampler is forced into the ground. The area ratio should be kept as low as possible.

For stiff formation, a_r > 20%

For soft soil, a_r, = 10% or less

Where

D_s = Inside diameter of sampling tube

D_t = Outside diameter of sampling tube

D_e= Inside diameter of cutting shoe

D_w = Outside diameter of cutting shoe

Sample Recovery Ratio:

It is the ratio of the length of sample retained in the sampler to the depth of penetration of the sampler. It is an important measure of disturbance in the soil while sampling.

Recovery ratio = Length of sample retained in the sample /Depth of penetration

For a perfect undisturbed sample, the recovery ratio should be equal to or slightly less than 1.0.

Preservation of Samples:

On withdrawal of sampler from the boreholes, the sampling tubes are removed and are sealed on both ends by paraffin's wax or petroleum jelly. The seal thickness should not be less than about 25 mm.

The sampling tubes are then labeled with the following information's:

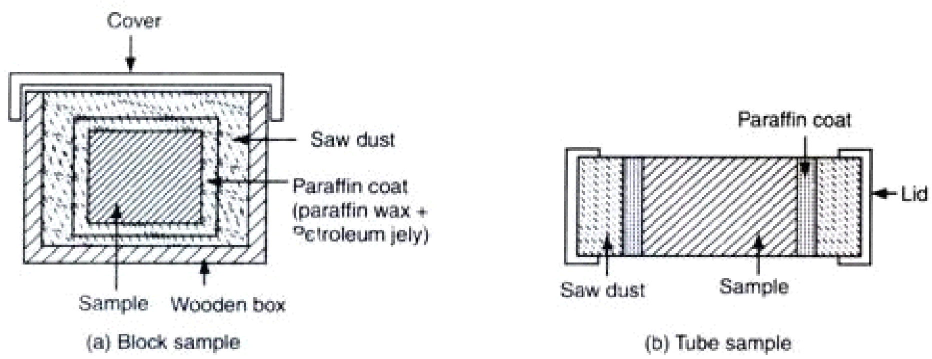
(i) Name of project

(ii) Number of boring

(iii) Depth of sampling

(iv) Date of sampling

While at site the sampling tubes are protected from direct sunshine, shock etc. The sampling tubes are taken to the laboratory as soon as possible and are kept in a humid room to preserve the natural water content of the samples.



Preservation of sample

Influence of Soil Condition on Exploratory Programme:

The knowledge of subsurface condition of the project site for a geotechnical engineer-in-charge is very essential as these have great influence on the planning of exploratory programme.

(i) If the soil conditions are known, then the cost and work of exploratory programme can be reduced.

(ii) If the sub-soil strata is uniform, then the number and depth of boring can be reduced which decreases the relative cost of site investigations.

(iii) Depending upon the soil type, the method of soil exploration is decided.

For example:

In clay soil open test pits are suitable for shallow exploration and boring is suitable for deep exploration. In rocky soil, rotary boring or percussion boring method is adopted.

(iv)If the groundwater table is high, trial pits create difficulties in taking samples for sandy soil and water table is to be lowered for taking samples. Boring method is adopted for taking samples below water table in case of sandy soil.

(v) If the soil around the borehole is not self-supporting, then casing pipe is to used to provide support of soil.

Possibility of Misjudgment of Subsoil Condition:

The subsurface investigation is always a difficult task. We explore the sub-surface conditions using borings and other methods and recover samples for testing and evaluation, but even a most detailed investigation covers a small fraction of soil and rock below the site.

We do not have the idea of soil condition in between the boreholes and must rely in interpolation combined with knowledge of soil deposition processes. Even after soil investigation, we are never sure about the samples collected and truly representative or not and so there is every possibility of misjudgment of sub-soil condition.

Figure 10.6 slows two layers of soils. The top layer is stiff clay and bottom layer is soft clay. The load test is conducted near the surface of the ground only measures the properties of stiff clay but does not indicate the nature of soft clay.

The effect of actual load on the building of the soil extends up-to the soft soil which is highly compressible and there will be failure.

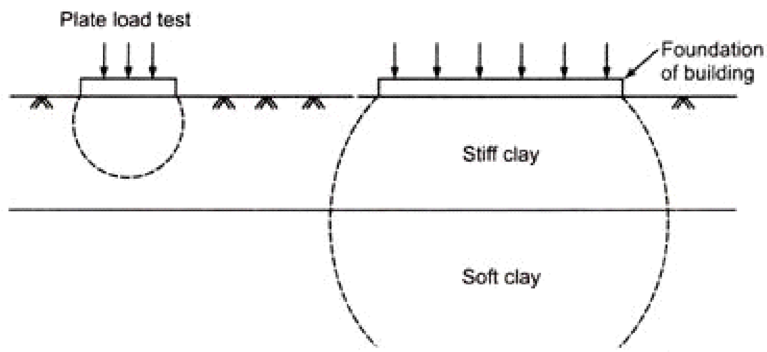
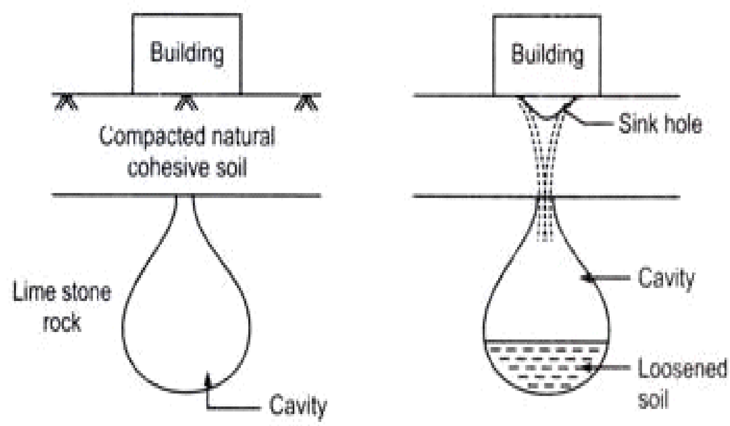


Plate load in non-homogeneous soils

Sometimes in soil investigation, a big bolder is misjudged as the bed of a rock and the design of a structure is made to be supported on rock. This may lead to disaster. By sub-soil investigation thickness of a clay layer overlying sandy strata is determined and foundation is designed accordingly. No consideration is made for entrapped water under the clay layer.

This misjudgement may lead to failure of foundation due to development of excessive water pressure when the soil is loaded. If a geotechnical engineer fails to detect the limestone rock underlying the cohesive soil and construction is done over it. With the construction and groundwater flow, cavity is formed in the limestone rock. This cavity goes on increasing and finally results in failure of the structure (figure).



Influence of Size of Project and Type of Structure on Exploratory Programme:

The size of project and type of structure has great influence on the exploratory programme. In case of small structures only general exploration or preliminary exploration is sufficient. The main aim of preliminary exploratory is to get an approximate idea of the sub soil at low cost, Few numbers of bore holes, test pits and penetration tests are carried out for general exploration. Disturbed samples are tested in the laboratory to determine the physical properties of soil.

If the size of the project is large and structure is heavy, the detailed exploration is carried out. Cost involved in detailed exploration is much more than the general exploration. In detailed exploration numbers of bore holes are tested. Depth of boring is at least 1.5 to 2B, where B is the width of foundation, undisturbed samples are tested in the laboratory to determine the engineering properties like shear strength, permeability, compressibility etc. Number of field tests such as plate load tests, standard penetration test, vane shear tests etc. is conducted.

Table 1: Rough guidelines for depth of boring for buildings in shallow foundation

S.No	Subsurface condition	Min.depth of Boring
1	Poor	$6S^{0.7}+D$
2	Average	$6S^{0.7}+5D$
3	good	$3S^{0.7}+D$

Where

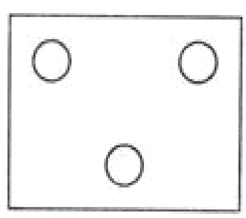
S=No. of Stories

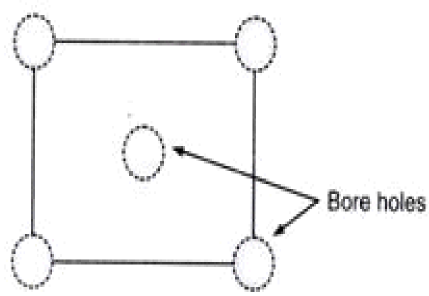
D=Anticipated Depth of Foundation

(Sowers,1979)

(i) For buildings:

On uniform soils, at least three borings, not in one line, should be made for small buildings and at least five borings one at each corner and one at the middle should be made for large buildings as shown in the figure 10.8. As far as possible the boreholes should be drilled closed to the proposed foundations but outside their outlines





For small buildings **For big buildings**

(ii) For roads:

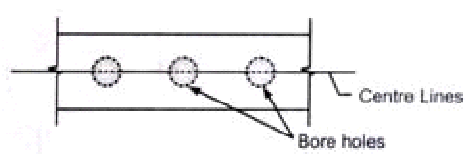
Boring should be usually located along the proposed centre line of the road as shown in figure Below.

(iii) For airports:

Boreholes should be located along the proposed centre line and at each edge of each runway.

(iv) For dams:

Boring should be located along the upstream face across one or both abutments.



For Roads

Depth:

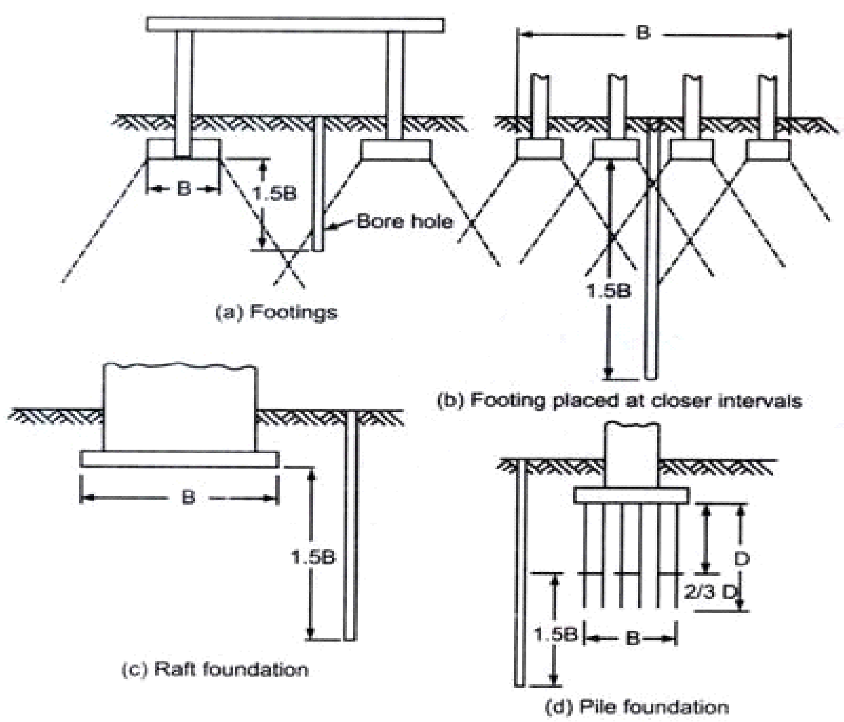
Exploration should extend below all strata which would contribute significant settlement or which might have inadequate shear strength for the support of foundation.

Spacing:
Spacing of exploration depends upon nature and condition of soil, nature and size of the project. In uniform soil, spacing of exploration (boring) may be 30 m to 100 m apart or more and in very erratic soil conditions, spacing of 10 m or less may be required.

Table 2: gives an approximate idea about spacing of boring required for different type of projects:

S.No	Type of Project	Spacing of bore holes(mm)		
		Type of soil in horizontal stratification		
		Uniform	Average	Erratic
1	Small Buildings	60	30	15
2	Multistoried buildings	45	30	15
3	Highways	300	150	100

Guidelines for Depth of Boring:
(i) At least one boreholes should extend to a depth of 1.5 to 2 times the anticipated largest size of foundation as shown in figure 10.10.
(ii) The boreholes should be drilled minimum to a depth beyond which the increase in stress due to foundation loading is not significant.
(iii) Wherever possible at least one borehole must be taken down to the level of solid rock.
(iv) Where foundation is taken down to solid rocks, at least one borehole must be drilled 3 m in the rock to confirm that it is bedrock and not a large boulder.
(v) The depth of exploration is in the range of 4 to 5 m for airport and highway pavement construction.



Depth of bore holes

Standard Penetration Test (SPT):

Standard penetration test (SPT) is the most commonly used in situ test for sub- surface investigation. In SPT a split spoon sampler is made to penetrate 15 cm by light blows of a 65 kgs drop hammer on the top of the drill rod. The drill rod is connected to the top of the split spoon sampler.

After initial penetration of 15 cm of the sampler, the drop hammer is allowed to fall from a height of 75 cms and number of blows required for 30 cms penetration of sampler is recorded. This number of blows is called N-value or penetration number. In this method the driving energy is supplied by the fail of the drop weight. Hence it is essentially a dynamic sounding method.

Detailed procedure of SPT is as follows:

Apparatus required:

(i) Split spoon sampler:

It has an outside diameter of 50 mm, inside diameter of 35 mm and minimum open length (cutting edge to air vent) of 600 mm. The coupling head has four 10 mm (minimum diameter) vent ports or a ball check value.

(ii) Drive assembly:

It consists of a tripod as hoisting equipment-one of the leg is provided with ladder, a drive mass (hammer) of 65 kgs, a guide to ensure a 75 cm free fall of the drive mass and an anvil (attached to the guide) for transmitting the blow to the sampler rod.

In general practice four methods of releasing the hammer are used:

(a) Normal lifting and releasing of the rope passing through a pulley.

(b) A trip hammer, such as the Pilcon or Dando hammers

(c) A trigger mechanism, such as the Japanese “Tombi”.

(d) The “split-rope” method of rapidly slackening the rope on the wink cathead.

(iii) Extension rods:

These rods are used to transmit the driving energy from the anvil to the sampler.

(iv) Drilling equipment:

Drilling equipment should be for making a reasonably clear hole of 60-75 mm diameter so as to ensure that the test is performed in undisturbed soil and not in the fall in material. Casing or drilling mud may have to be used where the boring sides fall in.

In general, hand operated auger of 75 mm diameter are used for drilling boreholes.

Procedure:

(1) A borehole is drilled to the required depth and is cleaned thoroughly.

(2) The sampler attached to the extension rods is lowered to the bottom of the hole and is allowed to rest under the self weight.

(3) The drive assembly is then connected to the rod and the sampler is driven with light blows from the drive mass to a seating penetration of 15 cm.

(4) The sampler is then driven to an additional penetration of 30 cm by blows from 65 kgs drive mass falling from a height of 75 cm. The number of blows required for 30 cm penetration is recorded as standard penetration resistance, N.

(5) The sampler is then lifted from the hole and opened. The undisturbed sample is removed from the sampler and sealed from both sides.

(6) The test is performed in each identifiable soil layer or at a interval of 1.5 m whichever is smaller. As per IS:2131, for a foundation of width B, penetration test has to be carried out at an interval of 0.75 m up to a depth of B from the bottom of the footing and at 1.5 m interval for the rest depth up to a depth of 1.5 to 2 B.

(7) The measured N-value may indicate more than the actual value in some cases and so they are to be corrected.
The standard penetration resistance i.e., N-value has been correlated to different soil properties by different investigators.

Some of the correlation is given in the following tables:
For cohesive soil:

Penetration Resistance(Blows/305mm)	Unconfined Compressive strength(t/m2)	Consistency
<2	<2.4	Very soft
2-4	2.4-4.8	Soft
4-8	4.8-9.6	Medium
8-15	9.6-19.2	Stiff
15-30	19.2-38.8	Very Stiff
>30	>38.8	Hard

Table3. Relation between N & qu

(From Terzaghi's & pech,1948)
The relationship b/w q_u & N Proposed by murthy (1982)

$$q_u = N/7.5 Kg/cm^2$$

Sanglerat (1972) has proposed the following relationship between q_u & N
For Clay $q_u = (N/4) Kg/cm^2$
For silty clay $q_u = (N/5) Kg/cm^2$

For Cohessionless soil

Table4.Relation between N-Value and angle of shearing resistance (ɸ)

Corrected N-value	5	10	15	20	25	30	35	40	45	50
ɸ(degrees)	28.5	30	32	33	35	36	37.5	39	40	41

(Peck el at,1974)

Table 5.Relation between N-values and density index

N-Value	Density Index(%)	Degree of Compaction
<4	0-15	Very loose
4-10	15-35	loose
10-30	35-65	Medium
30-50	65-85	Dense
>50	85-100	Very Dense

(Mitchell & Katti,1981)

Corrections to Measured Standard Penetration Resistance (N)

It has been observed by different investigators (Tergaghi and peck, 1948; Gibbs and Holtz, 1957; A.W. Skempton, 1986) that the value of N depends on several factors, such as effective over-burden pressure, submergence, borehole diameters, rod length etc. Therefore the observed N-value is to be corrected.

The effect of each and corrections are discussed briefly as follows:

Effect of Over-burden:

Gibbs and Holtz (1957) experimentally studied the effect of overburden pressure on the value of N.

Their modification for air dried or moist sand can be represented by the following relation:

$N_C = N\ 35/\ \sigma + 7$

Where

N_c = corrected N-value for overburden

N = observed SPT value

σ = effective overburden pressure, t/m^2 (not to exceed 28t/m^2)

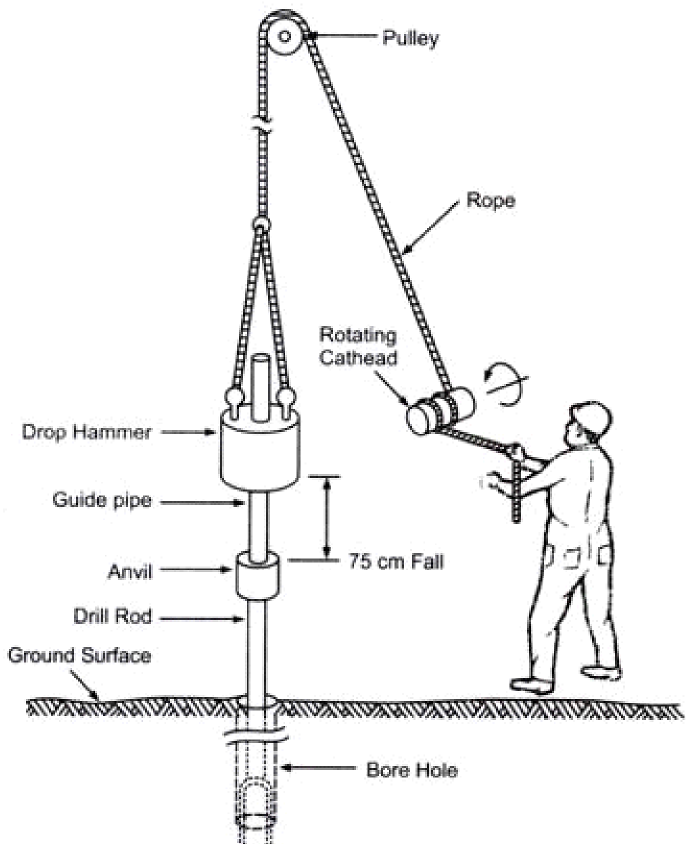


FIG. 10.11 SPT setup

Effect of Submergence:

Terzaghi and Peck (1948) recommended that where the soil consists of very fine or silty sand below the water table, the measured N-value, if greater than 15, should be corrected for increased resistance due to excess pore water pressure set up during driving and unable to dissipate immediately. The corrected value of N, N_c is given by

$$N_c = 15 + I/2\ (N-15)$$

where, both the overburden and submergence corrections are necessary, the overburden correction is applied first.

Effect of Rod Length:

Wave equation studies (Schmertman and Palacios, 1979) indicate that the theoretical maximum ratio decreases with decreasing rod length below a rod length of 10 m. The weight or stiffness of the rod stem, of a given length, appears to have little effect (Brown, 1977; Matsumo to and Matsubara, 1982).

Effect of Borehole Diameter:

In its original form the SPT was carried out from the bottom of 62.5 mm or 100 mm diameter wash borings (Skempton, 1986). The best modern practice still adheres to this dimension. In many countries 150 mm test boreholes are common and even 200 mm bore holes are permitted (Nixon, 1982). The effect of testing from relatively large bore holes in cohesive soils is probably negligible but in sands there is indication that appreciable lower N- values may results (Lake, 1974; Sanglerat and sanglerat, 1982).

Static Cone Penetration Test (CPT):

The static cone penetration test is normally called as the cone penetration test (CPT). CPT is a direct sounding test which gives a continuous record of variation of penetration resistance with depth. No sample is obtained from this test. A cone is used which has an apex angle of 60° and overall base diameter of 35.7 mm giving a cross-sectional area of 10 cm^2.

It is made of steel and tip hardened. The cone is attached to the lower end of a 15 mm diameter steel sounding rod passing through a steel mantle tube of uniform or non-uniform diameter. The external diameter of mantle tube is equal to the cone diameter. The cone is pushed into the ground manually or by using hydraulically operated driving mechanism. For obtaining cone resistance q_c, the cone alone is pushed vertically at the rate of 2 cm/s through a depth of 4 cm each time.

The pressure required for pushing is recorded as q_c. The outer mantle tube is then pushed down to the level of cone. The resistance due to friction on the mantle tube is then measured separately. The cone resistance variation with depth is then plotted to identify the different strata.

In recent year, the static cone penetrometer had been modified to incorporate Piezo cone. Piezoncone penetrometer gives simultaneous measurement of cone resistance, side friction and the pore water pressure as the cone is advanced in the soil. Piezocone penetrometer (CPTU) gives a more reliable determination of stratification and soil type than a standard CPT.

The CPT has three main applications:

1. To determine subsurface stratification and identify materials present.
2. To estimate geotechnical parameters.
3. To provide results for direct geotechnical design.

For fine grained soil as clay, the preliminary untrained shear strength (Cu) can be estimated from:

$Cu = q_c/N_k$

where

q_c = measured cone resistance

N_k = 17 to 18 for normally consolidated clays or,20 for over consolidated clays.

Dynamic Cone Penetration Test (Dcpt):

DCPT is similar to SPT as the use, except that there is no borehole for DCPT. This test is done by driving a standard 60° cone attached to a string of drill rods into the soil by blows of 65 kgs hammer falling from a height of 75 cm. The number of blows for every 30 cm penetration of the cone is recorded.

The number of blows required for 30 cm of penetration of cone is referred as cone resistances, N_c

DCPT is performed in two ways:

(i) Using 50 mm cone without benetonite slurry (IS-4968, part I)

(ii) Using 62.5 mm cone with bentonite slurry (IS-4968, part II)

For a 50 mm diameter cone without bentonite slurry, the cone is fitted to the driving rod (A-rod). The hammer head is joined to the other end of the A-rod with a A-rod coupling and a guide rod 150 cm long is connected to the hammer head. This assembly is kept vertical with the cone resting vertically on the ground at the point to be tested. The cone is then driven by the drop of the hammer and the driving is continued till the cone reaches the required depth.

For 62.5 mm cone with bentonite slurry, the setup should have arrangements for circulating slurry so that the friction on the driving rod is eliminated.

The N_c value of DCPT and N-value of SPT can be compared and an approximate correlation can be established for the site. With the help of these correlations, the data from DCPT at other locations can be deduced to know to the value of N. This type of work is adequate for small structures and is useful in the preliminary exploration for extensive sites.

Groundwater Level Measurement:

The presence of water in soil pores has a very significant impact on the engineering behavior of the soil, so determination of groundwater level and its fluctuation is an important part of any site exploration. Ground water level measurement is more important at the sites where deep execrations are to be carried out.

Importance of groundwater level measurement:

(i) Groundwater level is an indicative of type of soil and its permeability.

(ii) In waterlogged areas, dewatering is required for soil exploration. So measurement of groundwater level enables the geotechnical engineer- in-charge to decide about the type of dewatering units required for the site.

(iii) Groundwater level affects many important phases in the design and construction of foundation. So it must be measured with accuracy in each project.

Factors affecting groundwater level:

The factors which affect the ground water level are as follows:

(i) Type of soil

(ii) Weather conditions

(iii) Drainage conditions of adjoining areas

(iv) Seasons

Methods of groundwater level measurement:

The method of measuring the groundwater level in a borehole depends upon the permeability of the soil.

For pervious soils (sands, gravels etc.):

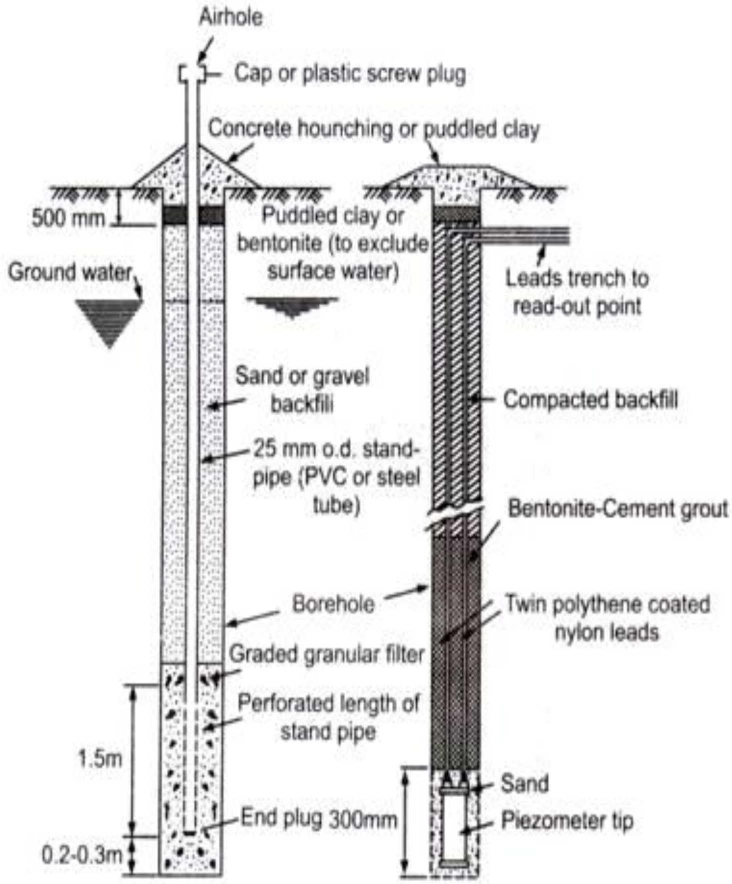
As the permeability of previous soils like sand, gravels etc., are more; water rises to its final level in a bore hole in a short time. The final level of water in the bore hole is the indicative of the water table in the region.

Water level in a borehole in such soils is measured after few minutes of boring by lowering a steel tape coated with chalk. In sands and gravels 30 to 45 minutes is enough for the water level is stabilize.

For impervious soils (silts, clays etc.):

As the permeability of impervious soils is less, groundwater takes more than 2 hrs, or several days to rise to its final level in a bore hole. When measurement of ground water level has to be made over a long period of time, an accurate method of determination is the install a series of stand pipes or piezometers in boreholes.

A simple stand pipe consists of a PVC tube with perforations at the lower end and packed around with granular filter along the perforated portion as shown in the figure 10.12. The bore hole is than backfilled with sand or gravel over which a puddle clay seal is provided. In irregular groundwater condition, hydraulic piezometer is installed for measurement of groundwater level.



Stand pipe for measurement of ground water level

Soil Investigation Report:

Soil investigation report is the final document of sub-soil investigation which contains important information's for the designer. The report must be prepared in such a manner that the reader is able to get complete picture of the subsurface condition of the site.

A good soil report should include the following:

1. Introduction
2. Borehole log
3. Method of investigation
4. Laboratory test results
5. Analysis of results
6. Recommendations.

The information's to be included in the introduction part of the soil report are:

(i) The nature and scope of the sub-soil investigation
(ii) A layout plan of the site showing locations of boreholes, location of other field test etc.
(iii) The different test carried out in the field and in laboratory.

The borehole log should include the following information:

(i) Boring number and type of boring

(ii) Starting and completion dates of boring
(iii) Diameter of boring

The other data of the bore logs are presented in the tabular form showing:

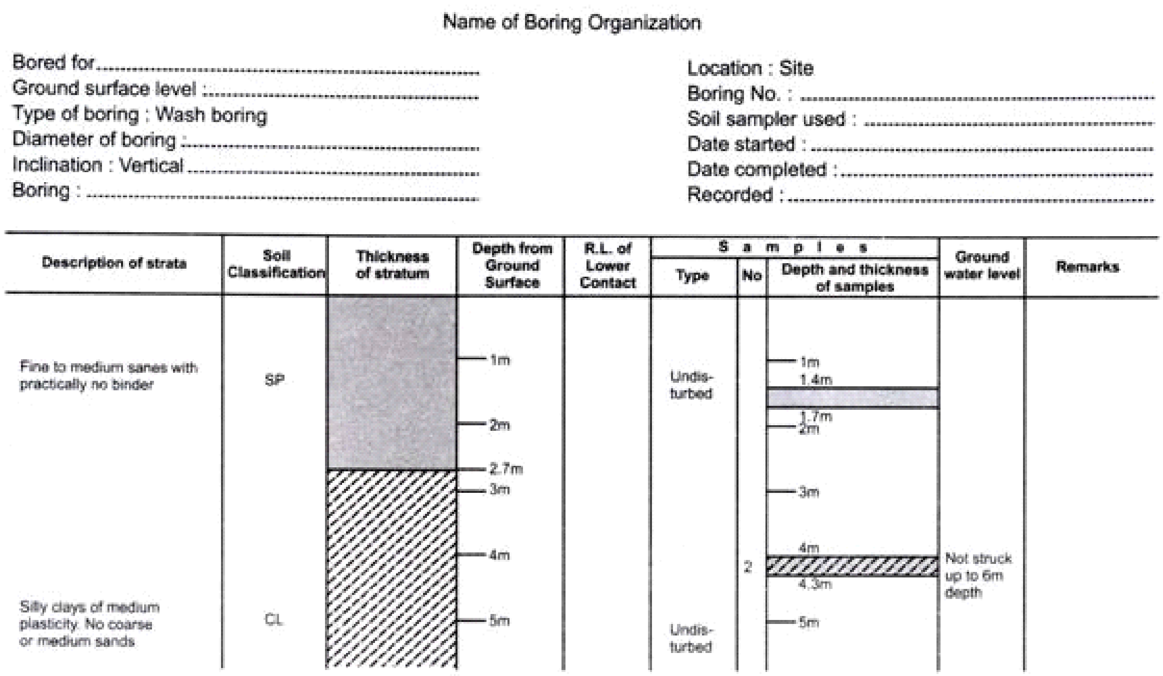
(i) Soil profile showing thickness of different strata
(ii) Description of the different soil strata
(iii) Groundwater level
(iv) Depth and thickness of samples

A typical record of boring (as per IS: 1892) is shown in figure 10.13. In method of investigation, the reason for choosing a particular method for field test is to be mentioned. The details of field test results are presented in this section of the soil report.

Laboratory test results are presented in the form of tables and graph. Important details of lab test procedures are included. Any special procedure followed for this investigation is explained in details.

The data obtained from field tests and laboratory tests are analyzed. Correlations between different test data are established. Range of design parameters and their average values should be identified.

Finally recommendations in the report are generally for the types of foundations and their design, if the scope permits.



Typical bore hole log

S. No.	Property of soil	Type of lab test	Type of sample
1.	Grain size distribution	(i) dry sieve analysis (ii) wet analysis	disturbed
2.	Consistency limits	(i) liquid limit (ii) plastic limit (iii) shrinkage limit	disturbed
3.	Unit weight (density)	Specific gravity test	disturbed
4.	Moisture content	Moisture content	disturbed
5.	Permeability	Permeability test (i) constant head (ii) falling head	undisturbed
6.	Compressibility	Oedometer test	undisturbed
7.	shear strength	(i) Direct shear (ii) unconfined compression test (iii) Triaxial test	undisturbed

Laboratory testing of logs

S.No.	Purpose of test	Type of test
1.	Relative density (coarse grained soil)	(*i*) SPT (*ii*) DCPT
2.	Shear strength (cohesive soil)	(*i*) Vane shear test (*ii*) CPT (*iii*) In-situ direct shear test
3.	Permeability	(*i*) Pumping test (*ii*) Piezometer test
4.	Bearing capacity and settlement	Plate load test
5.	Testing of piles	Pile load test
6.	Compaction control	Proctor's needle test

Field Test on soils