Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Introduction:

- An investigation of site is essential for judging its suitability for the proposed engineering works and for preparing adequate and economic designs.
- Site investigation is equally necessary for analyzing the safety or causes of failure of existing works, for selecting construction materials and for deciding upon the construction methods to be applied.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Introduction:

- In general, the purpose of a site investigation is to obtain necessary information about the soil and hydrological conditions at the site and to know the engineering properties of soil which will be affected.
- A timely and intelligently planned site investigation should be considered a pre-requisite for efficient, safe, economical design and construction.
- The method of site investigation are largely dependent upon the nature of engineering project and the site.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Introduction:

- In general, any investigation should start with the collection and examination of the already existing data about the soil and geological conditions of the site.
- In many areas, the existing local knowledge, records of trail pits, bore holes etc., in the vicinity and the behaviour of existing structures, particularly if they are similar to the proposed ones, are very helpful.
- The exploration should be preceded by site reconnaissance.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Site Reconnaissance:

- An inspection of the site and study of topographical features is often helpful in getting useful information about the soil and ground water conditions and in deciding the future programme of exploration.
- On going over the site, a study of the following features may be useful: local topography, excavations, cuttings, quarries, evidence of erosion on land slides, fills, water levels in wells and streams, flood marks and drainage patterns etc..

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Soil Exploration:

- The field and laboratory studies carried out for obtaining the necessary information about the subsoil characteristics including the position of ground water table, are termed as soil exploration.

(OR)

- The field and laboratory investigation required to obtain the necessary data for the soil for this purpose are collectively called as soil exploration.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Soil Exploration:

The elements of soil exploration depends mostly on the importance and magnitude of the project, but generally should provide the following:

- Information to determine the type of foundation required such as a shallow or deep foundation.
- Necessary information with regards to the strength and compressibility characteristics of the subsoil to allow the design consultant to make necessary recommendations on the safe bearing pressure.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Objectives of Soil Exploration:

- Determination of the nature of the deposits of soil at the site and its stratification.
- Determination of the depth and thickness of the various soil strata and their extent in the horizontal direction.
- Obtaining disturbed and undisturbed soil samples for visual identification and appropriate laboratory tests.
- The location of ground water and fluctuations in ground water table.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Objectives of Soil Exploration:

- Determining the depth and nature of bed rock.
- Obtaining soil and rock samples form the various strata.
- Determination of the in-situ properties by performing field tests.
- Determination of the engineering properties of the soil and rock strata.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Soil Exploration involves broadly the following:

- Planning of a program for soil exploration.
- Collection of disturbed and undisturbed soil samples from the holes drilled in the field.
- Study of ground water conditions and collection of water samples for chemical analysis.
- Geophysical exploration.
- Conducting all the necessary tests on the samples of soil and water collected.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Soil Exploration involves broadly the following:

- Preparation of drawings, charts etc..
- Analysis of the data collected.
- Preparation of report.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Methods of Exploration:

The sub soil explorations are usually carried out in two stages, namely:

- Preliminary Exploration (or) Investigation.
- Detailed Exploration (or) Investigation.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Preliminary Exploration:

- It consists of the geological study of the site and the site reconnaissance.
- During the site visits, the study of local topography, excavations, cuttings, drainage patterns and other natural features like streams, flood marks etc., will be useful.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Detailed Exploration:

- It follows the preliminary investigation and is normally carried out to determine the nature, sequence and thickness of various subsoil layers, their lateral variation, their physical properties and the positions of ground water table.
- Borings and detailed sampling are usually under taken to obtain this information.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Methods of Soil Exploration:

The various methods of the exploration may be grouped as follows:

- Direct method (or) Open excavations.
- Semi-direct methods (or) Borings.
- Indirect methods (or) Geophysical methods

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Direct Methods or Open Excavation:

- Test pits and trenches can be used for all types of soils.
- Soils can be inspected in their natural conditions and samples of disturbed and undisturbed soil is taken.
- The cost of open excavations, however, increases rapidly with depth.
- They are generally considered suitable for shallow depths upto 3m.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Semi-Direct Methods or Borings: making or drilling bore holes into the ground with a view to obtaining soil from specified or known depths is called boring. The common methods of bore holes are:

- Auger boring.
- Auger and shell boring.
- Wash boring.
- Percussion boring.
- Rotary boring.

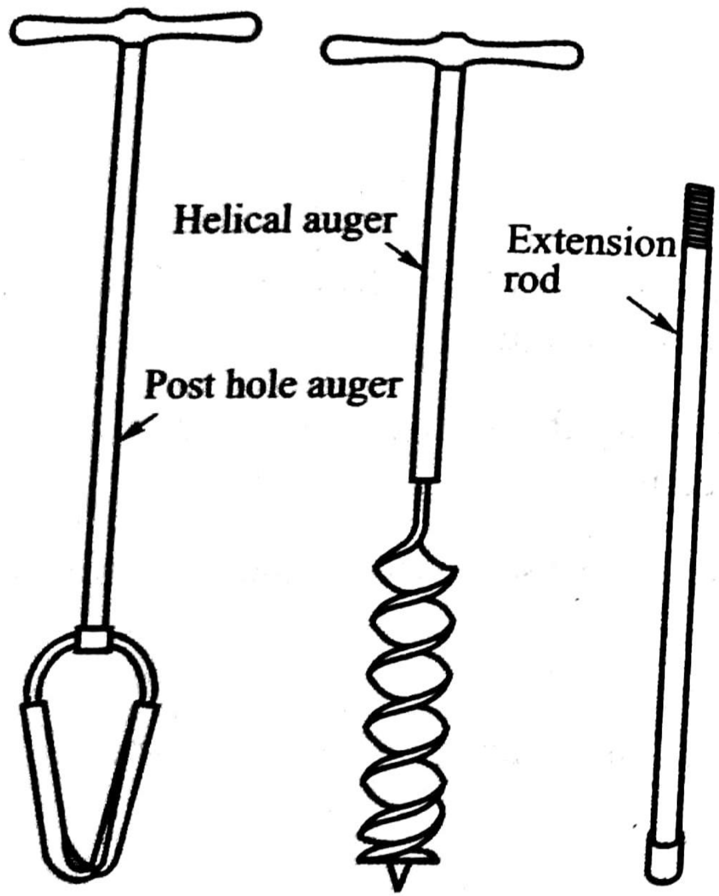


Fig. 17.1 Hand augers

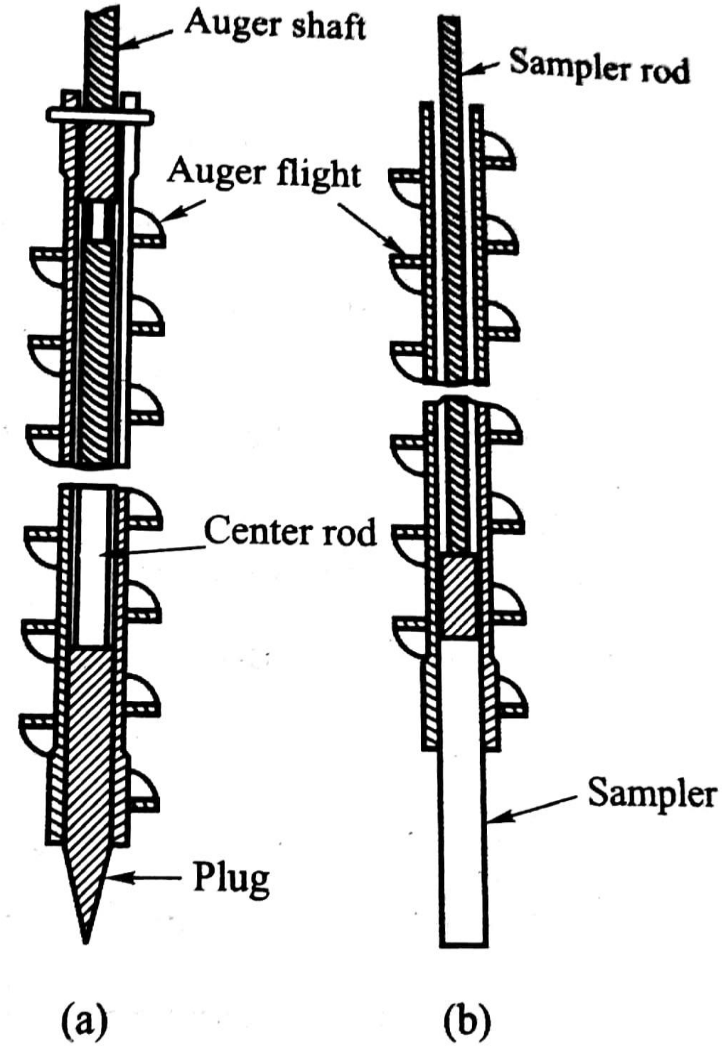


Fig. 17.2 Hollow-stem auger.
(a) Plugged while advancing the auger
(b) Plug removed and sampler inserted to sample soil below auger

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Auger Boring: augers are used in cohesive and other soft soils above the water table. Augers may be operated or power driven.

- Soil auger is a device that is useful for a bore hole into the ground.
- Boring by an auger is carried out by holding it vertically and pressing it down while the auger is rotated.
- The turning actions cuts the soil which fills the annular space.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Auger Boring:

- The hand operated augers are used upto a maximum depth of 10m and generally suitable for all types of soils above the water table.
- The hand operated augers are suitable only below water table in clay soils.
- The diameter of the holes vary from 10 to 20cm.
- In case of power driven augers, a continuous flight of augers are used for greater boring depths.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Auger Boring:

- The power driven augers are suitable in all types of soils.
- Samples obtained from the soils brought up by auger are useful for identification purpose only.
- Auger boring are well suited for exploration for shallow foundations, highways and borrow pits, where the required depth of exploration in relatively small.

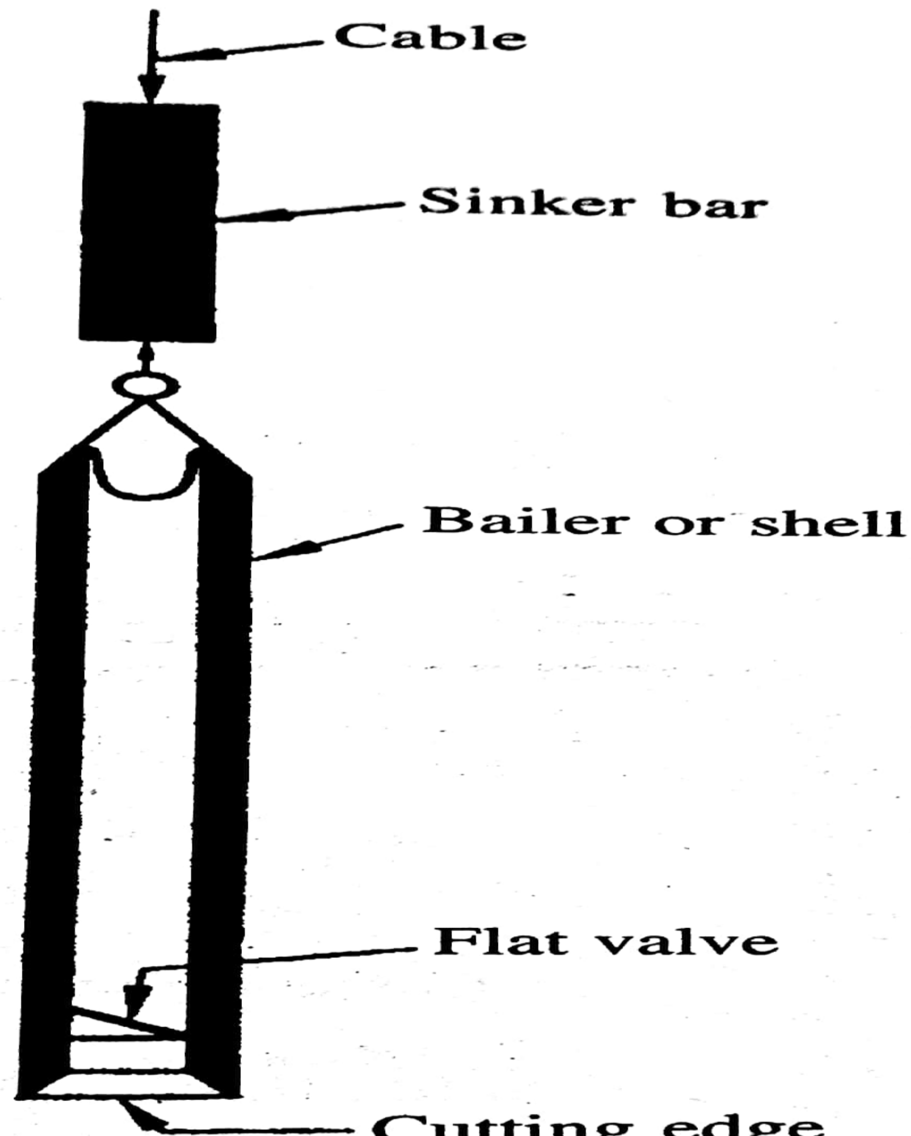


Fig. 17.3 Shell with sinker bar

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Auger & Shell Boring:

- A shell, which is also called as a sand bailer.
- Sand bailer is a heavy duty pipe with a cutting edge.
- The length and weight vary according to requirements.
- The sinker bars are sometimes used to add weight to the bailer.
- The shell is raised and dropped into a hole, which cuts the soil and soil enters the tube.
- Boring is always started, to begin with by augering and the shell is used when augering becomes difficult.

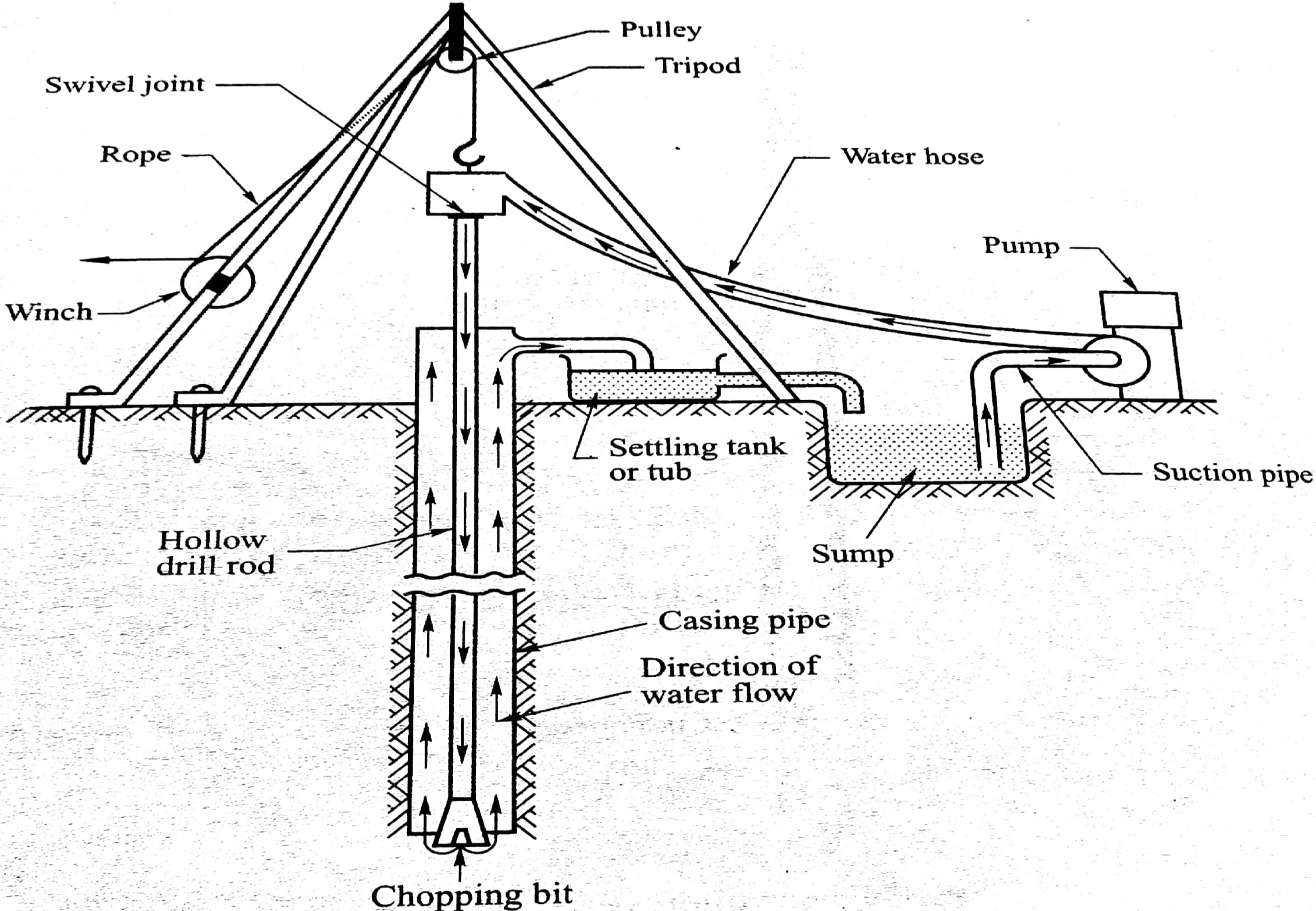


Fig. 17.4 Wash boring

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Wash Boring:

- Wash boring is a fast and simple method used for exploration below ground water table for which the auger method is unsuitable.
- This method is used in all kinds of soils except those mixed with gravel and boulders.
- The method consists of driving a casing pipe usually through a heavy drop hammer supported on a tripod and pulley.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Wash Boring:

- The hole is then continued by the use of a chopping bit fixed at the end of a string of hollow drill rods.
- Water is forced under pressure through a hollow drill rod which may be rotated or moved up and down inside the casing pipe.
- The soil thus cuts gets mixed with water and floats up through the annular space between the casing pipe and the drill rod.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Wash Boring:

- The slurry get discharged into a tub.
- Thus soil in suspension settles down in the tub and the clean water flows into a sump which is reused for circulation.
- Wash boring can be conveniently used even below water table in practically all types of soils expect hard soils or rocks.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Percussion Boring:

- Percussion boring or drilling is an alternative method of advancing a bore hole, particularly through hard soil and rock.
- In this method, a heavy drilling bit is raised and lowered to chop the hard soil.
- Casing is required for this type of drilling.
- The bore hole is usually kept dry, except for a limited quantity of water used to form the slurry of pulverized material.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Rotary Boring:

- Rotary boring is a very fast method of advancing hole in both rocks and soils.
- 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.
- A drilling mud is continuously forced down the hollow drill rods.
- The mud returning upwards through the annular space brings the cuttings to the surface.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Rotary Boring:

- This method is also known as mud rotary drilling.
- Core barrels with diamond bits are also used in rotary drilling and enables the simultaneously obtaining of rock cores. This method is known as core drilling.
- Shot drilling is also used for drilling of holes over 150mm.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Indirect Method or Geophysical Method: The common used methods of bore holes are as follows:

- Seismic refraction method.
- Electrical resistivity method.

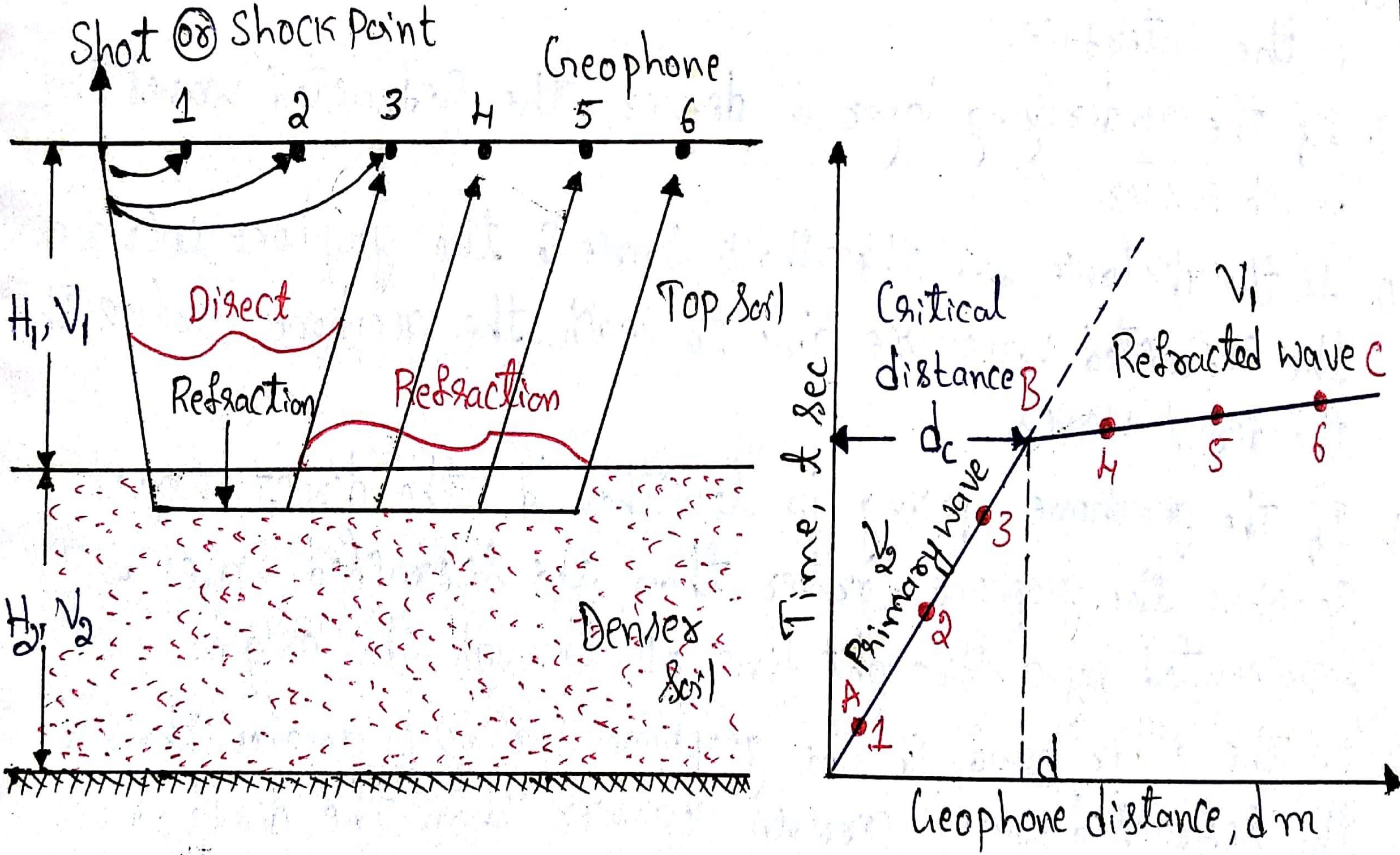


Fig:- SCHEMATIC REPRESENTATION OF SEISMIC REFRACTION METHOD

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Seismic Refraction Method:

- The method is based on the fact that seismic waves have different have different velocities in different types of soils or rock.
- The waves are refracted when they cross the boundary between different types of soil.
- The method enables the determination of the general soil types and the approximate depth of boundaries of bed rock.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Seismic Refraction Method:

- In this method, shock waves are generated by exploading a small charge at or near the ground surfaces.
- The radiating shock waves are recorded by a device called geophone which records the time of travel of the waves.
- The geophones are installed at suitable known distances on the ground in a line from the source of shock to produce shock waves at given intervals.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Seismic Refraction Method:

- Some of the waves, termed as direct or primary waves travel directly from the shock source along the ground surface and are picked up first by the geophone.
- Other waves travel in a download direction will be refracted at the interface.
- If the underlying layer is denser, the refracted waves travel much faster.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Seismic Refraction Method:

- As the distance between the shock source and the geophone increases, the refracted waves are able to reach the geophone earlier than the direct waves.
- If the geophone spacing is less than d, the direct waves reaches the geophone earlier than the refracted waves is represented by a straight line AB through the origin.
- On the other hand, if the geophone spacing is greater then d, the refracted waves arrives earlier than the direct waves is represented by a straight line BC.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Seismic Refraction Method:

- The slopes of lines AB and BC are the seismic velocities V1 and V2.
- The general types of soil or rock can be determined from a knowledge of these velocities.
- The depth of the boundary between the two strata can be estimated from the equation:

$$H_1 \text{ or } D = (d/2) \times \sqrt{(V_2 - V_1) / (V_2 + V_1)}$$

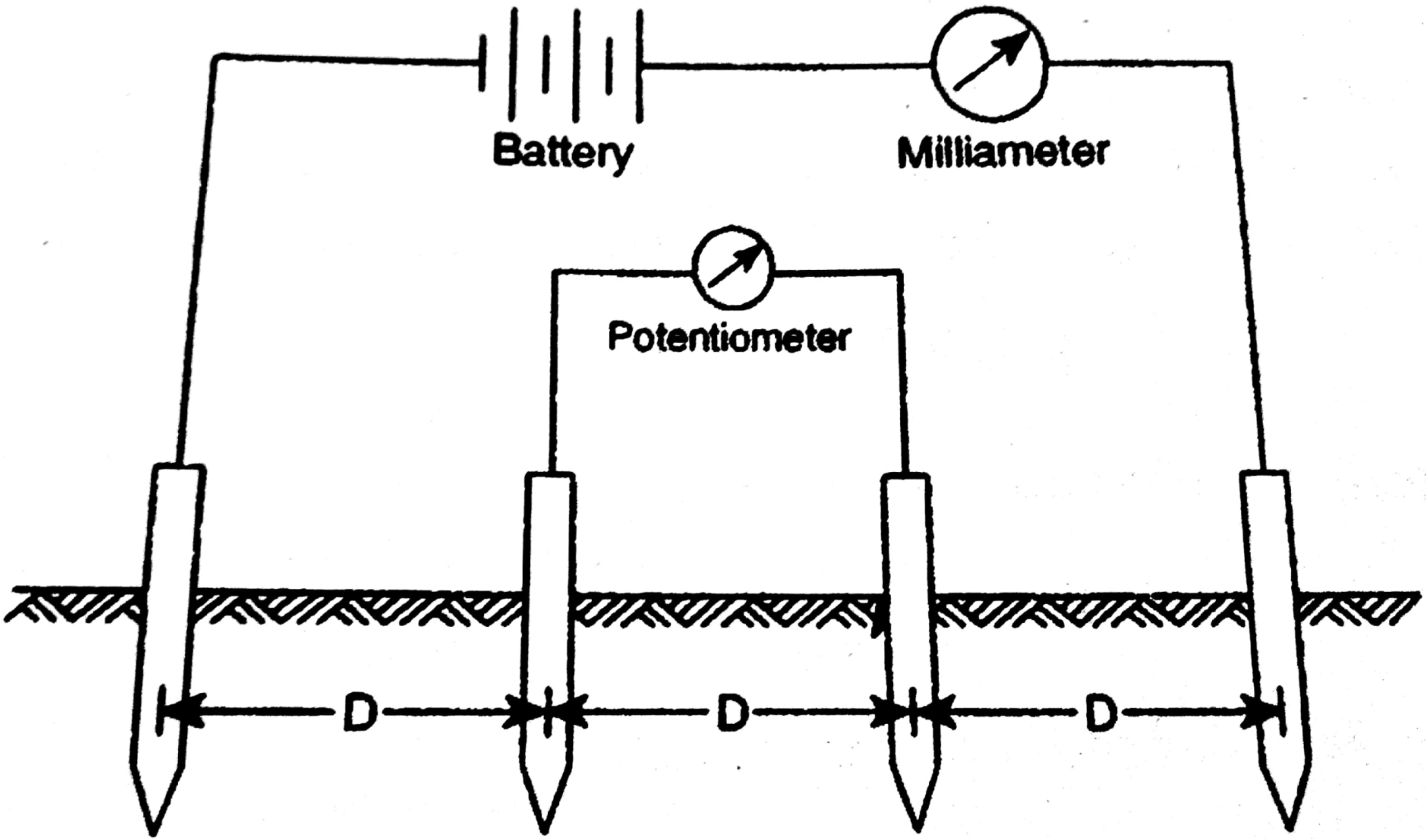


FIG. 32.8. RESISTIVITY METHOD

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Electrical Resistivity Method:

- The resistivity is usually defined as the resistance between the opposite faces of a unit cube of a material.
- The electrical resistivity method is based on the measurement and recording of changes in the mean resistivity or apparent specific resistance of various soils.
- Variations in resistivity can be detected between different types of soil strata, above and below the water table.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Electrical Resistivity Method:

- The test is carried out by driving four metal spikes to serve as electrodes into the ground along a straight line at equal distances.
- Current from a battery, flows through the soil between the two outer electrodes producing an electrical field within the soil.
- The potential difference between the two inner electrodes is then measured.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Types of Samples:

Soil samples can be classified into two categories, namely:

- Disturbed sample.
- Undisturbed sample.

Disturbed sample is further subdivided into two types, namely.

- Representative sample.
- Non-representative sample.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Types of Samples:

Disturbed sample: is that in which the natural structure of the soil gets modified partly or fully during sampling.

Undisturbed sample: is that in which the natural structure and other physical properties of soil remain preserved.

Representative sample: with suitable precautions, the natural moisture content and the proportion of mineral constituents can be preserved.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Types of Samples:

Non-representative Sample: in addition to alteration in the original soil structure, soils from other layers get mixed up or the mineral constituents get altered.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Types of Samplers:

Depending upon the mode of operation, samplers may be classified as the following:

- Open drive sampler.
- Stationary piston sampler.
- Rotary sampler.

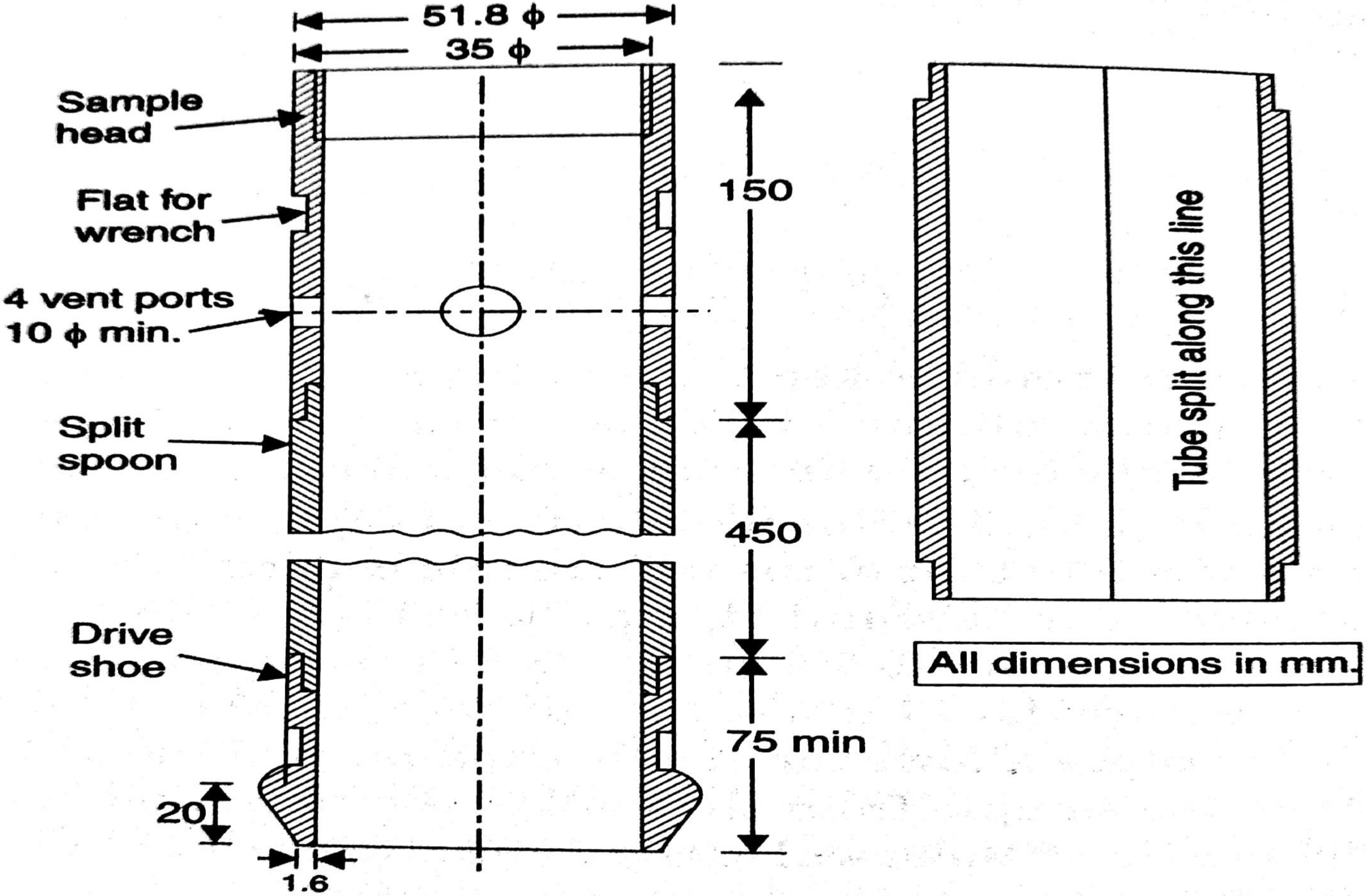


Fig. 18.6 Split spoon sampler (I.S.)

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Open Drive Sampler:

- This sampler essentially consists of a open end steel tube with a cutting edge.
- The tube is connected through a head to the drill rod.
- The head of the sampler is provided with vents or valve to permit water and air to escape during driving.
- The ball check-value helps to retain sample when the sampler is lifted up.
- The sampling tube may be thick-walled or thin-walled.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Stationary Piston Sampler:

- This sampler consists of a piston attached to a long piston rod extending upto the ground surface through drill rod.
- The lower end of the samples is kept closed with the piston while the sampler is lowered through the bore hole.
- When the desired elevation is reached, the piston rod is clamped, there by keeping the piston stationary and the sampler tube is pushed further into the soil.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Stationary Piston Sampler:

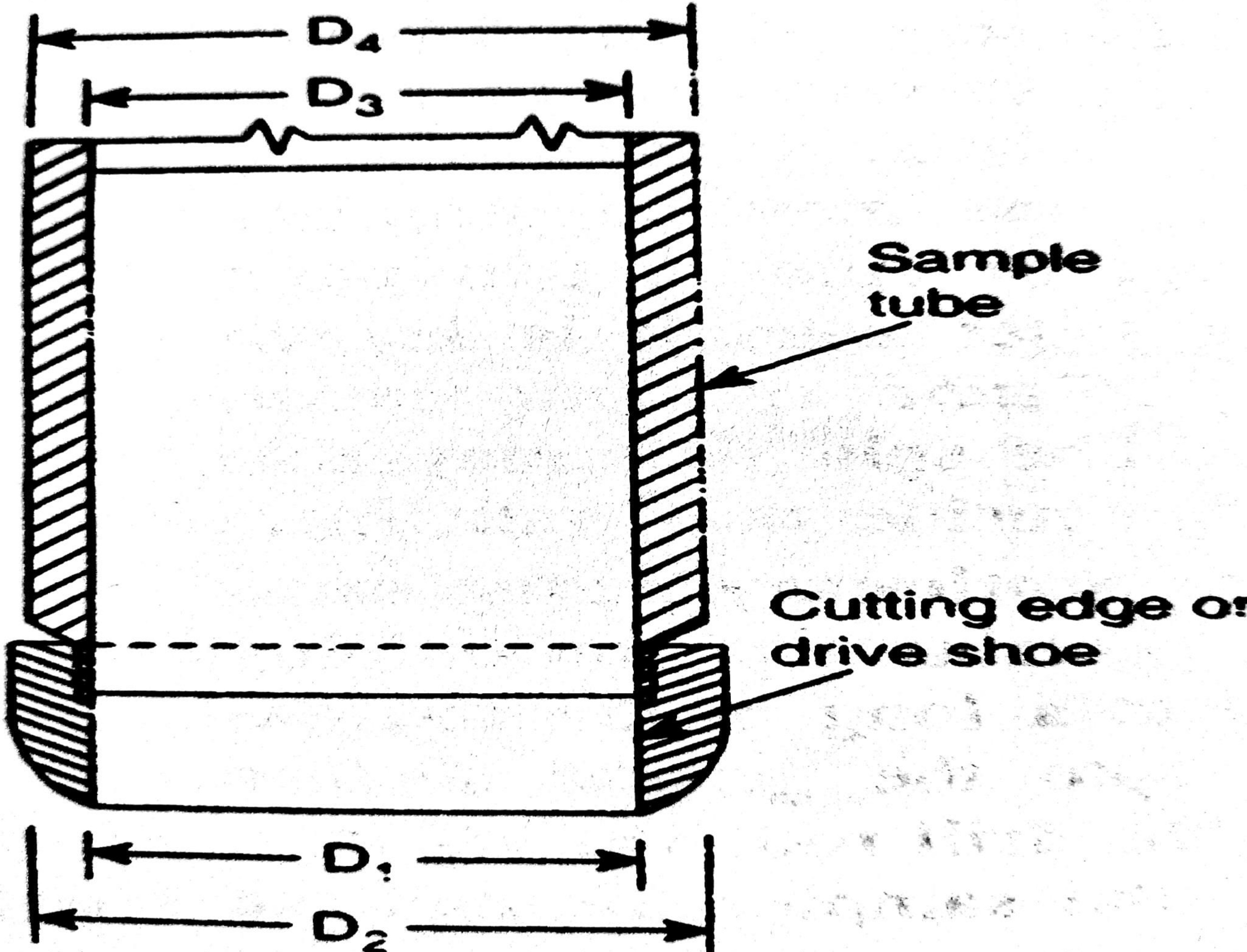
- The sampler is then lifted up and the piston rod clamped in position.
- The piston prevents the entry of water and soil into the tube when it is being lowered and also helps to retain the sample during the process of lifting the tube.
- The sampler is useful in sampling saturated sands and other soft and wet soils.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Rotary Sampler:

- This is a double-walled tube sampler with an inner removable liner.
- The outer tube is provided with a cutting edge.
- The cutting edge cuts an annular ring when the outer tube is rotated.
- The sample is collected in the inner liner.
- This samplers are useful for sampling in firm to hard cohesive soils and particularly in rocks.


D4
D3
Sample tube
Cutting edge or drive shoe
D1
D2

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Sample Disturbance:

- D_1 = Inner diameter of cutting edge.
- D_2 = Outer diameter of cutting edge.
- D_3 = Inner diameter of sampling tube.
- D_4 = Outer diameter of sampling tube.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Sample Disturbance:

According to sample disturbance the following four types are given below:

- Area Ratio. A_r
- Inside Clearance. C_i
- Outside Clearance. C_o
- Recovery Ratio. R_r

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Sample Disturbance:

Area Ratio: $A_r = ((D_2^2 – D_1^2) / D_1^2) \times 100$.

Inside Clearance: $C_i = ((D_3 – D_1) / D_1) \times 100$.

Outside Clearance: $C_o = ((D_2 – D_4) / D_4) \times 100$.

Recovery Ratio: $R_r = (L / H) \times 100$.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Stabilization of Bore Holes:

In all types of drilling the sides of the holes may be stabilized, if required, by the use of drilling mud or casing pipes.

- A drilling mud is nothing but bentonite clay mixed in water.
- Which can be mixed in powder form to the drilling water to create higher density suspension.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Advantages of Stabilization of Bore Holes:

- It is advantageous over water.
- It is more viscous and can therefore lift cuttings adequately at lower velocity.
- The cake formed on the outside of the bore hole improves bore hole stability.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Dis-Advantages of Stabilization of Bore Holes:

- The bentonite mud soil cakes are difficult to dispose off at the end of drilling.
- Bentonite mud must be properly mixed, using approximate equipment in order to ensure the dryness.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Boring Log or Borehole Logs or Bore Logs:

- Information on subsurface conditions obtained from the boring operation is typically presented in the form of a boring record, commonly known as boring log.
- The method of investigation and details of the equipment used should be stated on each log.
- The location, ground level and diameter of the hole should be specified.
- The log should include the difficulties faced during boring operation including the occurrence of sand boils and the presence of water conditions if any.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

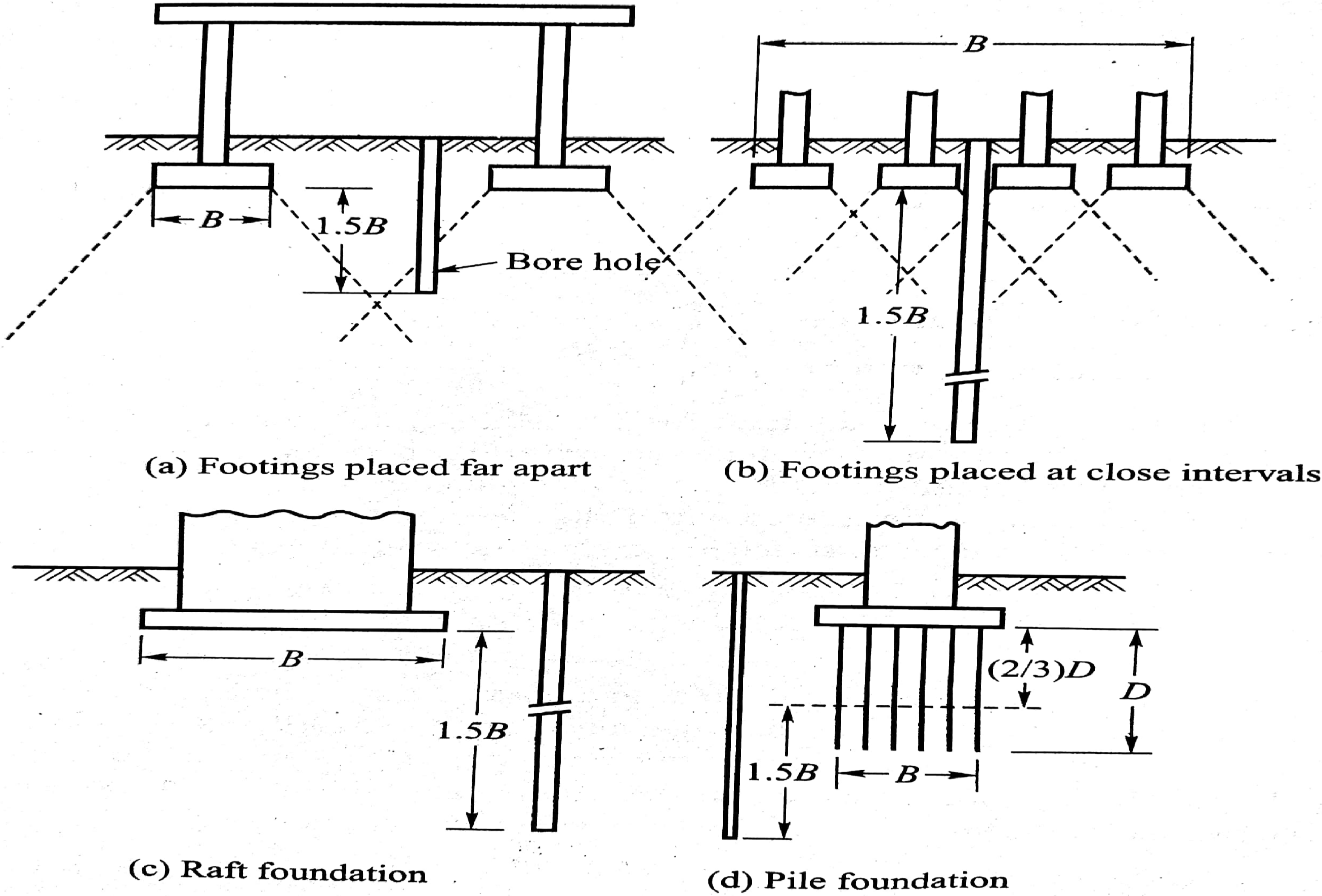
Boring Log or Borehole Logs or Bore Logs:

- The field log will consists of this minimum information, while a lab log might include test data presented alongside the boring sample actually tested.
- A typical example of a boring log is given below.

Soil Type		Level m	Depth m	SPT 15 cm	15 cm	15 cm	N	Sample type	Remarks
Yellowish stiff clay			1.0	4	6	8	14	D U	
		62.3							
Greyish sandy silt med. dense			3.3	7	10	16	26	D W	
		59.8							
Greyish silty sand dense			5.0	14	16	21	37	D	
			7.5	15	18	23	41	D U	
		56.3							
Blackish very stiff clay			9.0	9	10	14	24	D	
		53.3	11.0						

D = disturbed sample; U = undisturbed sample;
W = water sample; N = SPT value

Fig. 17.18 A typical bore-hole log



(a) Footings placed far apart

(b) Footings placed at close intervals

(c) Raft foundation

(d) Pile foundation

Fig. 17.17 Depth of Bore holes

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Depth of Borings:

- The depth upto which bore holes should be sunk depends upon the type of proposed structures, its total weight, the size, shape and disposition of the loaded area, soil profile and the physical properties of the soil that constitutes each individual stratum.
- The standard practice is to take boring upto a depth called significant depth at which the excess vertical stress caused by a fully loaded foundation is of the order of 20%.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Depth of Borings:

- The depth of bore hole as per practice works out to be 1.5 times the least width of the foundation from the base level of the foundation.
- Where strip or pad footings are closely spaced which results in the overlapping of the stressed zones, the whole loaded area becomes in effect a raft foundations with corresponding deep borings.
- In any case, the depth to which seasonal variations affect the soil should be regarded as the minimum depth for the exploration of the sites.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Penetrometer Tests:

- Standard Penetration Test (SPT)
- Static Cone Penetration Test or Dutch Cone Test (CPT)
- Dynamic Cone Penetration (DCPT)
- In-situ Vane Shear Test (VST)

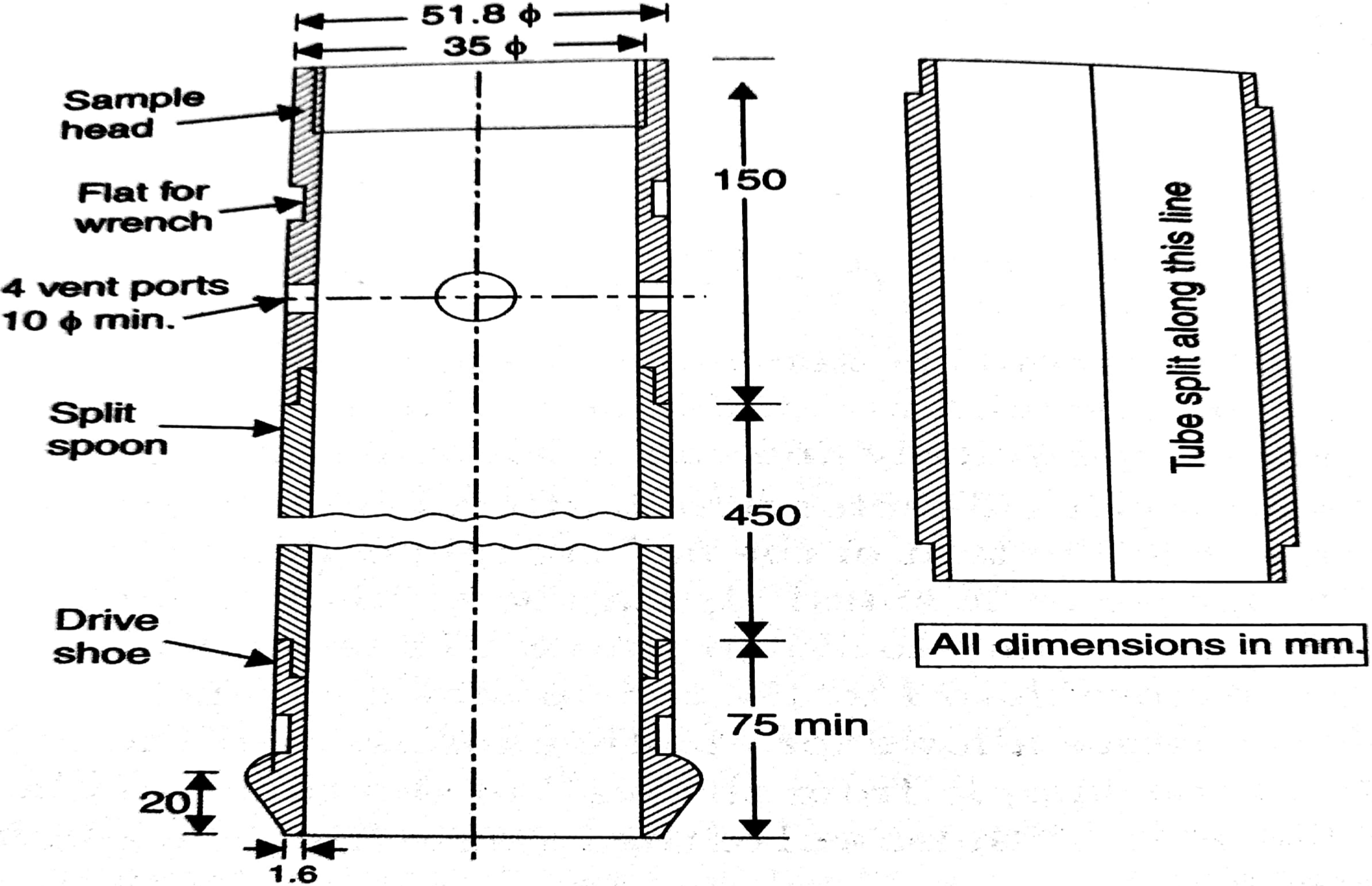


Fig. 18.6 Split spoon sampler (I.S.)

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Standard Penetration Test:

- The standard penetration test is widely used to determine the parameters of the soil in-situ.
- The test consists of driving a split spoon sampler into the soil through a bore hole 55 to 150mm diameter at the desired depth and the bottom cleaned.
- The split spoon sampler is driven into the soil for a distance of 450mm by blows of a drop hammer of 65 kg falling vertically and freely from a height of 750mm.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Standard Penetration Test:

- The number of blows required to penetrate every 150mm is recorded while driving the sampler.
- The number of blows required for the last 300mm of penetration is added together and recorded as the N value at that particular depth of the bore hole.
- The split spoon sampler is then withdrawn and is detached from the drill rods.
- The split barrel is disconnected from the cutting shoe and the coupling.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Standard Penetration Test:

- The soil sample collected inside the split barrel is carefully collected so as to preserve the natural moisture content and transported to the laboratory for tests.

Two types of corrections are applied to the observed N values:

- Correction for overburden pressure.
- Correction for dilatancy.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Correction for Overburden Pressure:

- Several investigators have found that the penetration resistance or the N value in a granular soil is influenced by the overburden pressure.
- Since the confining pressure increases with depth, the N values at shallow depths are underestimated and the N values at larger depths are overestimated.
- To allow for this, N values recorded from the field tests at different effective overburden pressure are corrected to a standard effective overburden pressure.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Correction for Overburden Pressure:

- The corrected N value is given by

$$N' = C_N N$$

Where N' = Corrected value of observed N

C_N = Corrected factor for overburden pressure

$$C_N = 0.77 \log_{10} (20 / P)$$

$$C_N = 0.77 \log_{10} (2000 / P)$$

Where P = Effective overburden pressure at the depth at which N is measured in kN/m^2.

Geotechnical Engineering (18CV54)

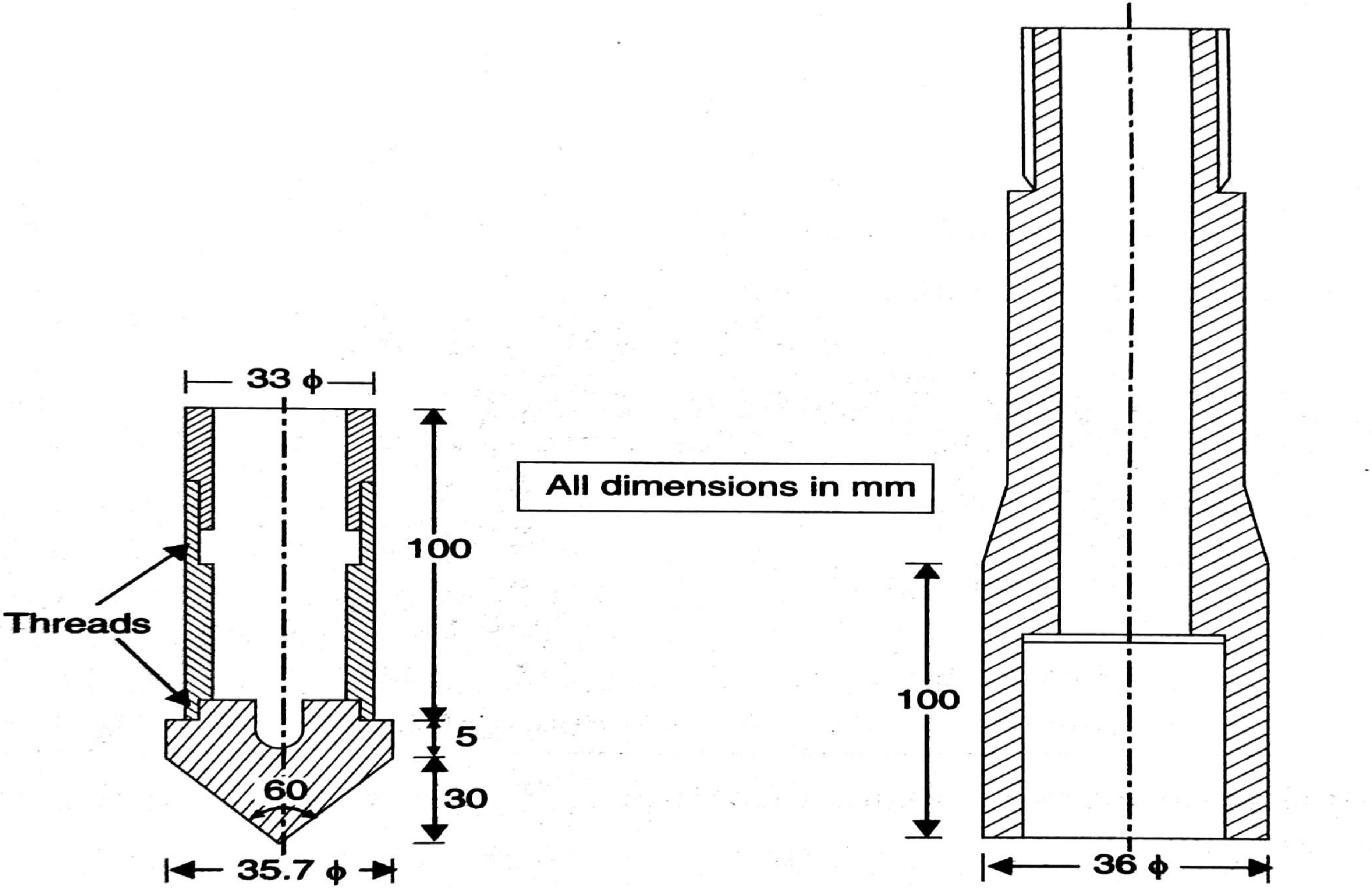
Module – 4: Soil Exploration

Correction for Dilatancy:

- Dilatancy correction is to be applied when N' obtained after overburden correction exceeds 15 in saturated fine sands and silts.
- Terzaghi and Peck recommended dilatancy correction using the equation

$$N'' = 15 + 0.5\,(N' - 15)$$

Where N'' = Final corrected value to be used in design charts.



(a) Cone assembly

(b) Friction jacket

Fig. 18.9 Cone assembly and friction jacket for static cone penetration test (IS)

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Static Cone Penetration Test:

- The equipment consists of a steel cone, a friction jacket, rod, tube, a driving mechanism and measuring equipment.
- This test is used for getting a continuous record of the resistance of soil by penetrating steadily under static pressure a cone of base $10 cm^2$ and angle of 60° at the vertex.
- The cone is carried at the lower end of a steel driving rod which passes through a steel tube with external diameter equal to the base of the cone.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Static Cone Penetration Test:

- The cone or a tube or both together can be forced into the soil by means of jacks.
- To determine the cone resistance, the cone alone is first forced down for a distance of 8cm and maximum value is recorded.
- The steel tube is then pushed down upto the cone, and both together are further penetrated through a depth of 20cm to given total cone resistance and the frictional resistance along the tube.

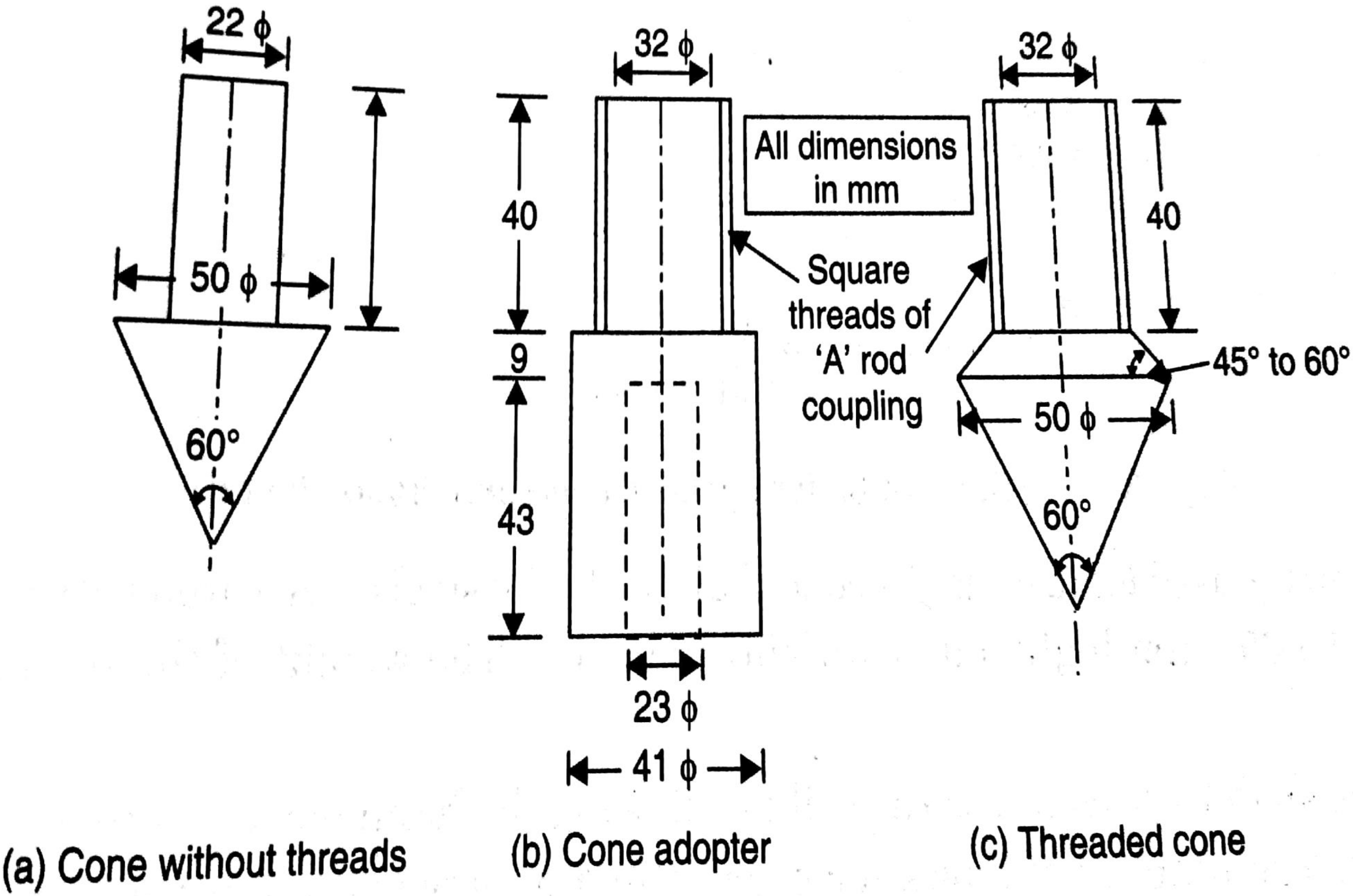


Fig. 18.10 Cone details for dynamic cone penetration test (IS)

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Dynamic Cone Penetration Test:

- The equipment consists of a cone, driving rod, driving head, hoisting equipment and a hammer.
- In this test, a cone which has an apex angle of 60° is attached to drill rod and it is driven into the soil by giving blows of a hammer of 65 kg, falling freely from a height of 750mm.
- The blow count for every 100mm penetration of the cone is recorded.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Dynamic Cone Penetration Test:

- The cone is driven upto the required depth and the drill rod are withdrawn, leaving the cone in the ground.
- The number of blows required for 300mm penetration is noted as the dynamic cone resistance.
- This test are performed either by using a 50mm diameter cone without bentonite slurry or a 65mm diameter cone with bentonite slurry.
- The dynamic cone test is a quick test and helps to cover a large area under investigation rather economically.

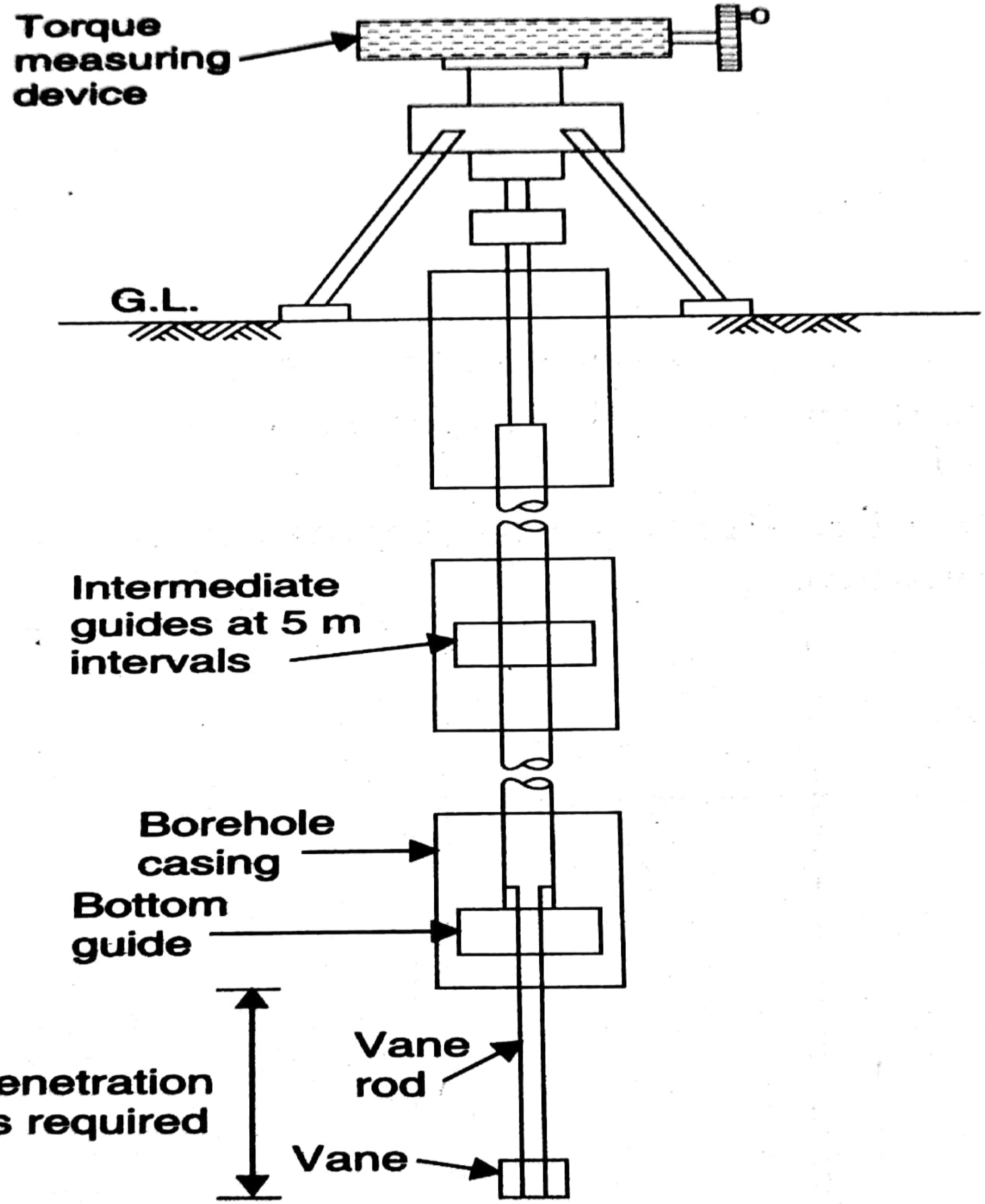


Fig. 18.13 Arrangement for vane test, from bottom of bore hole (IS)

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

In-situ Vane Shear Test:

- In-situ vane shear test is best suited for the determination of shear strength of saturated cohesive soils, especially of sensitive clays.
- The equipment consists of a shear vane, torque applicator, rods with guides, drilling equipment and jacking arrangement.
- The vane is pushed with a steady force upto a depth of four times the diameter of the bore hole, below the bottom.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

In-situ Vane Shear Test:

- Torque is not applied during the thrust.
- Torque applicator is tightened to the frame properly.
- After 5 minutes, the gear handled is turned so that the vane is rotated at the rate of 0.1° per second.
- The maximum torque reading is noted when the readings drop appreciably form the maximum.
- The torque is calculated by using the equation

$$\tau = (T / \pi D^2 \{ H / 2 + D / 6 \})$$

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

In-situ Vane Shear Test:

Where τ = Shear strength

T = Torque

D = Overall diameter of the vane

H = Height of the vane

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Soil Exploration Report:

- Scope of investigation.
- General description of the proposed structure for which the exploration has been conducted.
- Geologic conditions of the site.
- Drainage facilities at the site.
- Details of boring.
- Description of subsoil conditions.
- Ground water table as observed from the bore holes.

Geotechnical Engineering (18CV54)

Module – 4: Soil Exploration

Soil Exploration Report:

- Details of foundation.
- Limitations of the investigation.
- Graphical presentations of site location map, location of borings, boring logs, laboratory test results, other special presentations.

Geotechnical Engineering (18CV54)

Module – 4: Drainage and Dewatering

Introduction:

- The removal of excess water from the saturated soil mass is termed as drainage or dewatering.
- In many civil engineering problems, such as excavations for basements and foundations of buildings, foundations of dams, or laying sewer lines, the excavations are often carried below water table.
- Such excavations require lowering of water table below the bottom of excavation to prevent sloughing of the sides and to get dry working conditions.

Geotechnical Engineering (18CV54)

Module – 4: Drainage and Dewatering

Introduction:

- Drainage is also required for increasing the stability of soil by reducing seepage and pore water pressure and for reducing the danger of frost action.
- Drainage reduces the natural stresses in cohesionless soil and thereby increases the effective stress and strength.
- Drainage is also be essential to lower the water table of a waterlogged area to make it more suitable for cultivation purpose.

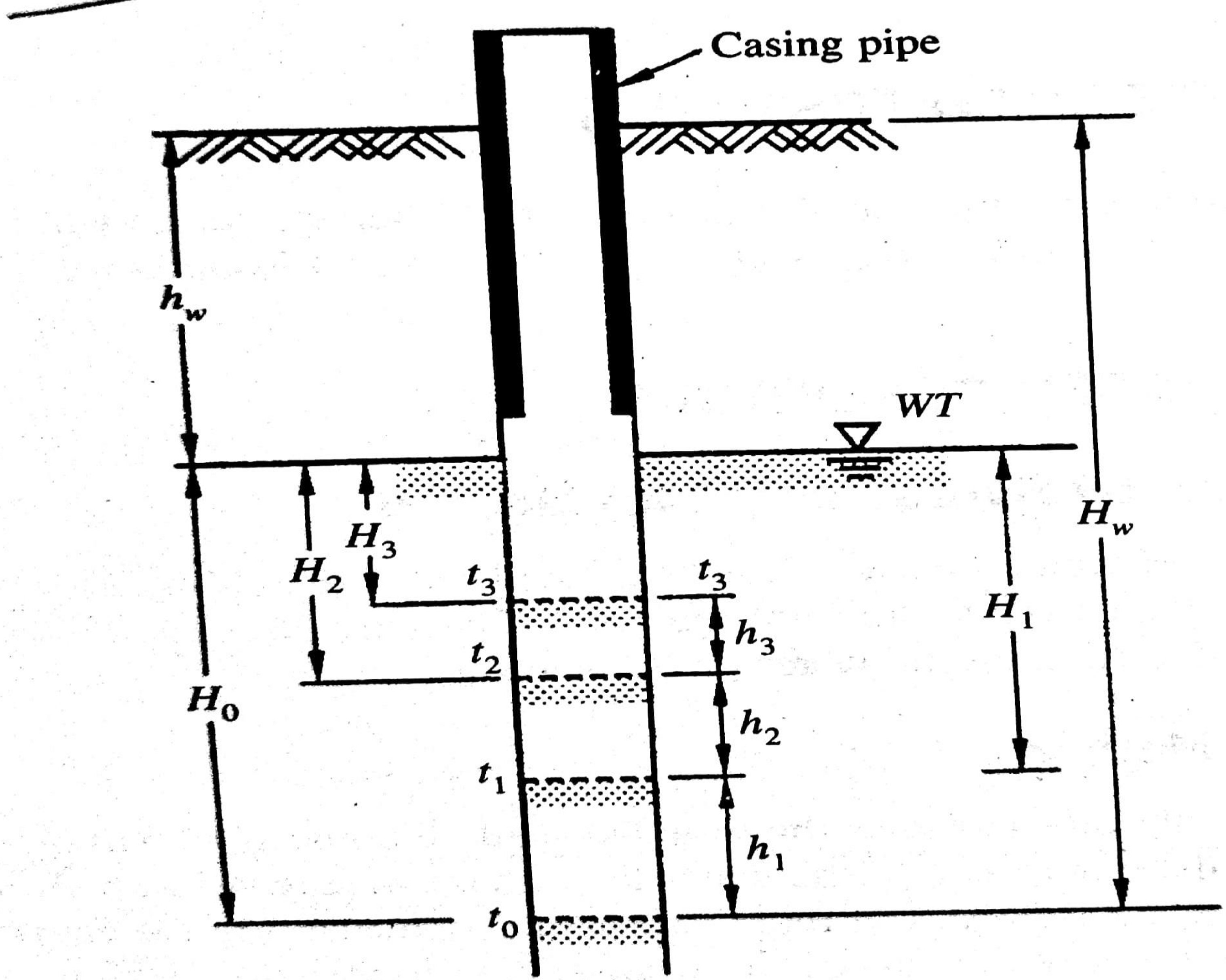


Fig. 17.13 Water table level location by rising water level method

Geotechnical Engineering (18CV54)

Module – 4: Drainage and Dewatering

Hvorselev's Method of Determination of GWL:

- This method is also known as "Time Lag Method".
- It consists of bailing the water out of the casing and observing the rate of rise of the water level in the casing at intervals of time until the rise in water level becomes negligible.
- The rate is observed by measuring the elapsed time and the depth of the water surface below the top of the casing.

Geotechnical Engineering (18CV54)

Module – 4: Drainage and Dewatering

Hvorselev's Method of Determination of GWL:

- The intervals at which the readings are required will vary some what with the permeability of the soil.
- In freely draining materials such as sands, gravels etc. the interval of time between successive readings may not exceed 1 to 2 hours.
- But in soils of low permeability such as fine sand, silts and clays, the interval may rise from 12 to 24 hours, and it may take a few days to determine the stabilized water table level.

Geotechnical Engineering (18CV54)

Module – 4: Drainage and Dewatering

Hvorselev's Method of Determination of GWL:

- According to the figure, let the time t_0, when the water table level was at depth of H_0 which is below the normal water table level.
- Rise in water levels takes place as h_1, h_2, h_3, etc. at time interval of t_1, t_2, t_3, etc. respectively.
- Here the difference in time is kept constant i.e.,

$$(t_1 - t_0) = (t_2 - t_1) = (t_3 - t_2) = \Delta t$$

Geotechnical Engineering (18CV54)

Module – 4: Drainage and Dewatering

Hvorselev's Method of Determination of GWL:

- From figure w.k.t

$$h_1 = H_0 – H_1$$

$$h_2 = H_1 – H_2$$

$$h_3 = H_2 – H_3$$

$$H_1 = (h_1^2 / h_1 – h_2)$$

$$H_2 = (h_2^2 / h_1 – h_2)$$

$$H_3 = (h_3^2 / h_2 – h_3)$$

Geotechnical Engineering (18CV54)

Module – 4: Drainage and Dewatering

Hvorselev's Method of Determination of GWL:

- The corresponding depths of water table level below the ground surface be h_{w1} h_{w2} h_{w3} etc. Now we have

$$h_{w1} = H_w - H_1$$

$$h_{w2} = H_w - (h_1+h_2+H_2)$$

$$h_{w3} = H_w - (h_1+h_2+h_3+H_3)$$

Where, H_w = is the depth of water level in the casing from the ground surface at the start of the test.

Geotechnical Engineering (18CV54)

Module – 4: Drainage and Dewatering

Importance of Drainage or Dewatering:

- Drainage is required for increasing the stability of soil by reducing seepage and pore water pressure.
- Drainage reduces the natural stresses in cohesionless soil and there by increases the effective stress and strength.
- Drainage may also essential to lower the water table of a water logged area to make it more suitable for cultivation purposes.
- To provide a suitable working surface at the bottom of the excavation.

Geotechnical Engineering (18CV54)

Module – 4: Drainage and Dewatering

Methods of Drainage or Dewatering:

- Ditches and Sumps.
- Well point systems.
- Shallow well systems.
- Deep well systems.
- Vaccum method.
- Electro-Osmosis method.

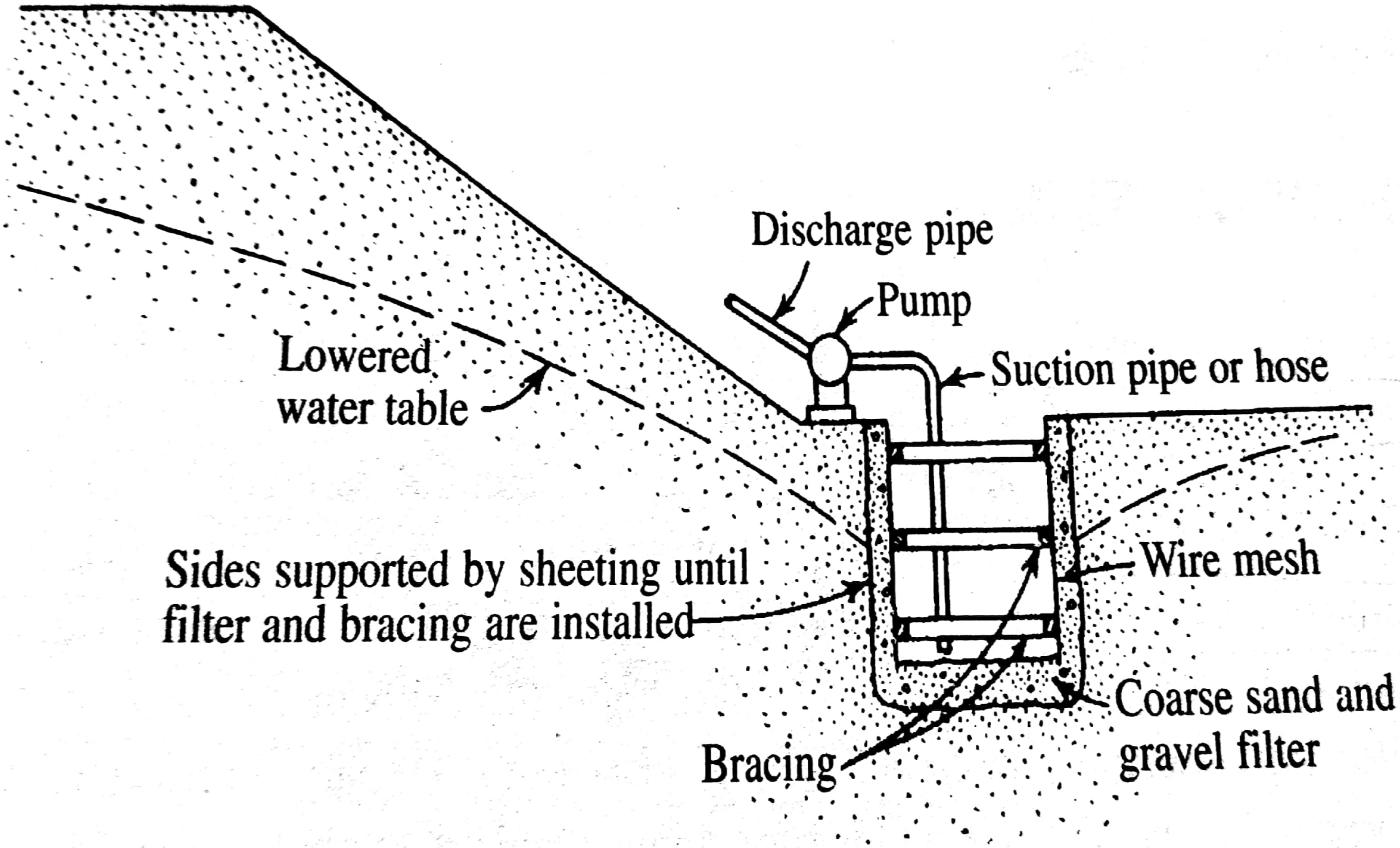


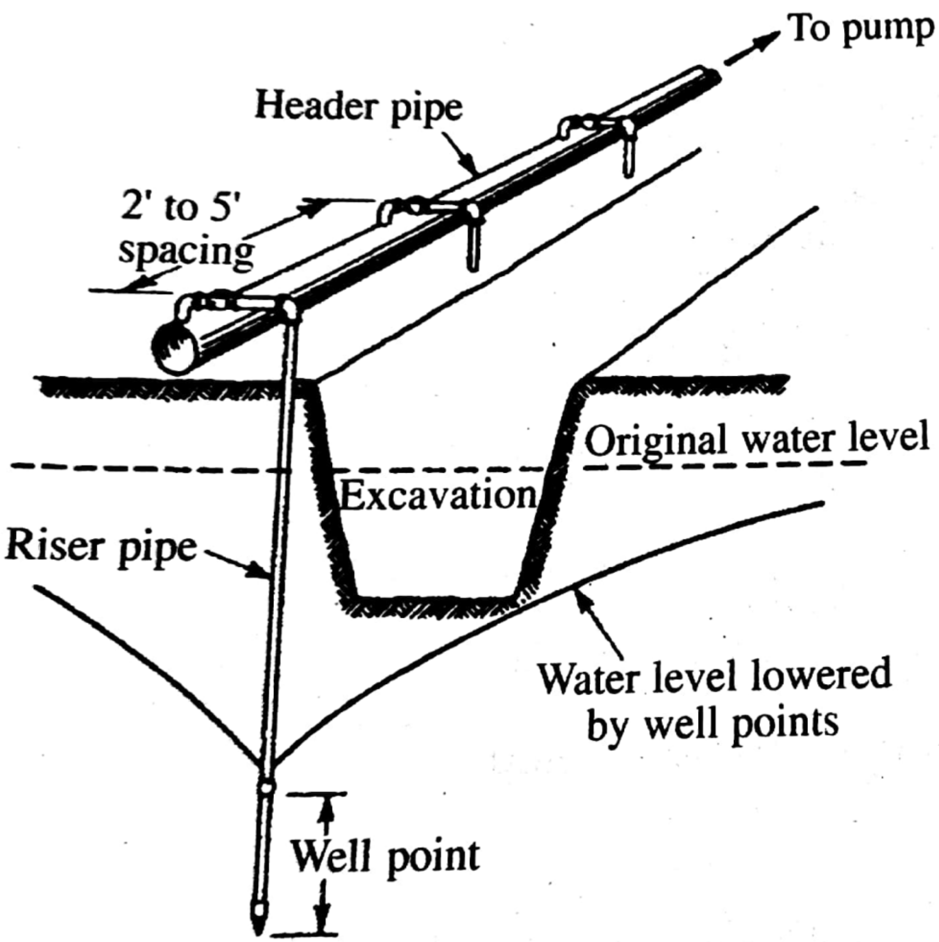
Fig. 22.8 Pump sump

Geotechnical Engineering (18CV54)

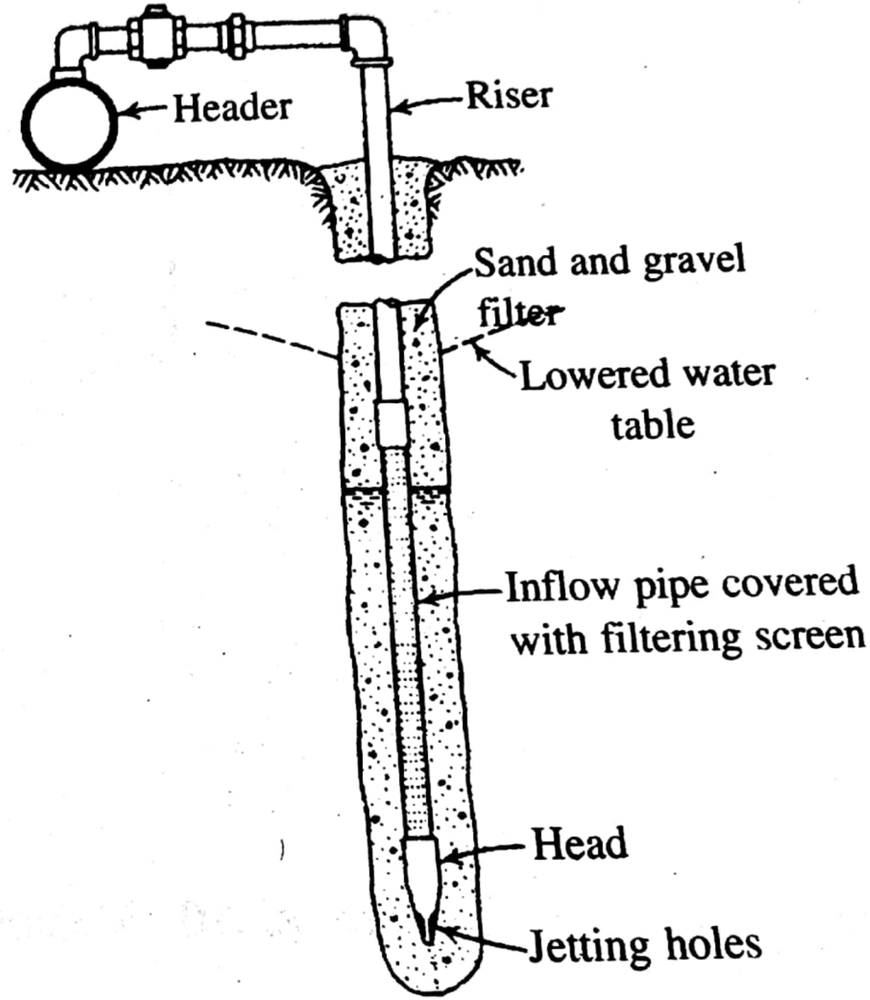
Module – 4: Drainage and Dewatering

Ditches and Sumps:

- This is the simplest form of dewatering used in the shallow excavations in coarse grained soils.
- A sump is merely a hole in a ground from which water is being pumped for the purpose of removing water from the adjoining area.
- One sump is sufficient for a small area.
- Large numbers of sumps with ditches are sufficient for a large area.



Well-Point system



Details of well-point assembly

Fig. 22.9 Well-point

Geotechnical Engineering (18CV54)

Module – 4: Drainage and Dewatering

Well Point System:

- A well point is a two or three inch diameter pipe and two or four feet long which is covered with a screen.
- The lower end of the pipe has a driving head with water holes for jetting.
- Well points are connected to two or three inches diameter pipes known as riser pipes and are inserted into ground by driving.
- The upper ends of a riser pipes leads to a header pipe which in turn connected to a pump.

Geotechnical Engineering (18CV54)

Module – 4: Drainage and Dewatering

Well Point System:

- The ground water is drawn by the pump into the well points through the header pipe and discharged.
- This type of dewatering system is effective in soils constituted primarily of sand fraction.
- In highly pervious soils such as coarse gravels, the well points become impracticable.
- They are not useful to draw water out of clays because of the slow process of water seepage.

Geotechnical Engineering (18CV54)

Module – 4: Drainage and Dewatering

Shallow Well System:

- In this system, a hole of 30cm in diameter or more is bored into the ground to a depth not exceeding 10m below the axis of the pump.
- A strainer tube of 15cm diameter is lowered in the bore hole having a casing tube.
- A gravel filter is formed around the stainer tube by gradually removing the casing tube and simultaneously pouring filter material in the annular space.

Geotechnical Engineering (18CV54)

Module – 4: Drainage and Dewatering

Shallow Well System:

- A suction pipe is lowered into filter well so formed.
- The suction pipes form a number of such wells may be connected to one common header leading to the pumping unit.

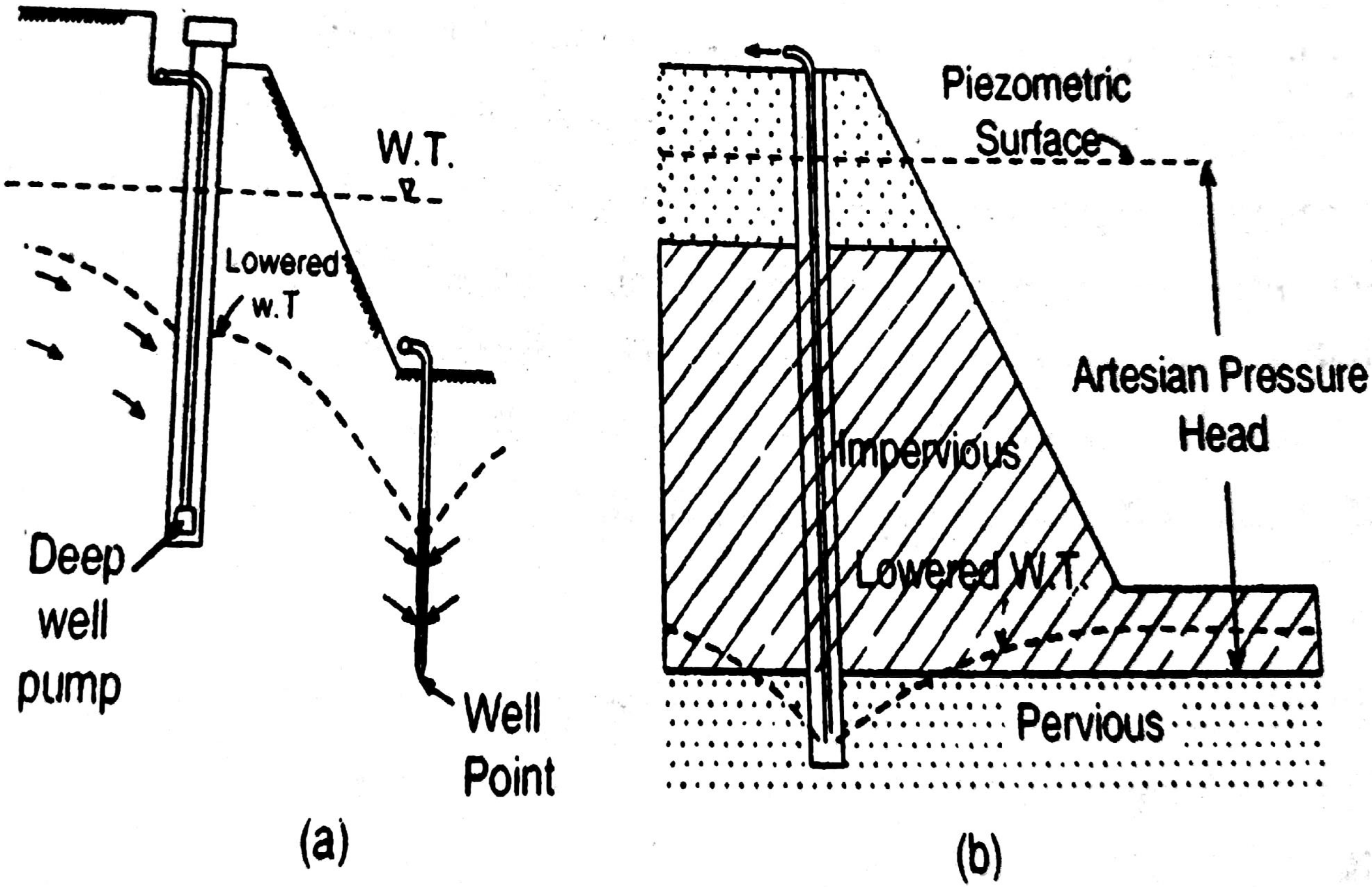


FIG 11.4. DEEP WELL SYSTEM.

Geotechnical Engineering (18CV54)

Module – 4: Drainage and Dewatering

Deep Well System:

- When the depth of excavation is more than 16m below the water table, deep well drainage system may be used.
- About 15 to 60cm diameter hole is bored and a casing with a long screen is provided.
- A submersible pump with a capacity to push the water upto a height of 30m or more is installed near the bottom of the well.
- Each well has its own pump.

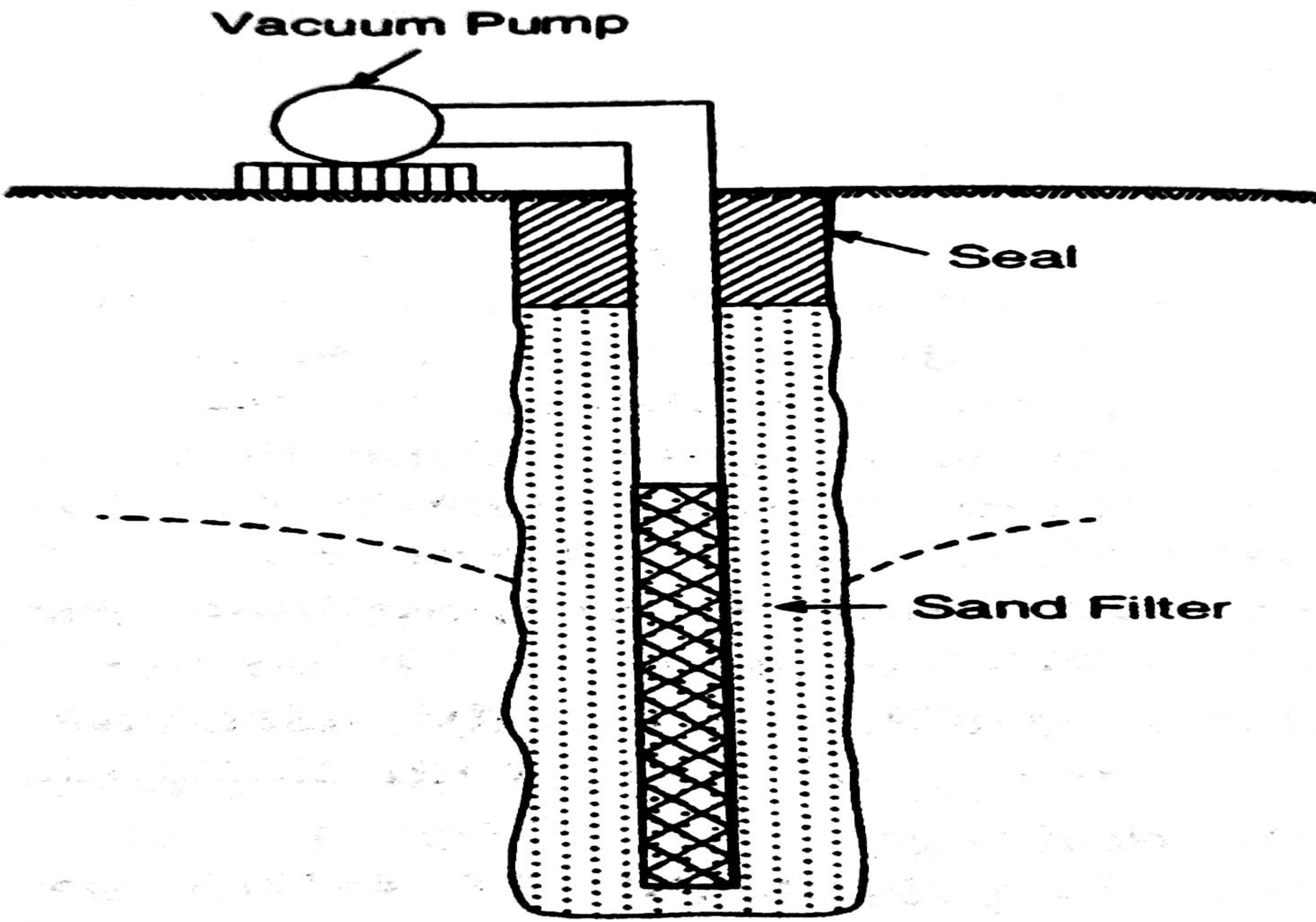


FIG. 11.5. VACUUM METHOD

Geotechnical Engineering (18CV54)

Module – 4: Drainage and Dewatering

Vaccum Method:

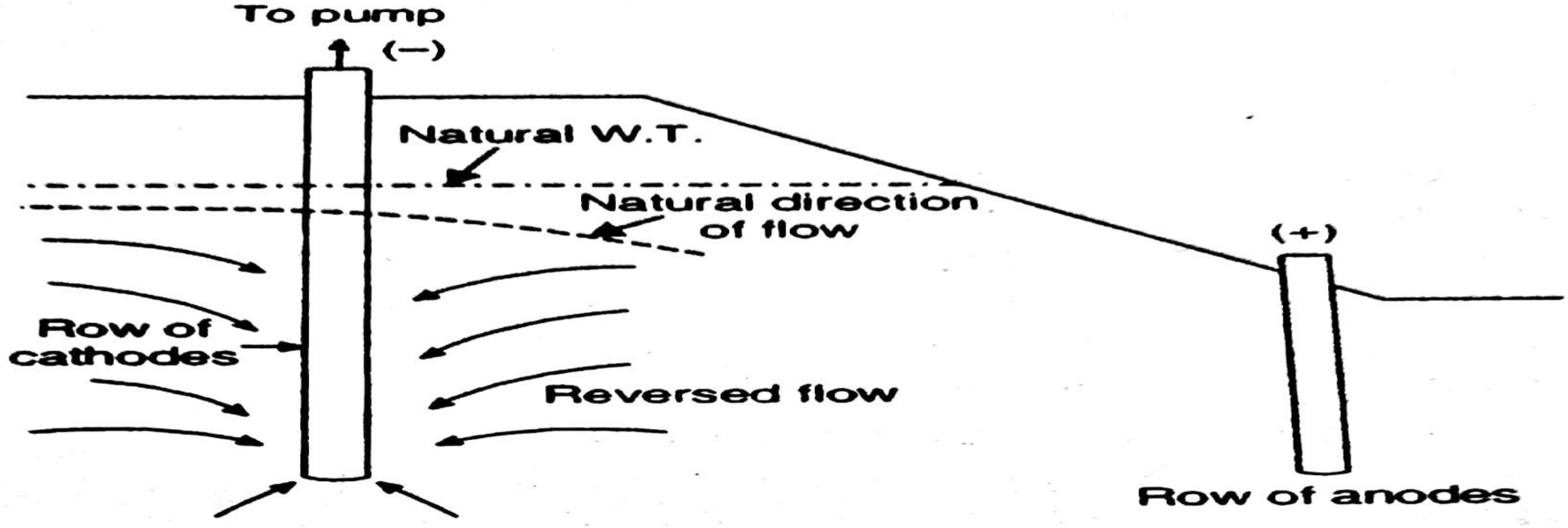
- Vaccum method is much suitable for a soil of less permeability.
- In this method, the well points are set in holes about 8 inches, in diameter made by augering.
- A filter of medium to coarse sand is then placed around the well point and pipe of about 2 to 3 feet of the surface.
- Above the filter an impervious material such as clay is tamped to form a seal.

Geotechnical Engineering (18CV54)

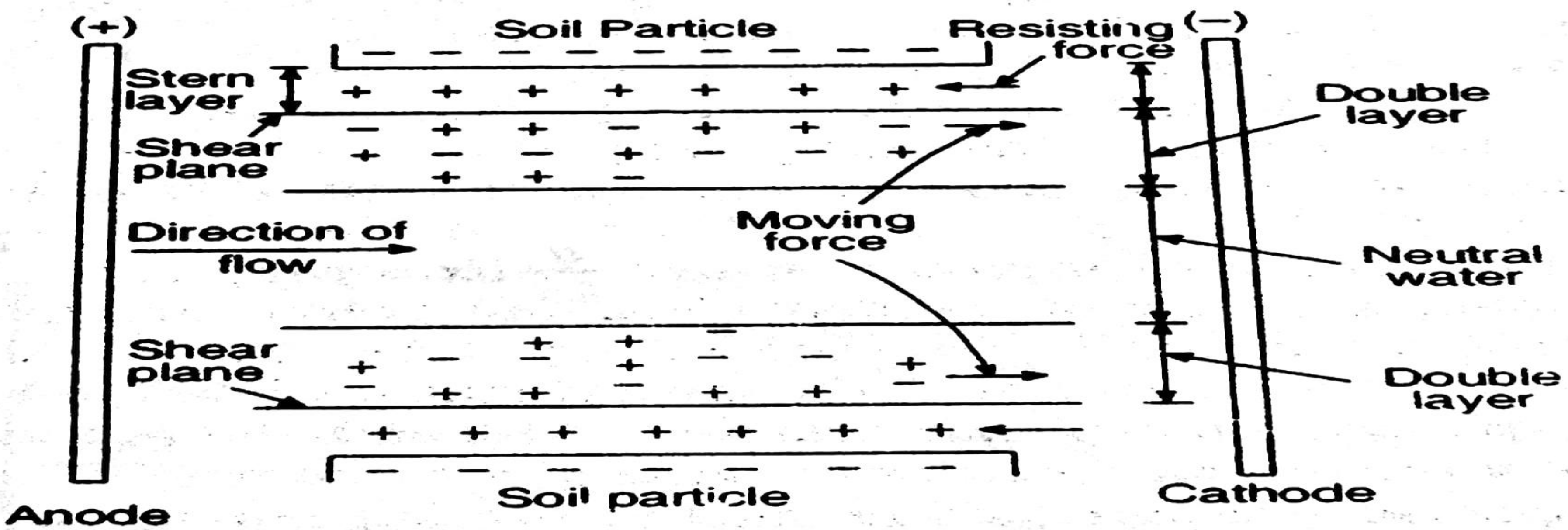
Module – 4: Drainage and Dewatering

Vaccum Method:

- The pumps for such an installation must be capable of maintaining a vaccum in the well points and the surrounding filter.
- Thus the soil becomes consolidated under this vaccum pressure.
- The vaccum process is highly effective in silts and organic silts.



(a) The Arrangement



(b) The Principle

FIG. 11.6. ELECTRO-OSMOTIC DRAINAGE

Geotechnical Engineering (18CV54)

Module – 4: Drainage and Dewatering

Electro-Osmosis Method:

- This method is suitable for fine grained cohesive soils.
- The application of electro-osmosis to dewatering of soil was largely developed by Casagrande.
- If direct current is passed between two electrodes into saturated soil mass, the soil water will travel form the positive electrode to the negative electrode.
- The cathode is made in the form of a well point or a metal tube for pumping out water.

Geotechnical Engineering (18CV54)

Module – 4: Drainage and Dewatering

Electro-Osmosis Method:

- A steel rod, a pipe can serve as the anode.
- The principle of electro-osmosis can be explained with respect to the electric double layer on the fine grained soil particles.
- The outer part of this layer carries, a net positive charge and it starts moving towards the cathode, as soon as an electric potential is applied to a saturated soil.

Geotechnical Engineering (18CV54)

Module – 4: Drainage and Dewatering

Electro-Osmosis Method:

- The neutral water filling the pores is also dragged towards the cathode by moving outer layers of the electrical double layer, form where it may be pumped out.
- Electro-osmosis is very successful in draining fine-grained soils.