Site Investigation

Objectives of Site Investigation

- To know about the order of occurrence of soil and rock strata.
- To know about the location of the groundwater table level and its variations.
- To determine engineering properties of soil.
- To select a suitable type of foundation.
- To estimate the probable and maximum differential settlements.
- To find the bearing capacity of the soil.
- To predict the lateral earth pressure against retaining walls and abutments.

- To select suitable soil improvement techniques.
- To select suitable construction equipment.
- To forecast problems occurring in foundations and their solutions.

Planning a subsoil exploration programme

- The two important aspects of planning a sub-soil exploration programme are:

1. Depth of exploration
2. Lateral extent of explorations

- The depth of exploration is governed by the depth of influenced zone. As per IS: 1892-1979, “ Code of practice for subsurface Investigation for Foundation:, the depth of exploration depend upon:

Type of structure

Intensity of loading

Shape and disposition of the loaded area

Soil profile

Physical properties of soil etc.

1. Depth of exploration

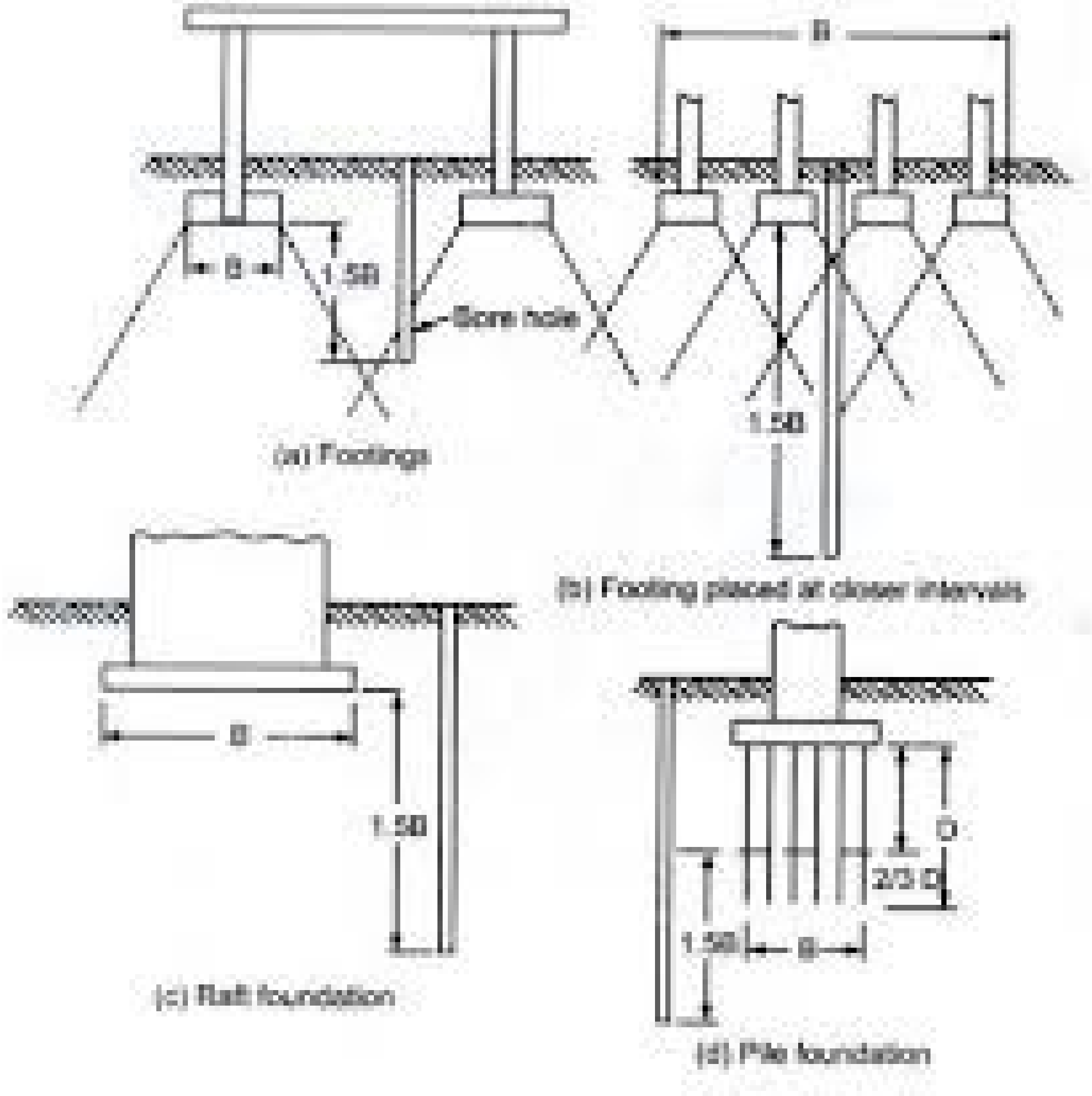


FIG. 10.10 Depth of bore holes

DEPTH OF EXPLORATION

- Depth of exploration at particular site depends upon degree of variation of subsurface data in horizontal and vertical direction.

For square footing 1.5B=D.

For strip footing 3B=D.

For pile foundation D=1.5 times the width of the pile group.

In case of friction pile D=1.5 times the width of the pile group measured from lower 3_{rd} point.

2. Lateral extent of explorations

- For small and less important building.
- Building covering 0.4hectares (4000m^2)
- For multistoried building (spacing 10m to 30m).
- For highway (150 to 300m), if erratic spacing 30m.
- Concrete dam (40 to 80m).

Stages in Site Investigation

Site investigation or sub-soil exploration is carried out stage-wise as given below.

1. Site Reconnaissance
2. Preliminary site exploration
3. Detailed exploration
4. Preparation of soil investigation report

1. Site Reconnaissance

- Site reconnaissance is the first stage of site investigation. In this stage, visual inspection of the site is done and information about topographical and geological features of the site are collected.
- The general observations made in site reconnaissance are as follow.

- Presence of drainage ditches and dumping yards etc.
- Location of groundwater table by observing well in that site.
- Presence of springs, swamps, etc.
- High flood level marks on the bridges, high rise buildings, etc. are observed.
- Presence of vegetation and nature of the soil.
- Past records of landslides, floods, shrinkage cracks, etc. of that region.
- Study of aerial photographs of the site, blueprints of present buildings, geological maps, etc.
- Observation of deep cuts to know about the stratification of soils.
- Observation of Settlement cracks of existing structures.

2. Preliminary Site Exploration

- Preliminary site exploration is carried out for small projects, light structures, highways, airfields, etc. The main objective of preliminary exploration is to obtain an approximate picture of sub-soil conditions at low cost. It is also called general site exploration.

- The soil sample is collected from experimental borings and shallow test pits and simple laboratory tests such as moisture content test, density, unconfined compressive strength test, etc. are conducted. Simple field tests such as penetration methods, sounding methods, geophysical methods are performed to get the relative density of soils, strength properties, etc.

- The data collected about subsoil should be sufficient enough to design and build light structures. Following are some of the general information obtained through primary site exploration.

i. Approximates values of soil’s compressive strength.
ii. Position of the groundwater table.
iii. Depth and extent of soil strata.
iv. Soil composition.
v. Depth of hard stratum from ground level.
vi. Engineering properties of soil (disturbed sample)

3. Detailed Site Exploration

- Detailed exploration is preferred for complex projects, major engineering works, heavy structures like dams, bridges, high rise buildings, etc. A huge amount of capital is required for a detailed site exploration hence, it is not recommended for minor engineering works where the budget is limited. For such type of works, data collected through preliminary site exploration is enough.
- In this stage, numerous field tests such as in-situ vane shear test, plate load test, etc. and laboratory tests such as permeability tests, compressive strength test on undistracted soil samples are conducted to get exact values of soil properties.

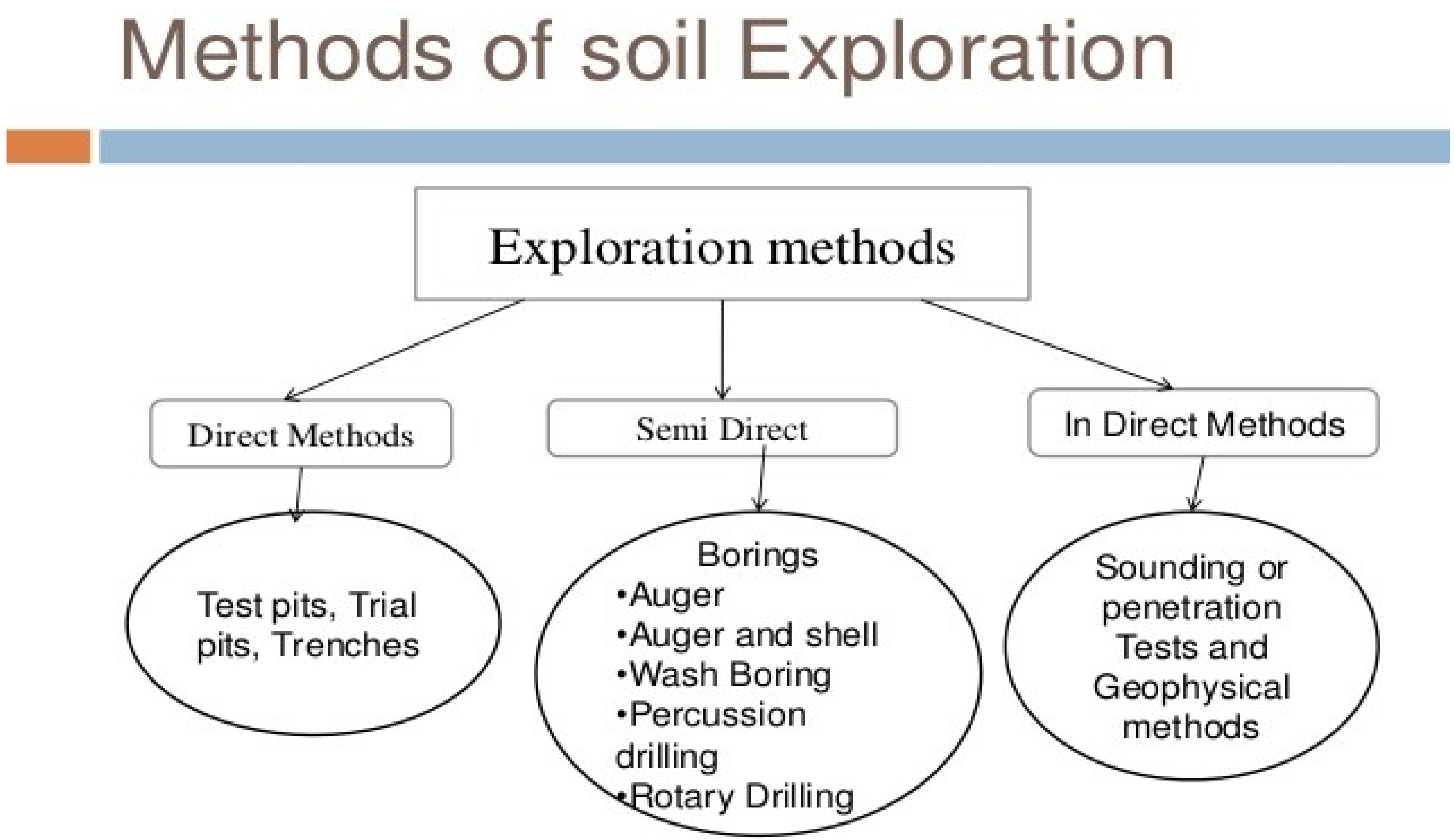
4. Preparation of Report of Sub-Soil Exploration

- After performing preliminary or detailed site exploration methods a report should be prepared. A sub-soil investigation or exploration report generally has the following sections :
- Introduction
- Scope of site investigation
- Description of the proposed structure, purpose of site investigation
- Site reconnaissance details
- Site exploration details such as number, location and depth of boreholes, sampling details etc.

- Methods performed in site exploration and their results.
- Laboratory tests performed and their results.
- Details of Groundwater table level and position.
- Recommended improvement methods if needed.
- Recommended types of foundations, structural details, etc.
- Conclusion.

Depth (m)
Casing (mm)
Core Bit
Returning Water
Sampling Type
Water Level
Graphic Symbolism
Description
Photographic
T.C.R. %
R.Q.D. %
Index Properties
Unit Weight
Discontinuities
Dip Angle
Discontinuity Type
Type of Infilling
Weathering
Compression Test
Permeability Test (DMT) (m/s)
20 40 60 80
128.00/119.00
TES-D-116
75.0%
50.0%
D
9.30m
blue-gray, blue-white, Limestone, Moderately weathered
blue-gray, blue-white, Limestone, Slightly weathered
Limestone, Intensely weathered
25.2 25.6
25.1 25.3
25.9 26.2
20 D CS II-III III
40 D CS VII II
60 D MS VII II
70 J CS II-III II
60 2
75 1.5
LUGEON
1
2
3
4
5
6
7
8
9
10

Methods of Sub-Soil explorations



Direct methods

1. Pits and Trenches
2. Drifts and Shafts

- **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.

Semi-direct methods

Borings

(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.

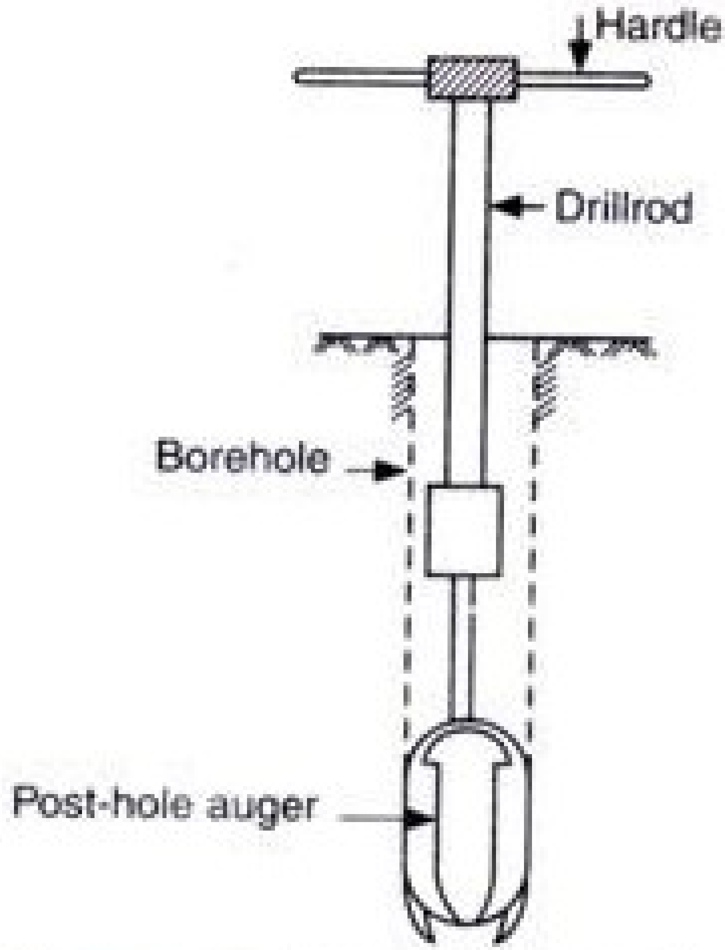
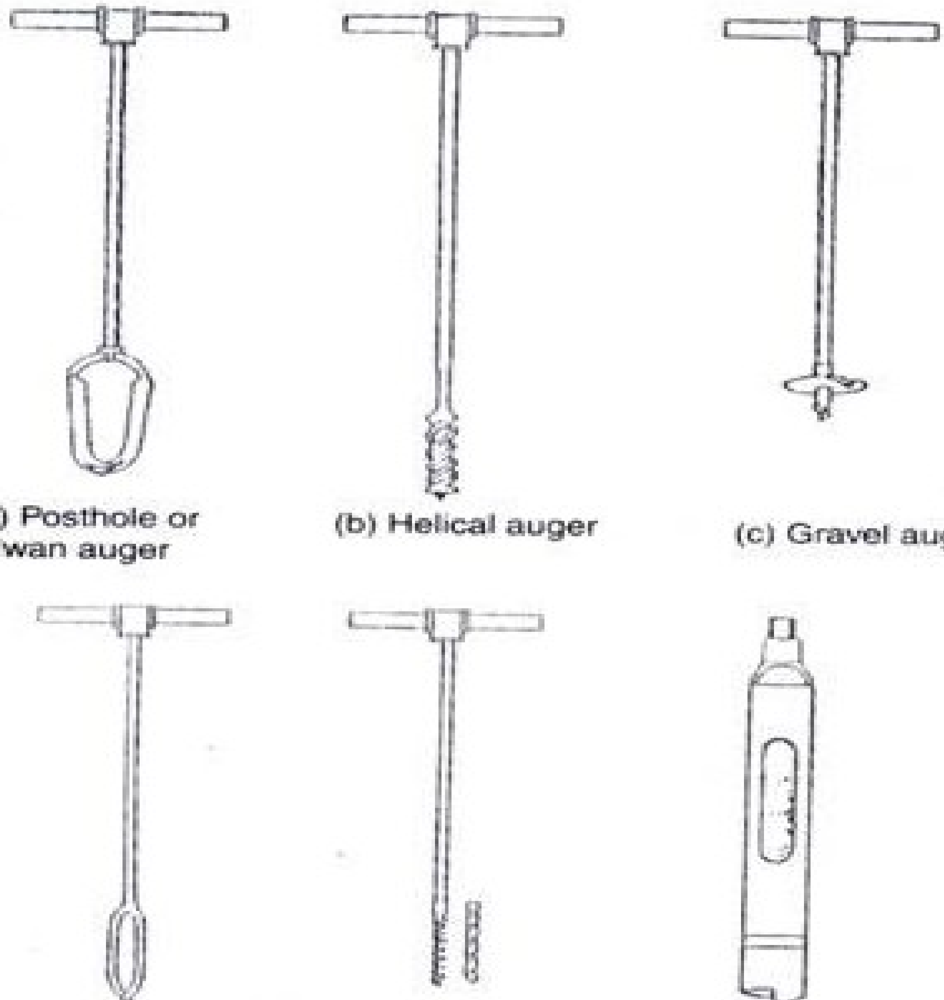
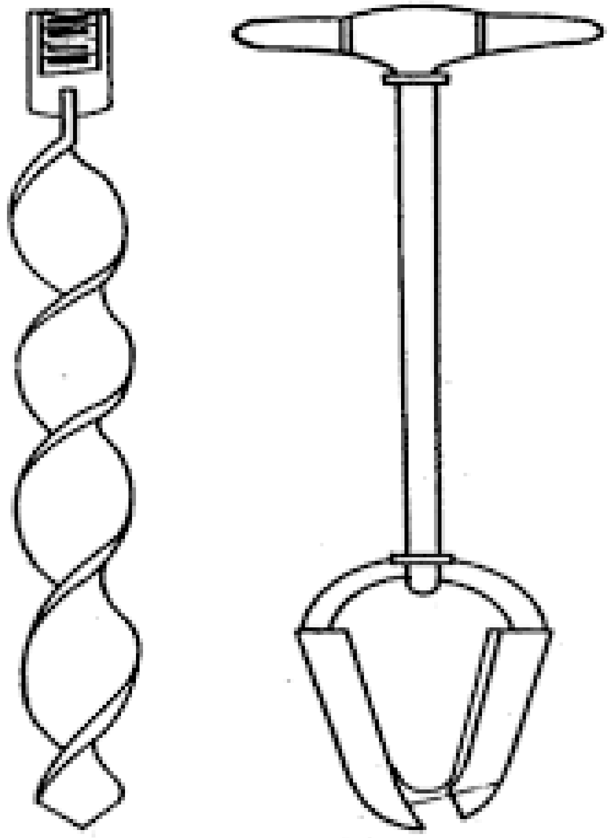


FIG. 10.1 (a) Auger boring



(a) Posthole or Iwan auger
(b) Helical auger
(c) Gravel auger
(d) Dulch auger
(e) Open and Spriol au
Auger
(f) Flot sprial shoe Barrel auger

FIG. 10.1 (b) Auger



(a) HELICAL AUGER (b) POST-HOLE AUGER.

Auger and Shell Boring

- Casing is provided in case of weak strata
- First the casing is driven and then the auger
- Boring rig is used for power drivng (hand rig for depth upto 25 m)
- Soft rocks are broken using chisel bits
- Sand pumps are used in the case of sandy soils.

Disadvantage:

- Whenever the casing is to be extended, the auger has to be withdrawn which hinders the quick progress of the work.

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.

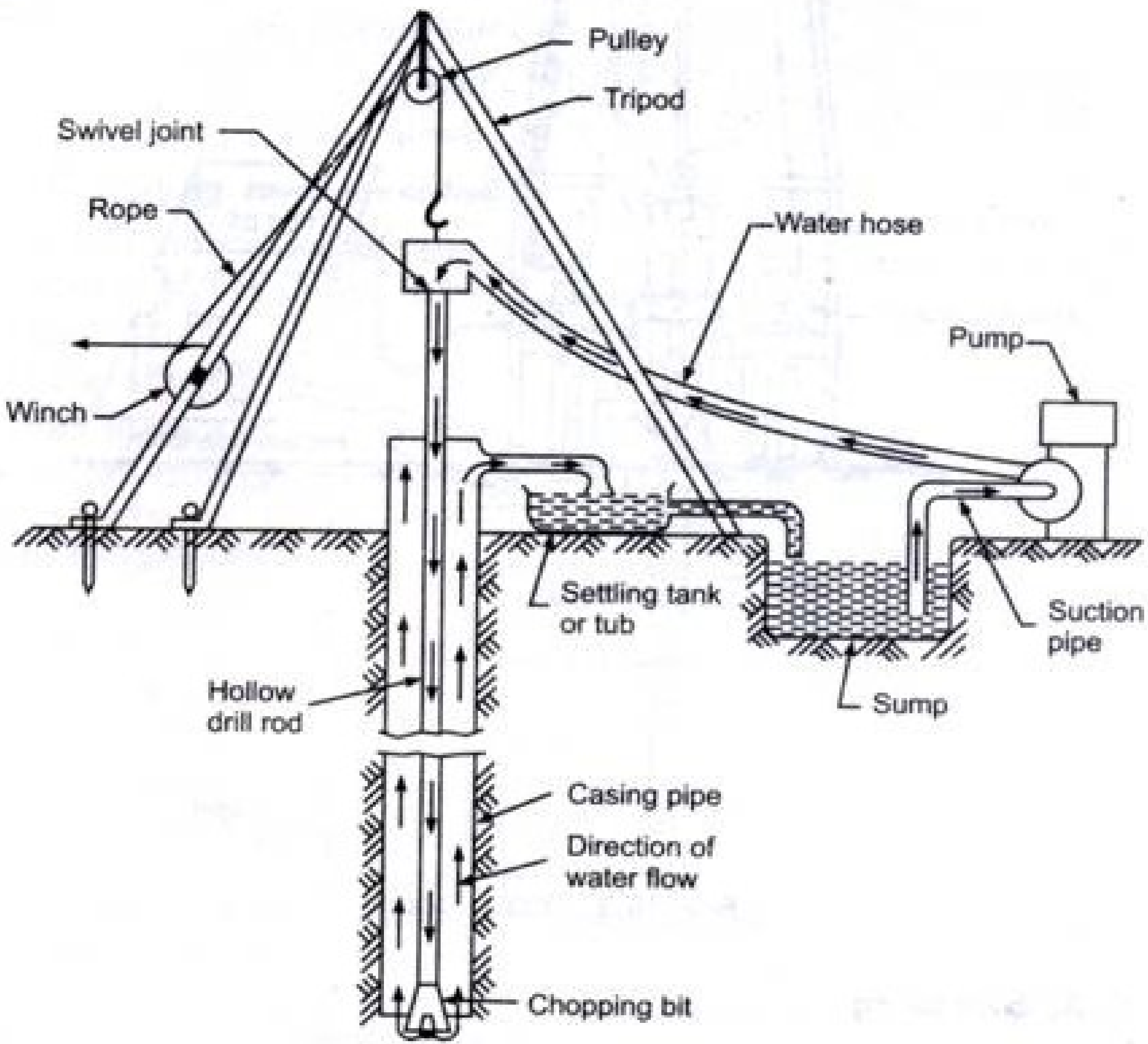


FIG. 10.2 Wash boring

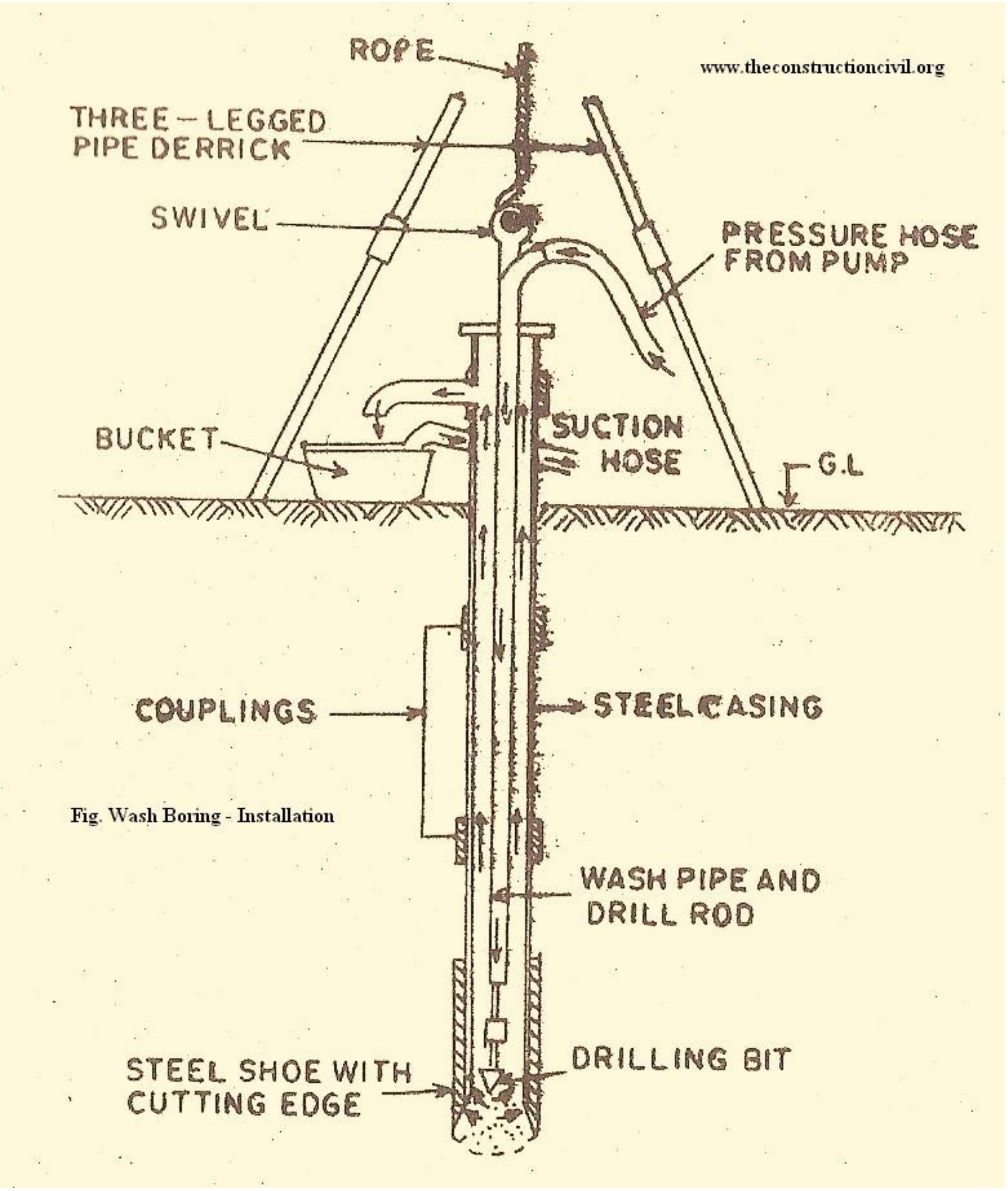


Fig. Wash Boring - Installation

(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.

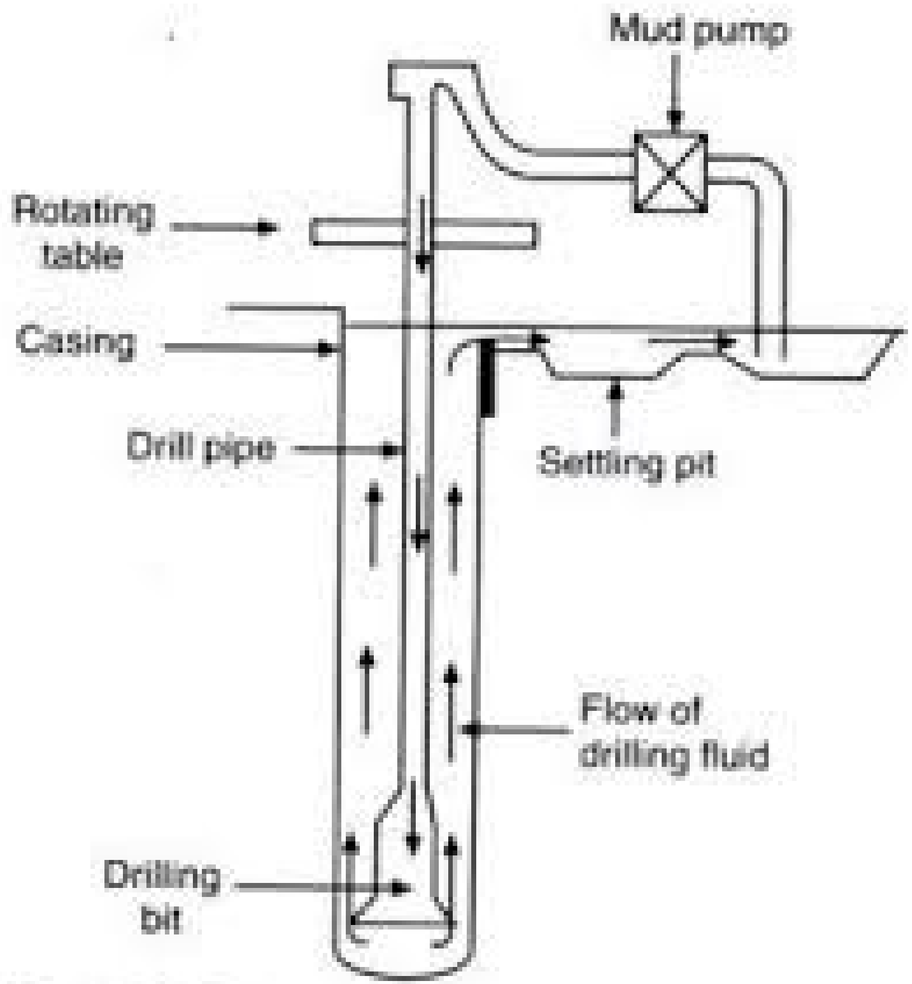


Fig. 18.8. Schematic diagram of rotary method

(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.

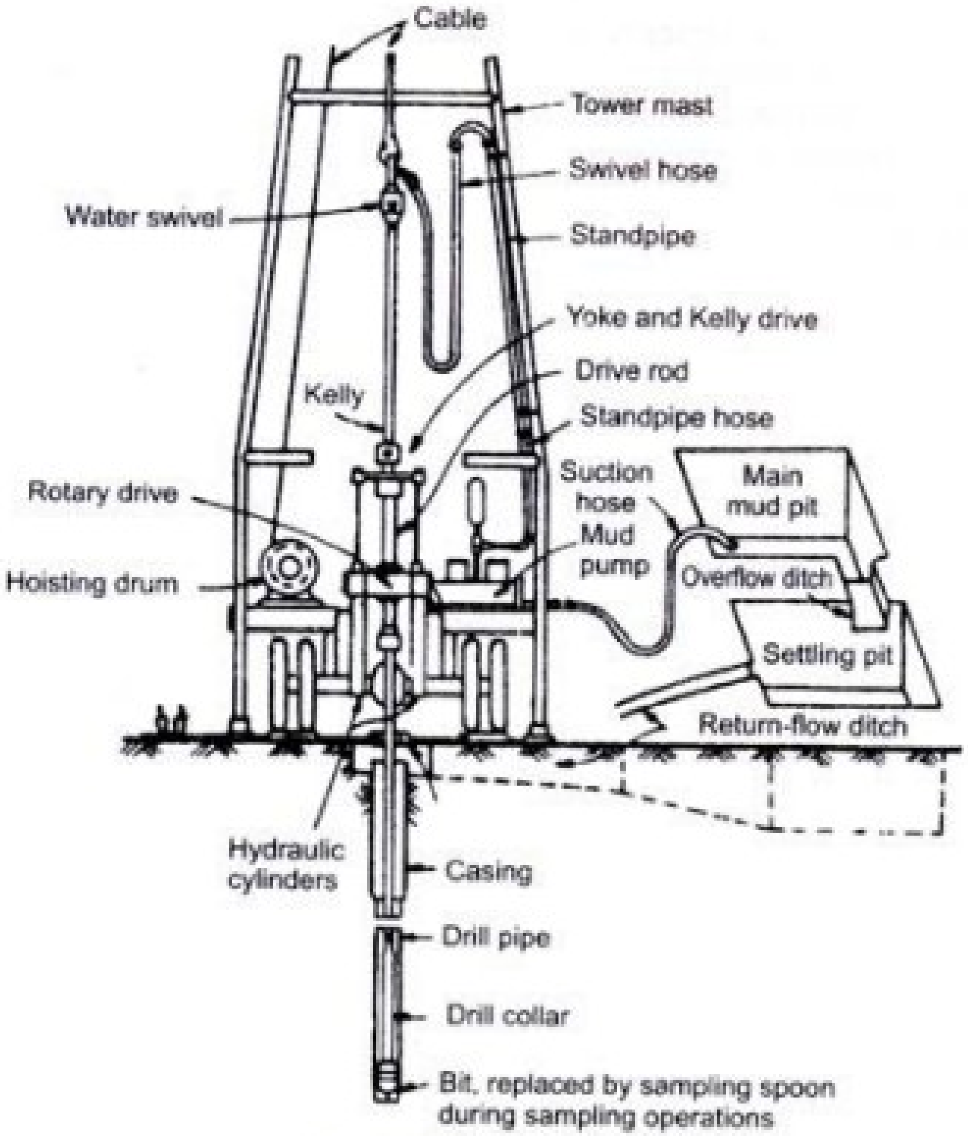
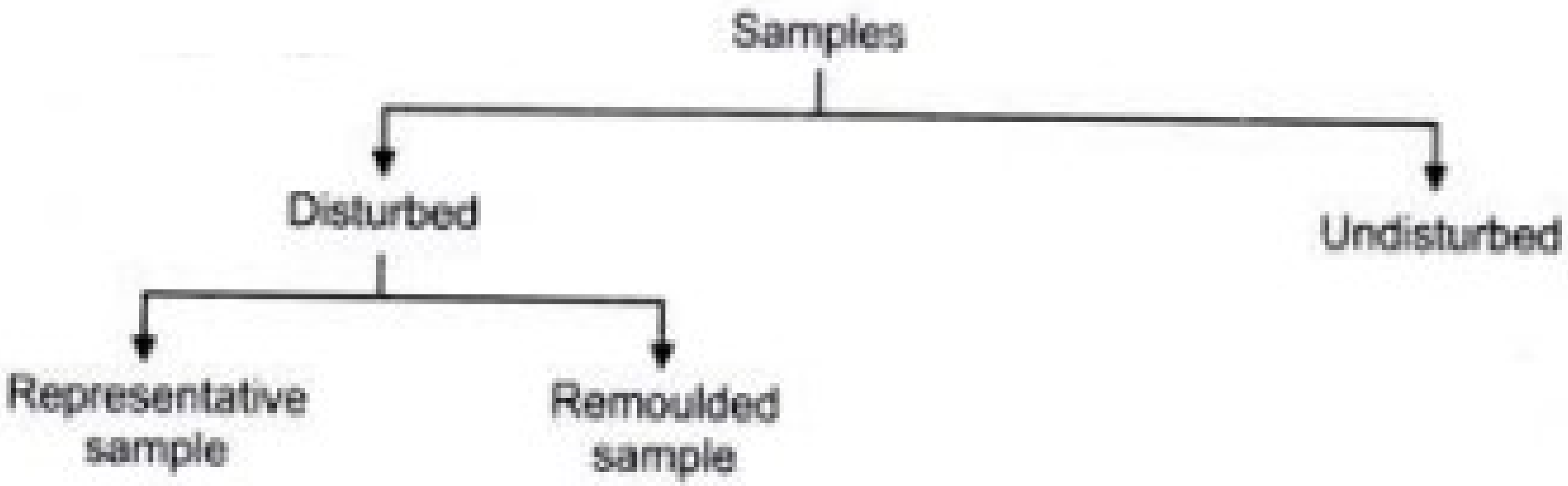


FIG. 10.3 Rotary boring

Soil sampling



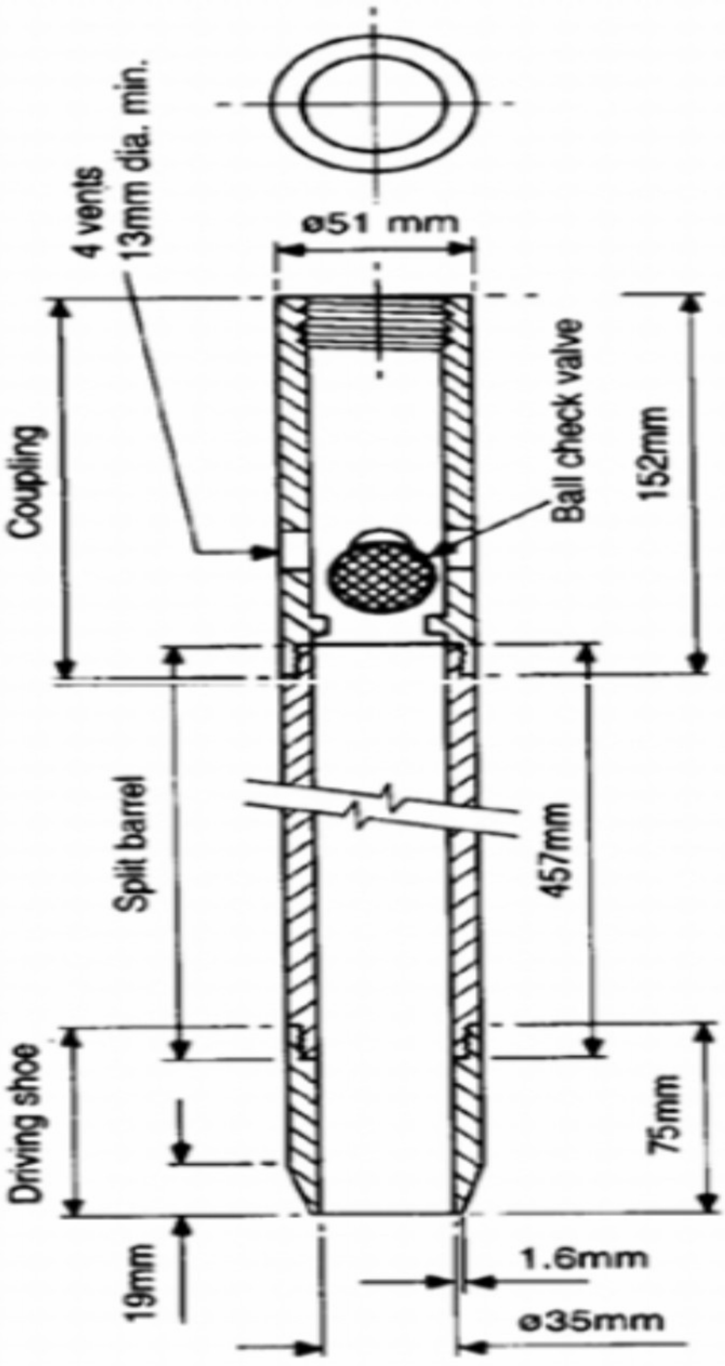
- **Samples which can be taken out from trial pits or boreholes are mainly of two type:**
- **(i) Disturbed sample:**
- Disturbed sample is a sample in which soil structure is significantly or completely disturbed and the moisture content may also differ from in-situ value. The particle size distribution 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 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

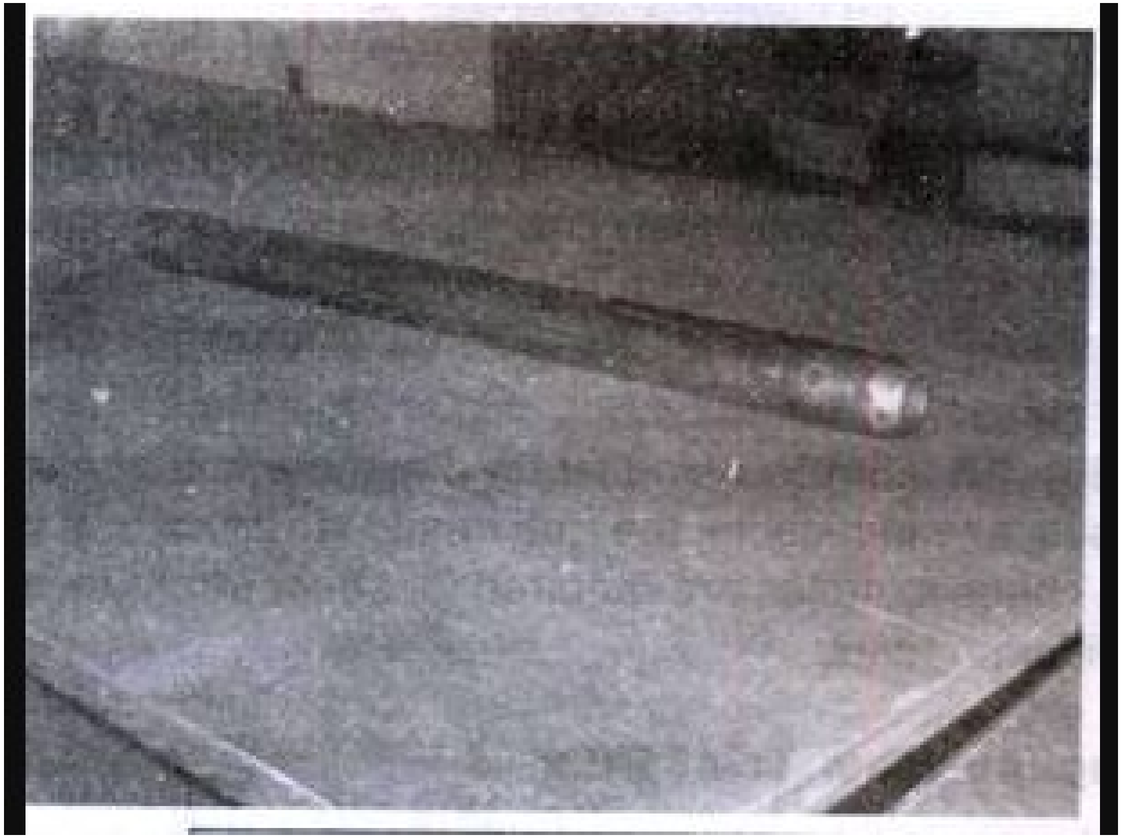
(a) Open drive sampler:

- 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.


4 vents
13mm dia. min.
ø51 mm
Ball check valve
152mm
Coupling
Split barrel
457mm
Driving shoe
75mm
19mm
1.6mm
ø35mm

Split Spoon Sampler

Shelby tube

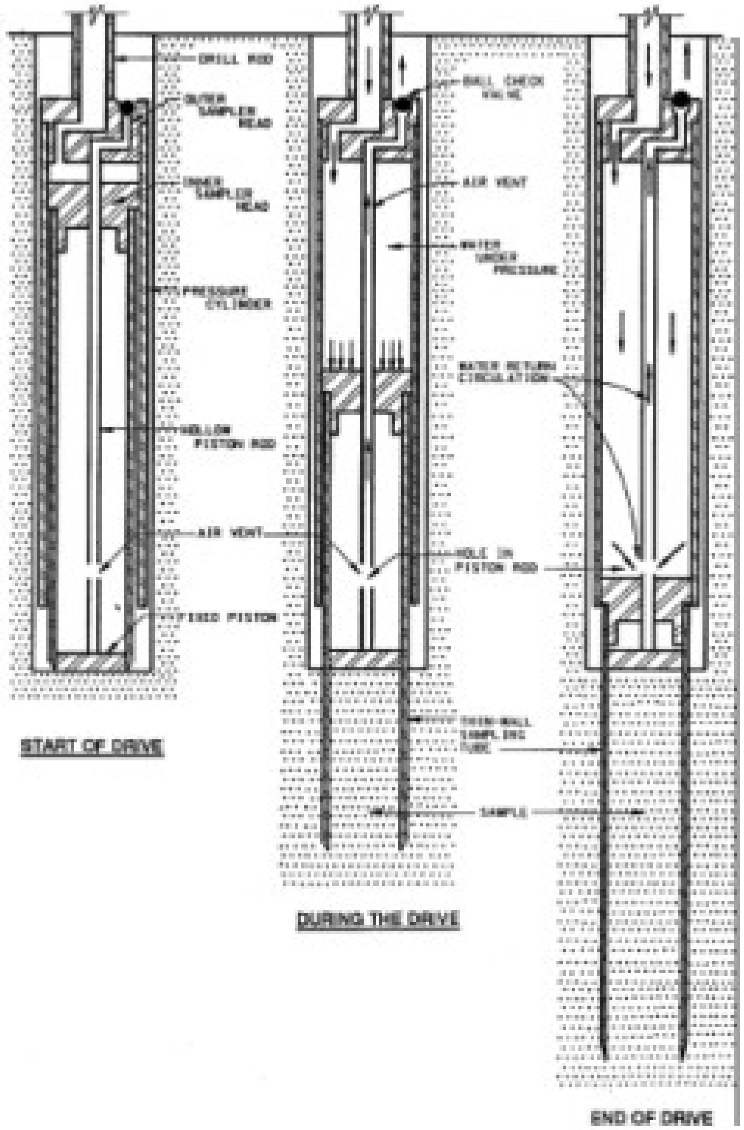


(b) Piston sampler:

- 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.

Stationary piston sampler



Sample disturbance

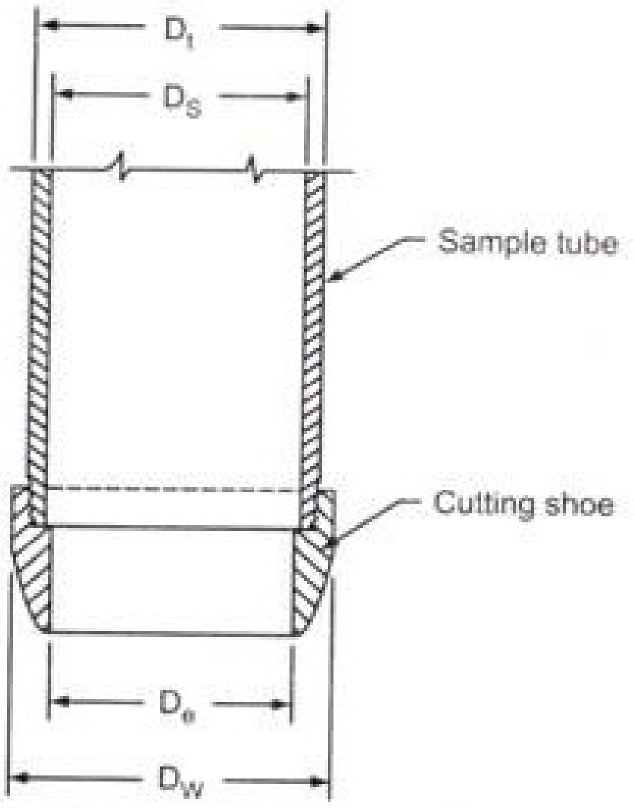


FIG. 10.4 (c) Details of cutting edge

(a) Inside Clearance

$C_i = D_s\text{-}D_e/D_e$

- = 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

$C_0 = D_W - D_t / D_t = 2\text{-}3\%$

- 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

d) Inside wall friction

e) Design of non return wall

f) Method of applying forces

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.

Standard Penetration Test

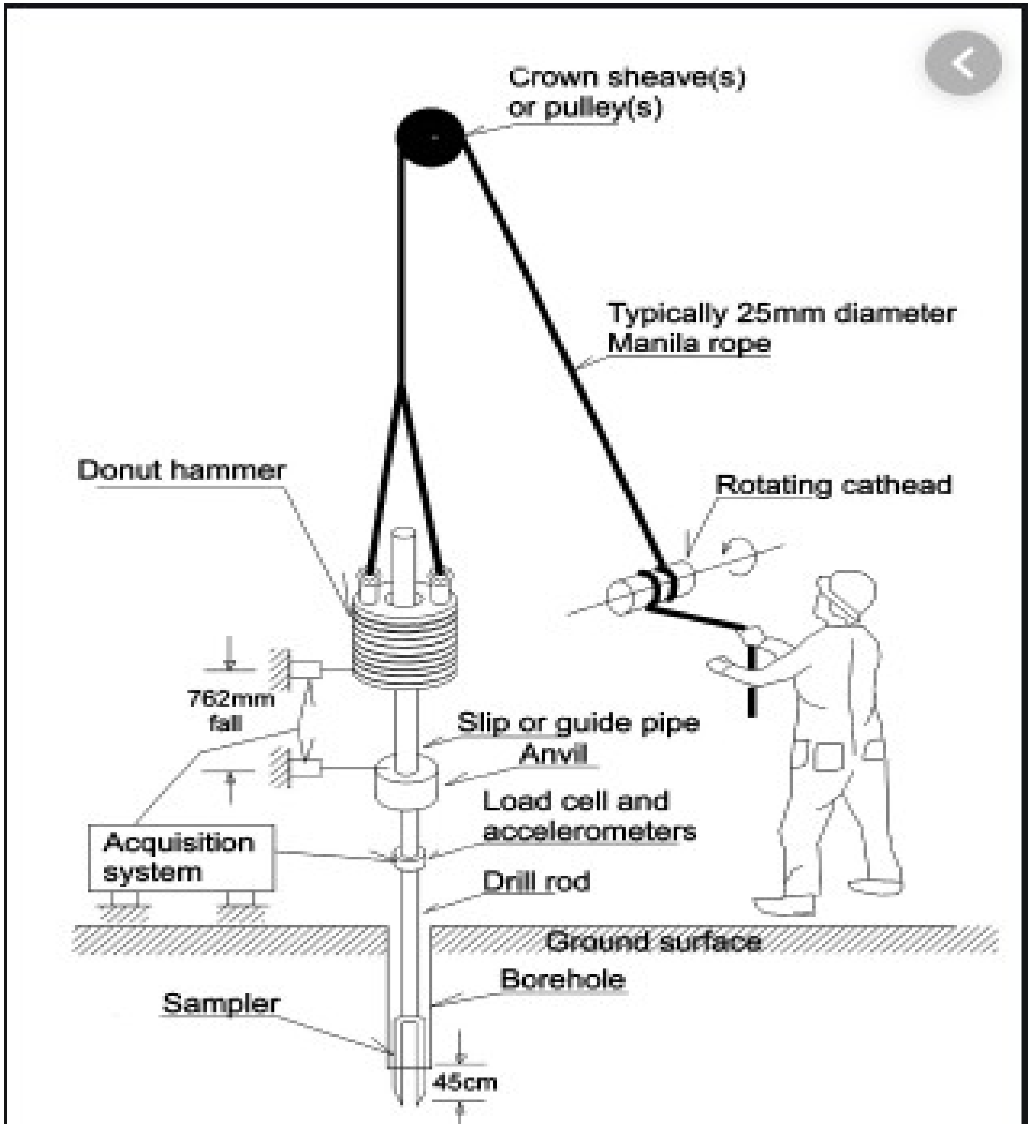


Table 14.5 Correlation for SPT N cohesionless soils

N (Blows)	*Relative Density (%)*	*ϕ (deg.)*	*Compactness*
0–4	0–15	<28	Very loose
4–10	15–35	28–30	Loose
10–30	35–65	30–36	Medium
30–50	65–85	36–41	Dense
>50	85–100	>41	Very dense

SPT Corrections

CORRECTIONS

DILATANCY CORRECTION

- Terzaghi and Peck (1967) recommended the following correction-

$$N_c = 15 + \frac{1}{2}(N_R - 15)$$

Where;

N_c - Corrected Penetration Number

N_R - Recorded Value

- If N_R<=15 ; $N_c = N_R$

Overburden Pressure Correction

CORRECTIONS

1. GIBBS AND HOLTZ' CORRECTION (1957)

- Applicable for $\overline{\sigma_o} \leq 280$ kN/m^2 and for dry or moist clean sand.

$$N_C = N_R \times \frac{350}{\overline{\sigma_o} + 70}$$

where;

N_C – Corrected N-Value

N_R – Observed N-Value

$\overline{\sigma_o}$ – Effective Overburden Pressure (kN/m^2)

- Ratio (N_C/ N_R) should lie between 0.45 and 2.0
- If this ratio is greater than 2.0, N_C should be divided by 2.0 to obtain the design value used in finding the bearing capacity of the soil
- Overburden pressure correction is applied first and then the dilatancy correction is applied.

638 × 479

2. PECK, HANSEN AND THORNBURN'S CORRECTION

- They gave the chart for correction of N-Values to an effective overburden pressue of 96 kN/m^2.
- According to them, for $\overline{\sigma_o} \geq 24$ kN/m^2

$$N = 0.77\ N_R\ \log(\frac{1905}{\overline{\sigma_o}})$$