Geotechnical Engineering (18CV54)

Module – 1: Introduction

Soil and Soil Engineering:

- The term ‘Soil’ has various meanings, depending upon the general professional field in which it is being considered.
- To an agriculturist, “Soil is the substance existing on the earth’s surface, which grows and develops plant life”.
- To the geologist, “It means the disintegrated rock material which has not been transported from the place of origin”.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Soil and Soil Engineering:

- To an engineer, "Soil is the unaggregated or uncemented deposits of mineral or organic particles or fragments covering large portion of the earth's crust".
- **"Karl Von Terzaghi is rightly regarded as Father of Geotechnical Engineering"**
- According to Terzaghi, "Soil Mechanics is the application of laws of mechanics and hydraulics to engineering problems dealing with sediments and other unconsolidated accumulations of solid particles produced by the mechanical and chemical disintegration of rocks".

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Soil and Soil Engineering:

- Foundation Engineering, "Is a branch of civil engineering, which is associated with the design, construction, maintenance, renovation of footings, foundation walls, pile foundations, caissons and all other structural members which form the foundation of buildings and other engineering structures".
- Soil is considered by the engineer as a complex material produced by the weathering of the solid rock.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Soil and Soil Engineering:

- The formation of soil is as a result of the geologic cycle continually taking place on the face of the earth.
- The cycle consists of weathering, transportation, deposition and upheaval, again followed by weathering, and so on.
- Weathering is caused by the physical agencies such as periodical temperature changes, impact and splitting action of flowing water, ice and wind, splitting actions of ice, plants and animals.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Origin and Formation of Soil:

- Soil has originated from the Latin word "Solum".
- Soil is formed by the process of 'Weathering' of rocks, disintegration and decomposition of rocks and minerals at or near the earth's surface through the actions of natural or mechanical and chemical agents into smaller and smaller grains.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Origin and Formation of Soil:

- The factors of weathering may be atmospheric, such as changes in temperature and pressure, erosion and transportation by wind, water and glaciers, chemical actions such as crystal growth, oxidation, hydration, carbonation and leaching by water, especially rainwater with time.
- It is to be noted that 95% of the earth's crust consists of igneous rocks, and only remaining 5% of sedimentary and metamorphic rocks.

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Module – 1: Introduction

Origin and Formation of Soil:

- Leaching, is the process where by water-soluble parts in the soil such as calcium carbonate are dissolved and washed out from the soil by rainfall.

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Module – 1: Introduction

Fields of Application of Soil Mechanics:

- Foundation Design and Construction
- Pavement Design
- Design of Underground structures and Earth Retaining Structures
- Design of Embankments and Excavations
- Design of Earth Dams

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Soil as a Three Phase System:

- A soil mass is a three phase system consisting of solid particles (called soil grains), water and air.
- The void space between the soil grains is filled partly with water and partly with air.
- However, if we take dry soil mass, the voids are filled with air only.
- In case of perfectly saturated soil, the voids are filled completely with water.

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Module – 1: Introduction

Soil as a Three Phase System:

- In general, the soil mass has three constituents which do not occupy separate spaces but are blended together forming a complex material, the properties of which depend upon the relative percentages of these constituents, their arrangement and a variety of other factors.
- For calculation purposes, it is always more convenient to show these constituents occupying separate spaces, as shown in figure.

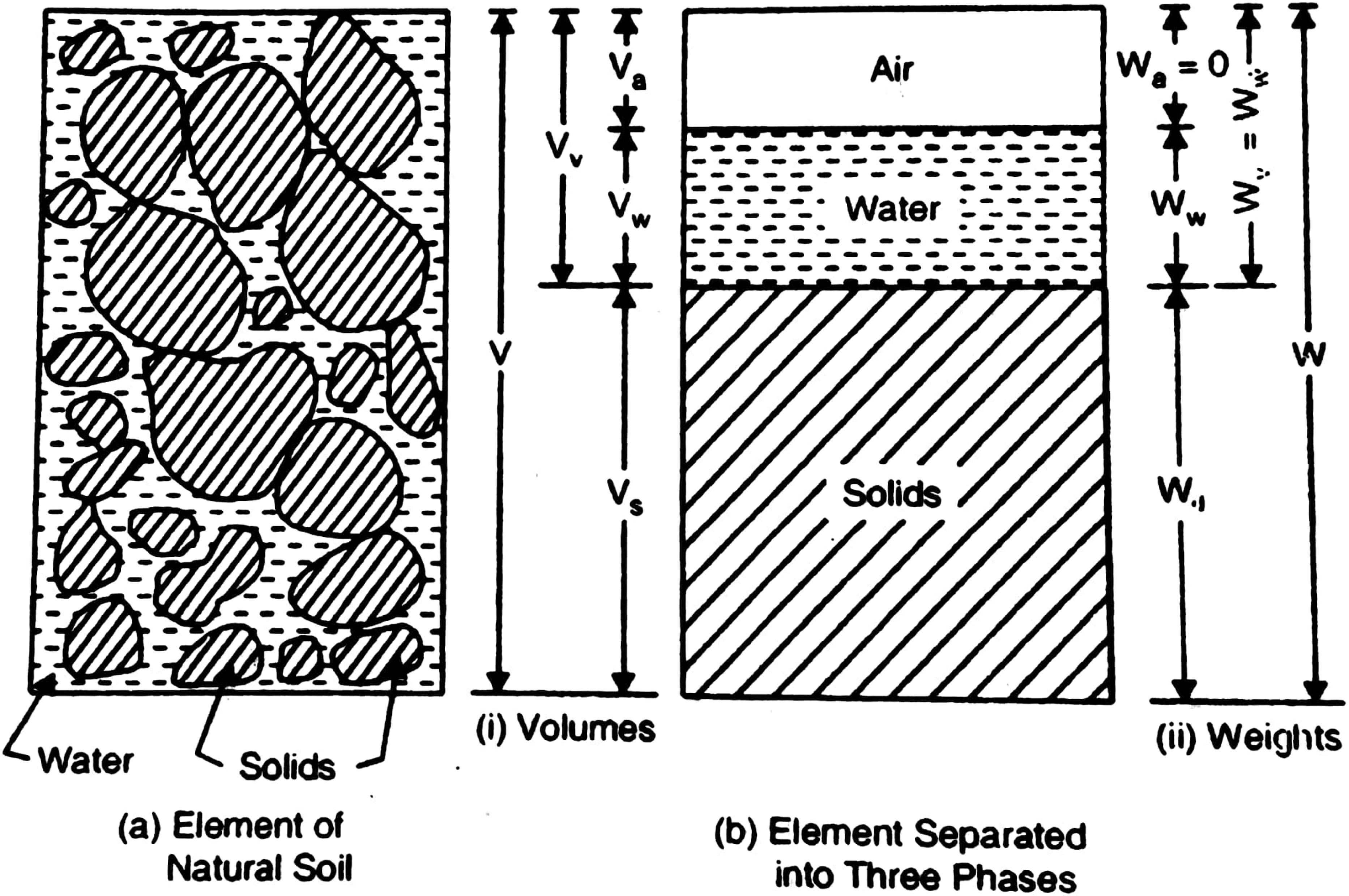

FIG. 2.1. SOIL AS A THREE PHASE SYSTEM

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Module – 1: Introduction

Soil as a Three Phase System:

- As shown in figure 2.1 (b) (i), the total volume V of the soil mass consists of
- (i) volume of air V_a
- (ii) volume of water V_w
- (iii) volume of solids V_s
- (iv) $V_v = V_a + V_w$
- (v) $V = V_a + V_w + V_s$

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Soil as a Three Phase System:

- Similarly, figure 2.1 (b) (ii) shows the weights.
- The weight of air is considered to be negligible.
- Hence the weight of total voids is equal to the weight of water W_w
- The weight of solids is represented by W_d (or) W_s
- The total weight W of the moist sample is therefore equal to $W_w + W_d$

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Definitions:

Water Content or Moisture Content (w): is defined as the ratio of weight of water to the weight of solids in a given mass of soil.

$$w = (W_w / W_d) \times 100$$

Density of Soil: is defined as the mass of the soil per unit volume.

Bulk Density (ρ): is the total mass M of the soil per unit of its total volume V. Its is expressed as g/cm^3 or kg/m^3

$$\rho = (M / V)$$

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Definitions:

Dry Density (ρ_d): is the mass of solids per unit of total volume of the soil mass.

$$\rho_d = (M_d / V)$$

Density of Solids (ρ_s): is the mass of soil solids per unit volume of solids.

$$\rho_s = (M_d / V_s)$$

Saturated Density (ρ_{sat}): when the soil mass is saturated, its bulk density is called saturated density. Thus, saturated density is the ratio of the total soil mass of saturated sample to its total volume

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Definitions:

Submerged or Buoyant Density (ρ'): is the submerged mass of soil solids per unit of total volume of the soil mass.

$$\rho' = ((M_d)_{sub} / V)$$

$$\rho' = \rho_{sat} - \rho_w$$

Where, ρ_w is the density of water which may be taken as 1 g/cm^3 for calculation purposes.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Definitions:

Unit Weight of Soil Mass: is defined as its weight per unit volume.

Bulk Unit Weight (γ): is the total weight W of a soil mass per unit of its total volume V.

$$\gamma = (W / V)$$

Dry Unit Weight (γ_d): is the weight of solids per unit of its total volume of the soil mass.

$$\gamma_d = (W_d / V)$$

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Definitions:

Unit Weight of Solids (γ_s): is the weight of soil solids per unit volume of solids.

$$\gamma_s = (W_d / V_s)$$

Saturated Unit Weight (γ_{sat}): when the soil mass is saturated, its bulk unit weight is called the saturated unit weight. Thus, saturated unit weight is the ratio of the total weight of a saturated soil sample to its total volume.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Definitions:

Submerged or Buoyant Unit Weight (γ'): is the submerged weight of soil solids per unit of total volume of the soil mass.

$$\gamma' = ((W_d)_{sub} / V)$$

$$\gamma' = \gamma_{sat} - \gamma_w$$

Where, γ_w is the unit weight of water which may be taken as 9.81 kN/m^3 for calculation purposes.

$$1 \text{ g/cm}^3 = 9.81 \text{ kN/m}^3$$

$$\boldsymbol{\gamma = 9.81 \times \rho}$$

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Definitions:

Specific Gravity of Solids (G): is defined as the ratio of the weight of a given volume of soil solids at a given temperature to the weight of an equal volume of distilled water at that temperature, both weights being taken in air. In other words, it is the ratio of the unit weight of soil solids to that of water.

$$G = (\gamma_s / \gamma_w)$$

The Indian Standard specifies 27°C as the standard temperature for reporting the specific gravity.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Definitions:

Mass or Apparent or Bulk Specific Gravity (G_m): is defined as the ratio of unit weight of soil to the unit weight of water at standard temperature.

$$G_m = (\gamma / \gamma_m)$$

Specific Gravity of Water (G_w): is defined as the ratio of the unit weight of water to the unit weight of water at the standard temperature.

$$G_w = (\gamma_w / \gamma_w)$$

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Definitions:

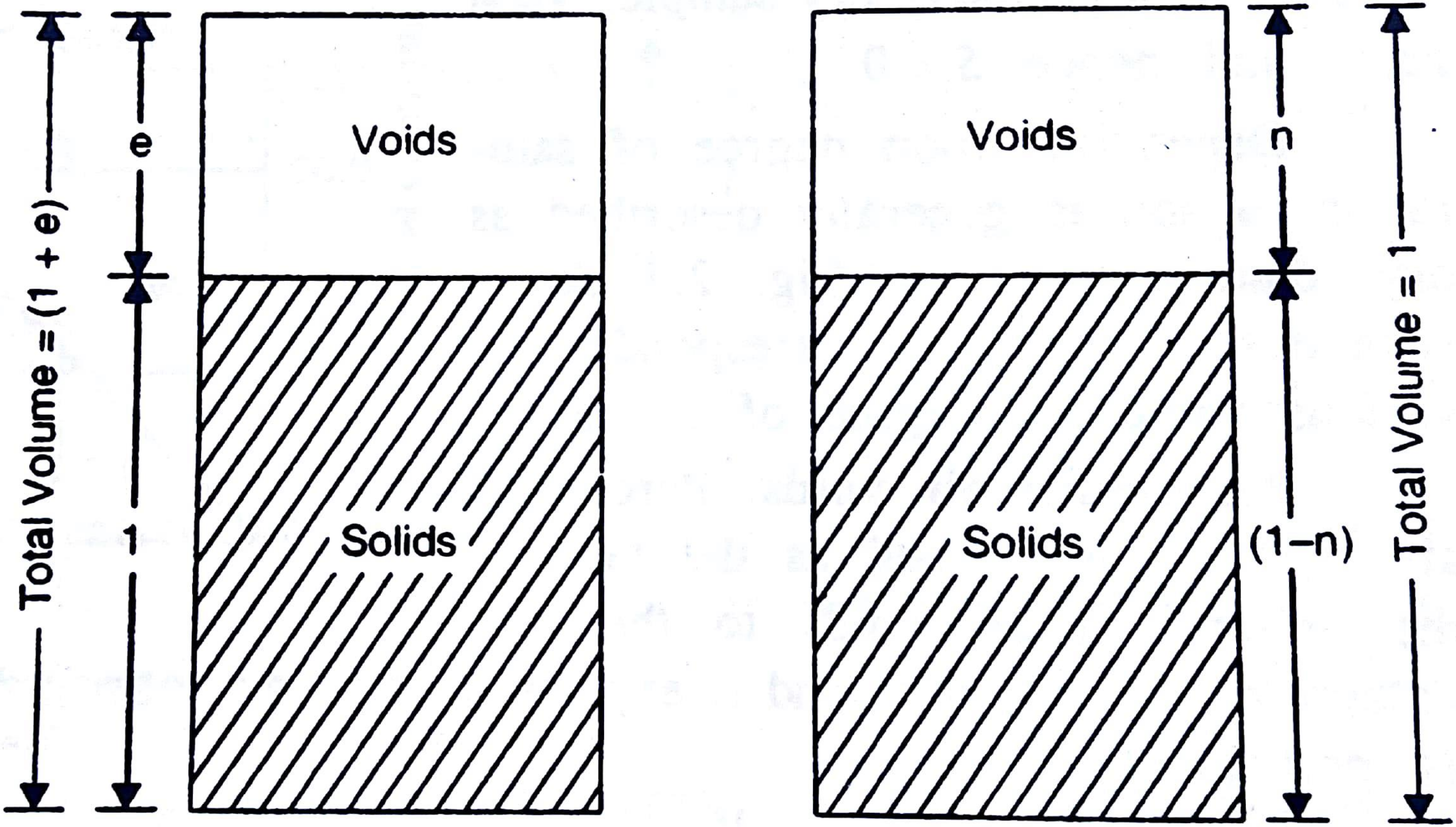
Voids Ratio (e): is the ratio of the volume of voids to the volume of soil solids in the given soil mass.

$$e = (V_v / V_s)$$

Porosity (n): is the ratio of the volume of voids to the total volume of the given soil mass.

$$n = (V_v / V)$$

The voids ratio e is generally expressed as a fraction, while the porosity n is expressed as a percentage.



(a) Soil Element in Terms of e

(b) Soil Element in Terms of n

FIG. 2.2. VOIDS RATIO AND POROSITY

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Module – 1: Introduction

- Figure 2.2 (a) shows the soil element in terms of voids ratio e.
- If the volume of voids is taken equal to e, the volume of solids, by definition would be equal to 1, and the total volume equal to (1+e).
- Figure 2.2 (b) shows the soil element in terms of porosity n.
- If the volume of the voids is taken equal to n, the total volume of the element will be 1 and hence the volume of solids would be equal to (1-n).

Geotechnical Engineering (18CV54)

Module – 1: Introduction

- Figure 2.2 (a), we have by definition of porosity,

$$n = (V_v / V)$$
$$= (e / 1+e)$$

- Figure 2.2 (b), we get by definition of voids ratio,

$$e = (V_v / V_s)$$
$$= (n / 1 – n)$$

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Module – 1: Introduction

Definitions:

Degree of Saturation (S): is defined as the ratio of the volume of water present in a given soil mass to the total volume of voids in it.

$$S \text{ or } S_r = (V_w / V_v)$$

The degree of saturation is usually expressed as a percentage and is also known as percent saturation.

For fully saturated sample $V_w = V_v$ and hence $S = 1$.

For a perfectly dry sample, $V_w = 0$ and hence $S = 0$.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Definitions:

Percentage Air Voids (n_a): is defined as the ratio of the volume of air voids to the total volume of the soil mass and is expressed in percentage.

$$n_a = (V_a / V) \times 100$$

Air Content (a_c): is defined as the ratio of volume of air voids to the volume of voids and is expressed in percentage.

$$a_c = (V_a / V_v)$$

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Module – 1: Introduction

Definitions:

Density Index or Relative Density or Degree of Density (I_D): is defined as the ratio of the difference between the voids ratio of the soil in its loosest state e_{max} and its natural voids ratio e to the difference between the voids ratios in the loosest and densest states.

$$I_D = (e_{max} – e) / (e_{max} – e_{min})$$

Where, e_{max} = voids ratio in the loosest state

e_{min} = voids ratio in the densest state

e = natural voids ratio of the deposit

Module – 1: Introduction

Relative Density (%)	Density Description
0 -15	Very loose
15 - 35	Loose
35 - 65	Medium
65 - 85	Dense
85 - 100	Very Dense

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Functional Relationships:

Problems:

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Index Properties:

- The determination of (i) water content, (ii) specific gravity, (iii) particle size distribution, (iv) consistency limits, (v) in-situ density and (vi) density index. These properties are known as index properties.
- For a proper evaluation of the suitability of soil for use as foundation or construction materials, information about its properties, in addition to classification, is frequently necessary. Those properties which help to assess the engineering behavior of a soil are termed as index properties.

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Module – 1: Introduction

Water Content Determination:

- Oven drying method
- Sand bath method
- Alcohol method
- Calcium carbide method (or) Rapid moisture meter method
- Pycnometer method
- Radiation method
- Torsion balance moisture meter method

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Water Content Determination:

Oven drying method: this is the most accurate method of determining the water content and is therefore, used in the laboratory. A specimen of soil sample is kept in a clean container and put in a thermostatically controlled oven with interior of non-corroding material to maintain the temperature between 105 to 110°C.

Procedure:

- A clean non-corrodible container is taken and its mass is found with its lid, on a balance accurate to 0.01 g.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Water Content Determination:

Procedure:

- A specimen of the moist soil is placed in the container and the lid is replaced.
- The mass of the container and the contents is determined.
- With the lid removed, the container is then placed in the oven for drying.
- After drying, the container is removed from the oven and allowed to cool in a desiccator.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Water Content Determination:

Procedure:

- The lid is then replaced, and the mass of container and the dry soil is found.
- The water content is calculated from the following expression:

$$w = ((M_2 – M_3) / (M_3 – M_1)) \times 100$$

Where, M_1 = mass of container with lid

M_2 = mass of container with lid and wet soil

M_3 = mass of container with lid and dry soil

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Water Content Determination:

Sand bath method: this is a field method of determining rough value of the water content, where the facility of an oven is not available.

Procedure:

- First prepare a sand bath using a metal container.
- The container with the wet soil is placed on a sand bath.
- The sand bath is heated over a kerosene stove.

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Module – 1: Introduction

Water Content Determination:

Procedure:

- The soil becomes dry within ½ to 1 hour.
- The water content is then determined using the following expression:

$$w = ((M_2 - M_3) / (M_3 - M_1)) \times 100$$

Where, M_1 = mass of container with lid

M_2 = mass of container with lid and wet soil

M_3 = mass of container with lid and dry soil

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Water Content Determination:

Alcohol method: this is also a field method.

Procedure:

- The wet sample is kept in a evaporating dish and mixed with sufficient quantity of methylated spirit.
- The dish is then properly covered and the mixture is ignited.
- The mixture is kept stirred by a wire during ignition.
- Hence the dry weight of sample is taken after the ignition.

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Module – 1: Introduction

Water Content Determination:

Procedure:

- The water content is determined from the following expression:

$$w = ((M_2 - M_3) / (M_3 - M_1)) \times 100$$

Where, M_1 = mass of empty dish

M_2 = mass of dish and wet soil

M_3 = mass of dish and dry soil

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Water Content Determination:

Calcium Carbide method: a device known as "Rapid Moisture Tester" has been developed for rapid determination of the water content of a soil sample. Rapid moisture tester is a portable equipment which can be conveniently used in field as well, for the determination of the water content.

Procedure:

- In this method, 6 g of wet soil sample is placed in an air-tight container (called moisture tester).

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Module – 1: Introduction

Water Content Determination:

Procedure:

- Then soil is mixed with sufficient quantity of fresh calcium carbide powder.
- The mixture is shaken vigorously.
- The acetylene gas, produced by the reaction of the moisture of the soil and the calcium carbide, exerts pressure on a sensitive diaphragm placed at the end of the container.

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Module – 1: Introduction

Water Content Determination:

Procedure:

- The dial gauge located at the diaphragm reads the water content directly.
- However, the calibration of the dial gauge is such that it gives the water content based on the wet weight of the sample.
- Knowing the water content based on wet weight, the water content based on dry weight can be found from the equation:

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Module – 1: Introduction

Water Content Determination:

Procedure:

$$w = (w' / (1 - w'))$$

Where, w' = water content based on wet weight

w = water content based on dry weight

- The method is very quick– the result can be obtained in 5 to 10 minutes.
- The field kit contains the moisture tester, a small single-pan weighing balance, a bottle containing calcium carbide and a brush.

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Module – 1: Introduction

Water Content Determination:

Pycnometer method: this is also a quick method of determining the water content of those soils whose specific gravity G is accurately known. Pycnometer is a large size density bottle of about 900 ml capacity. A conical brass cap, having a 6 mm diameter hole at its top is screwed to the open end of the pycnometer. A rubber washer is placed between conical cap and the rim of the bottle so that there is no leakage of water.

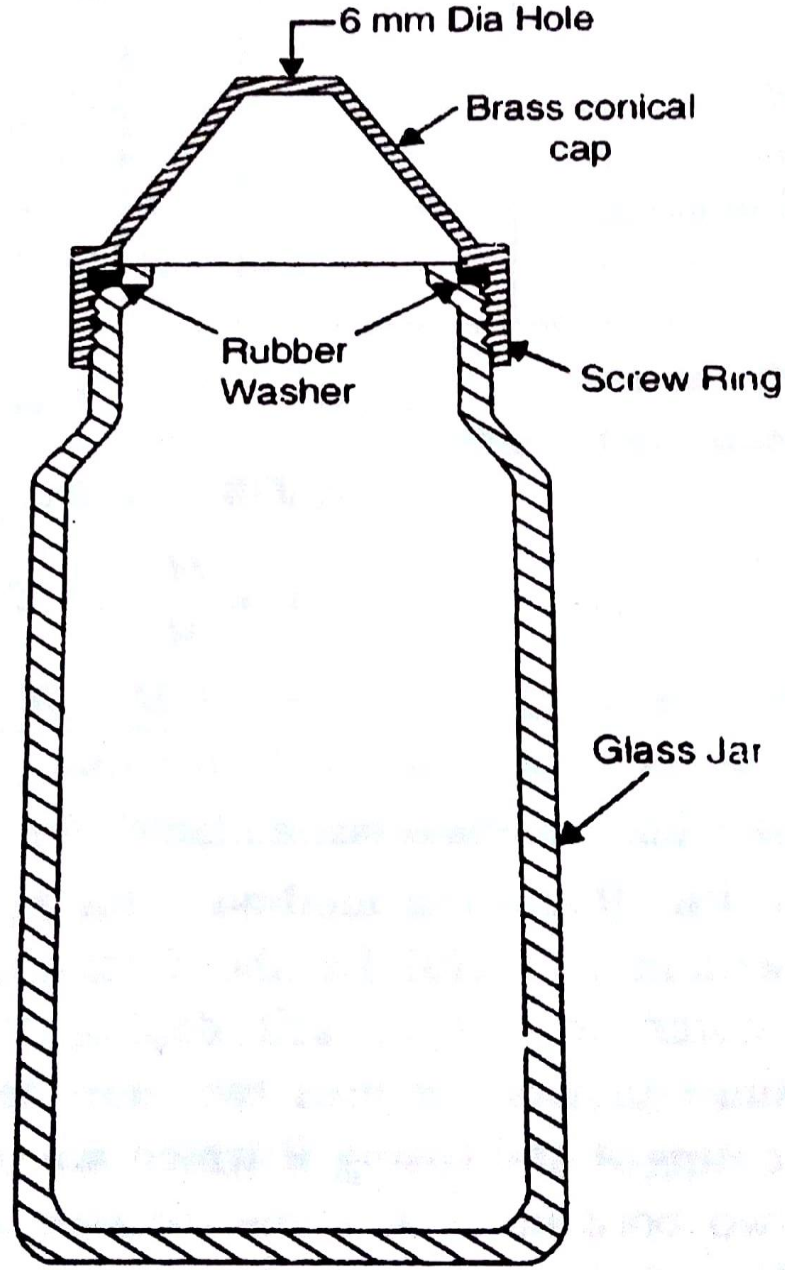

FIG. 3.1 (a). PYCNOMETER.

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Module – 1: Introduction

Water Content Determination:

Procedure:

- Take a clean, dry pycnometer, and find its mass with its cap and washer (M_1).
- Put about 200 g to 400 g of wet soil sample in the pycnometer and find its mass with its cap and washer (M_2).
- Fill the pycnometer to half its height and mix it thoroughly with the glass rod. Add more water, and stir it.

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Module – 1: Introduction

Water Content Determination:

Procedure:

- Replace the screw top and fill the pycnometer flush with the hole in the conical cap. Dry the pycnometer from outside, and find its mass (M_3).
- Empty the pycnometer, clean it thoroughly, and fill it with clean water to the hole of the conical cap, and find its mass (M_4).

Module – 1: Introduction

Water Content Determination:

Procedure:

- The water content is then calculated from the following expression:

$$w = \{((M_2 - M_1) / (M_3 - M_4) \times ((G - 1) / G)) - 1\} \times 100$$

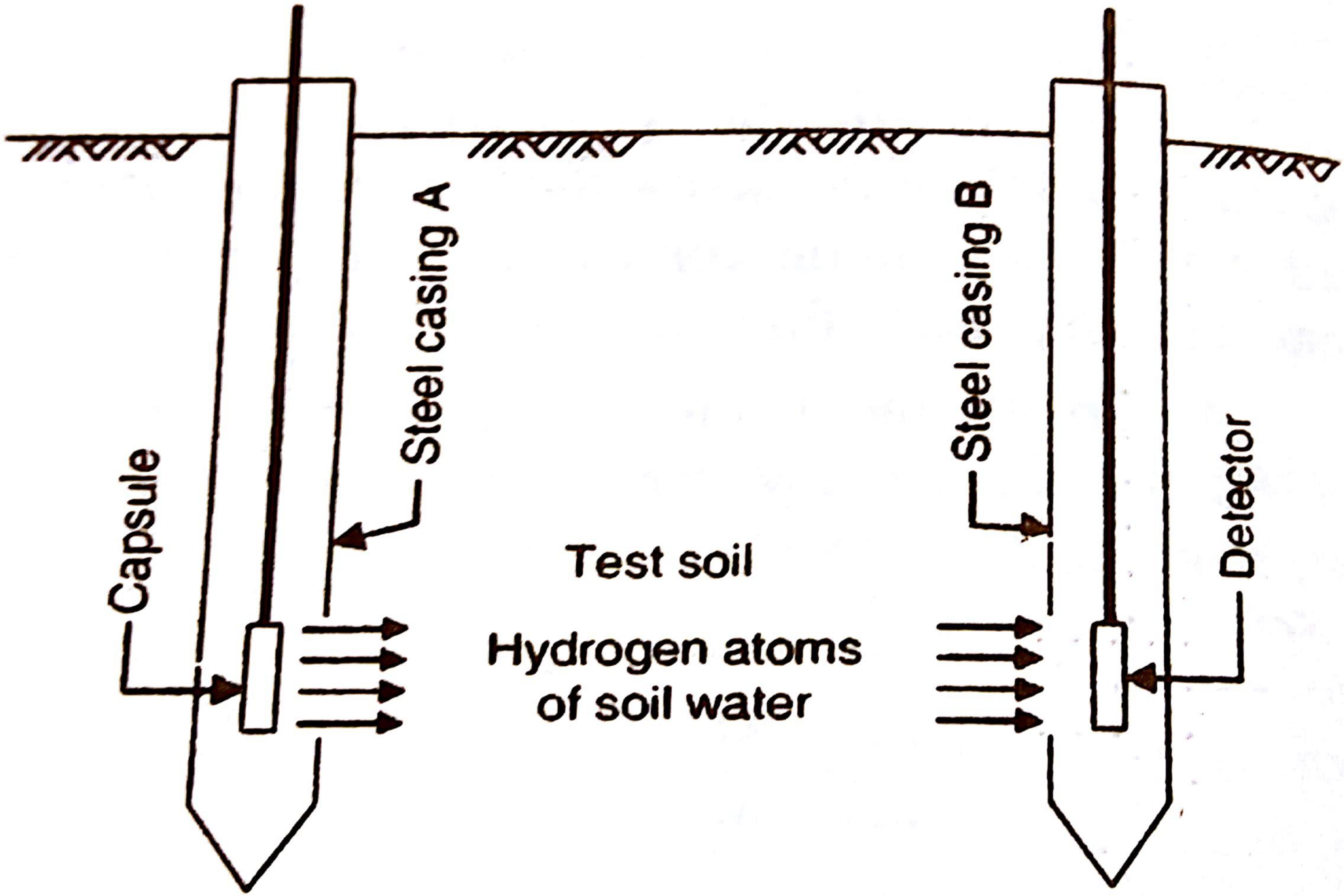

FIG. 3.2 RADIATION METHOD

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Module – 1: Introduction

Water Content Determination:

Radiation method: this method is extremely useful for the determination of water content of soil deposit in the in-situ condition.

Procedure:

- It uses two steel casings – A and B which are placed in two bore holes at some distance apart, in the soil deposit the field moisture content of which is to determined.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Water Content Determination:

Procedure:

- A device containing some radio-active isotope material (such as cobalt – 60) is placed in a capsule which in turn is lowered into casing A.
- Similarly, a detector unit is lowered in steel casing B.
- Small opening are made in both casing A and B, facing each other.
- When the radio active device is activated, it emits neutrons.

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Module – 1: Introduction

Water Content Determination:

Procedure:

- When these neutrons strike with the hydrogen atoms of water in the sub-soil, they loose energy.
- The loss of energy is evidently equal to water content in the soil.
- The detector device is calibrated to give directly the water content of the subsoil, at that level of emission.
- However, proper shielding precautions should be taken to avoid radiation problems.

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Module – 1: Introduction

Water Content Determination:

Torsion Balance method: the equipment has two main parts: (i) infra-red lamp and (ii) torsion balance. The infra-red radiation is provided by 250 watt lamp built in the balance for use with alternating current 220-230 V, 50 cycle, single phase mains supply. The weighing mechanism, a torsion balance, has a built-in magnetic damper to reduce pan vibration during quick drying. The balance scale is divided in terms of water percentages from 1 to 100 water content in 0.2 percent division.

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Module – 1: Introduction

Water Content Determination:

Procedure:

- The test specimen is kept in a suitable container so that the water content to be determined is not affected by ambient conditions.
- Torque is applied to one end of the torsion wire by means of a calibrated drum to balance the loss of weight of the sample and it dries out under infrared lamp.

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Module – 1: Introduction

Water Content Determination:

Procedure:

- To determine the percent reduction of mass at any instant, rotate the drum scale by turning the drum drive knob until the point returns to the index.
- The percent is read directly from the scale.
- However, this percent (w') is the percent of water based upon the initial mass (i.e., wet mass) of the sample.
- The water content (w) based on the dry mass is computed from the equation: $w = (w' / (1 - w'))$

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Specific Gravity Determination:

- The specific gravity of soil is determined by: (i) a 50ml density bottle, or (ii) a 500ml flask, or (iii) a pycnometer.
- The density bottle method is the most accurate, and is suitable for all types of soils.
- The flask or pycnometer is used only for coarse grained soils.
- The density bottle method is the standard method used in the laboratory.

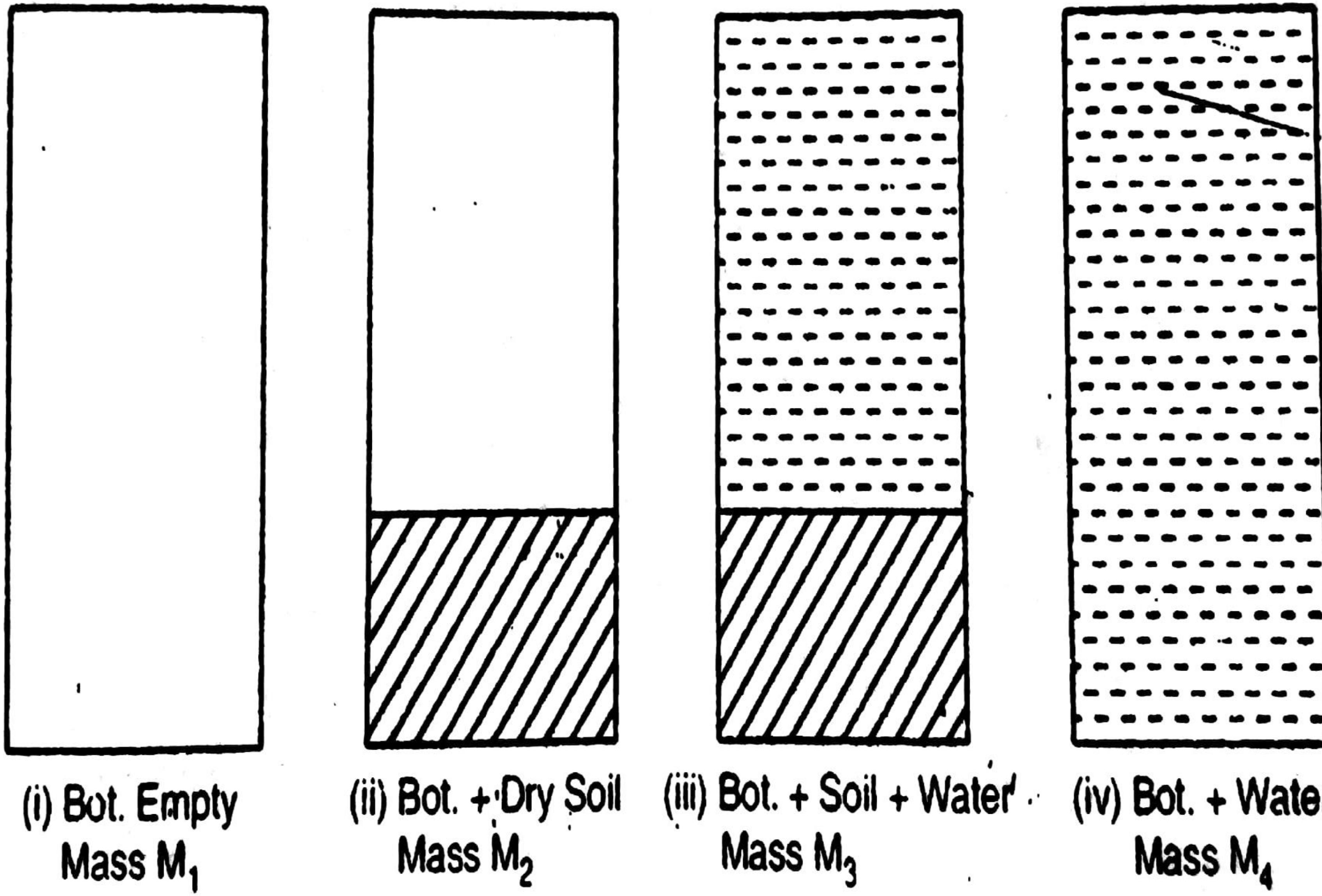

FIG. 3.3 SPECIFIC GRAVITY COMPUTATION.

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Module – 1: Introduction

Specific Gravity Determination:

Procedure:

- The mass of the empty, dry bottle is first taken.
- A sample of oven-dried soil, cooled in desiccator, is put in the bottle and the mass is taken.
- The bottle is then filled with distilled water gradually, removing the entrapped air either by applying vacuum or by shaking the bottle.
- The mass of the bottle, soil and water (full up to the top) is taken.

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Module – 1: Introduction

Specific Gravity Determination:

Procedure:

- Finally, the bottle is emptied completely and thoroughly washed, and clean water is filled to the top, and mass is taken.
- Based on these four observations, the specific gravity can be computed as follows:

G = Dry mass of soil / Mass of water of equal volume

$$G = ((M_2 – M_1) / (M_2 – M_1) – (M_3 – M_4))$$

$$G = ((M_d) / M_d – (M_3 – M_4))$$

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Specific Gravity Determination:

Soil Type	Grain Specific Gravity
Quartz	2.64-2.65
Silt	2.68-2.72
Silt with organic matter	2.40-2.50
Clay	2.44-2.92
Bentonite	2.34
Loess	2.65-2.75
Lime	2.70
Peat	1.26-1.80
Humus	1.37

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Particle – Size Distribution:

- The percentage of various sizes of particles in a given dry soil sample is found by a particle-size analysis or mechanical analysis. By mechanical analysis is meant the separation of a soil into its different size fraction. The mechanical analysis is performed in two stages : (i) sieve analysis (ii) sedimentation or wet mechanical analysis.
- The first stage is meant for coarse-grained soils only, while the second stage is performed for fine-grained soils.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Particle – Size Distribution:

Sieve Analysis:

- In the BS (BS : 410 – 1962) and ASTM (ASTM : E 11 – 1961) standards, the sieve sizes are given in terms of the number of openings per inch.
- The number of openings per square inch is equal to the square of the number of the sieve.
- In the Indian Standard (IS : 460 – 1962), the sieves are designated by the size in mm.

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Module – 1: Introduction

Particle – Size Distribution:

Sieve Analysis:

- The complete sieve analysis can be divided into two parts – the coarse analysis and fine analysis.
- An oven-dried sample of soil is separated into two fractions by sieving it through a 4.75mm IS sieve.
- The portion retained on it is termed as the gravel fraction and is kept for the coarse analysis, while the portion passing through it is subjected to fine analysis.

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Module – 1: Introduction

Particle – Size Distribution:

Procedure:

- Take 1000 g of a oven-dried soil sample for the sieve analysis.
- Arrange the set of sieves: 4.75mm, 2.36mm, 1.18mm, 600µ, 425µ, 300µ, 212µ, 150µ, 75µ and pan.
- Take the empty weight of each sieves.
- Place the set of sieve on a sieve shaking machine.
- Pour the 1000 g of soil on the top sieve.

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Module – 1: Introduction

Particle – Size Distribution:

Procedure:

- Switch on the sieve shaking machine and sieve it for 10 minutes.
- Then note down the mass of each sieve along the soil which is retained.
- On the basis of the total weight of sample taken and the weight of soil retained on each sieve, the percentage of the total weight of soil passing through each sieve can be calculated as below:

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Module – 1: Introduction

Particle – Size Distribution:

Procedure:

- Percentage retained on particular sieve = (Weight of soil retained on that sieve / Total weight of soil taken) X 100.
- Cumulative percentage retained = Sum of percentage retained on all sieves of larger sizes and the percentage retained on that particular sieve.
- Percentage finer = 100% - Cumulative percentage retained.

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Module – 1: Introduction

Particle – Size Distribution:

Sieve No.	Weight of sieve	Weight of sieve + soil	Weight of soil	Percentage weight retained	Cumulative percentage retained	Percentage finer
4.75 mm						
2.36 mm						
1.18 mm						
600 μ						
425 μ						
300 μ						
212 μ						
150 μ						
75 μ						
Pan						

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Particle – Size Distribution:

Sedimentation Analysis:

- In the wet mechanical analysis, or sedimentation analysis, the soil fraction, finer than 75 micron size is kept in suspension in a liquid (usually water) medium.
- The analysis is based on Stokes law, according to which the velocity at which grains settle out of suspension, all other factors being equal, is dependent upon the shape, weight and size of the grain.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Particle – Size Distribution:

Sedimentation Analysis:

- However, in the usual analysis it is assumed that the soil particles are spherical and have the same specific gravity.
- With this assumption, the coarser particles settle more quickly than the fine ones.
- If v is the terminal velocity of sinking of a spherical particle, it is given by:

$$v = ((1 / 18) \times D^2 \times (\gamma_s - \gamma_w) / \eta)$$

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Particle – Size Distribution:

Sedimentation Analysis:

Where, D = diameter of the spherical particle (m)

v = terminal velocity (m/sec)

γ_s = unit weight of particles (kN/m^3)

γ_w = unit weight of water (kN/m^3)

η = viscosity of water ($kN\text{-}s/m^2$) = (μ/g)

μ= viscosity in absolute units of poise

g = acceleration due to gravity

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Particle – Size Distribution:

Sedimentation Analysis:

Assumptions:

- Soil particles are spherical.
- Particles settle independent of other particles and the neighboring particles do not have any effect on its velocity of settlement.
- The walls of jar, in which the suspension is kept, also do not affect the settlement.
- An average value of specific gravity is used.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Particle – Size Distribution:

Sedimentation Analysis:

Limitations:

- In actual practice, the fine particles of soil, for which this analysis is primarily meant, are not truly spherical.
- The particles of fine grained soils are thin platelets which do not settle out of suspension in the same manner and at the same rate as smooth spheres.
- When the particle diameter is about 0.2mm beyond which the liquid tends to develop a turbulent motion.
- For particle smaller than 0.0002mm, Stokes law is not valid.

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Module – 1: Introduction

Particle – Size Distribution:

Hydrometer Method:

- In hydrometer analysis, M_D is computed indirectly by reading the density of the soil suspension at a depth H_e at various time intervals.
- In the hydrometer test, the sampling depth H_e (also known as the effective depth) goes on increasing as the particles settle with the increase in the time intervals.
- It is, therefore, necessary to calibrate the hydrometer and the sedimentation jar before the start of the test.

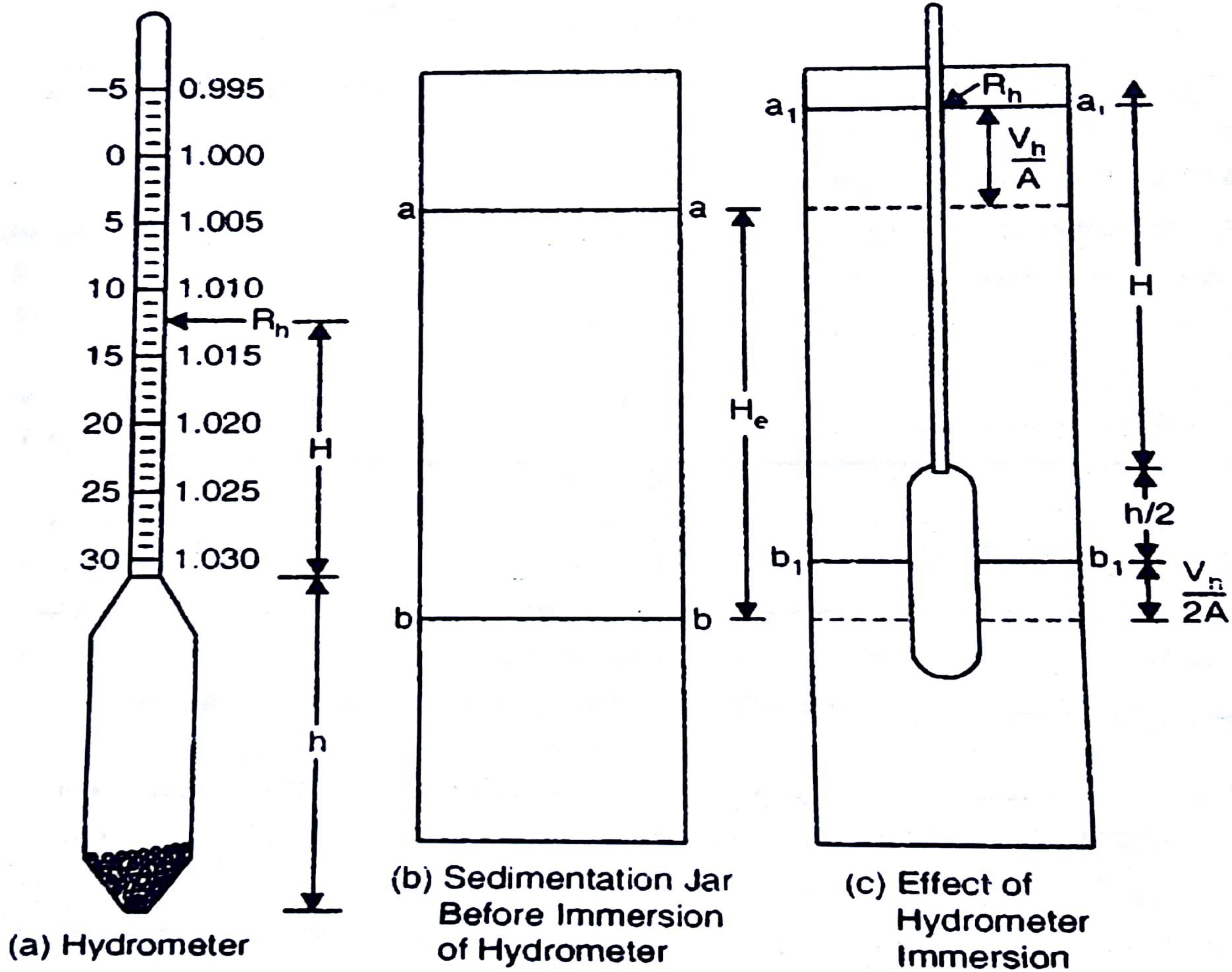

FIG. 3.6. HYDROMETER ANALYSIS.

Module – 1: Introduction

Particle – Size Distribution:

Calibration of Hydrometer:

- Figure 3.6 (a) shows the hydrometer.
- The readings on the hydrometer stem give the density of the soil suspension situated at the center of the bulb at any time.
- For convenience, the hydrometer readings are recorded after subtracting 1 and multiplying the remaining digits by 1000.
- Such a reduced reading is designated as R_h

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Module – 1: Introduction

Particle – Size Distribution:

Calibration of Hydrometer:

- If the density reading at the intersection of horizontal surface of soil suspension with the stem, is 1.010, it is recorded as 10 (i.e., $R_h = 10$).
- The hydrometer readings R_h increase in the downward direction towards the hydrometer bulb.
- Let H be the height in cm, between any hydrometer reading and the neck, and h the height of the bulb.

Module – 1: Introduction

Particle – Size Distribution:

Calibration of Hydrometer:

- Figure 3.6 (b) shows the jar, containing the soil suspension.
- When the hydrometer is immersed in the jar, the water level aa rises to a_1a_1, the rise being equal to the volume V_h of the hydrometer divided by the internal area of cross-section A of the jar.
- Similarly, the level bb rises to b_1b_1
- The rise between bb and b_1b_1 will be approximately equal to $V_h / 2A$.

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Module – 1: Introduction

Particle – Size Distribution:

Calibration of Hydrometer:

- Hence the effective depth H_e is given by the equation:

$$H_e = (H + h/2 + V_h/2A) - (V_h/A)$$

(or)

$$H_e = H + 0.5 \times (h - V_h/A)$$

The effective depth H_e and the depth H which depends upon the hydrometer reading R_h

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Module – 1: Introduction

Particle – Size Distribution:

Procedure:

- A soil of about 50 g dry mass is mixed with distilled water and made into a thin paste.
- The paste is mixed well with a suitable quantity of deflocculating agent.
- Transfer the paste into a sedimentation jar and add the distilled water to bring the level to the 1000 ml.
- The suspension is mixed well by placing the palm of the hand over the open end, turning the jar upside down and back.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Particle – Size Distribution:

Procedure:

- The jar is next placed on the table.
- The hydrometer is inserted carefully into the suspension and the timer started.
- Readings are taken at the time interval of ½, 1, 2 and 4 minutes.
- After 4 minutes remove the hydrometer.
- The suspension is remixed as before, the hydrometer is inserted.

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Module – 1: Introduction

Particle – Size Distribution:

Procedure:

- The subsequent readings are taken at an time interval of 8, 15, 30, 60, 120, 240, 480 and 1440 minutes.
- After each reading in the suspension, the hydrometer should taken out and inserted into another jar of distilled water.
- A suitable corrections is then applied to the hydrometer readings.

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Module – 1: Introduction

Particle – Size Distribution:

Correction to Hydrometer Readings:

The following corrections are applied to the hydrometer readings:

- Meniscus correction
- Dispersing agent correction
- Temperature change correction

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Particle – Size Distribution:

Correction to Hydrometer Readings:

- The hydrometer are generally calibrated at 27°C.
- If the temperature of the soil suspension is not 27°C, a temperature correction C_t should be applied to the observed reading.
- If the test temperature is more then 27°C, the hydrometer readings will naturally be less than what they should be, and hence the correction is positive.

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Module – 1: Introduction

Particle – Size Distribution:

Correction to Hydrometer Readings:

- Similarly, if the test temperature is lower than 27°C, the temperature correction will be negative.
- Since the soil suspension is opaque, the hydrometer reading is taken at the top of the meniscus.
- Actual reading, to be taken at the water level, will be more since the readings increases in the downward direction.
- Hence the meniscus correction C_m is always positive.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Particle – Size Distribution:

Correction to Hydrometer Readings:

- Its magnitude can be found by immersing hydrometer in a jar containing clear water, and finding the difference between the reading corresponding to the top and bottom of the meniscus.
- The addition of dispersing agent in water increase its density, and hence the dispersing agent correction C_d is always negative.

$$R = R'_h + C_m \pm C_t - C_d$$

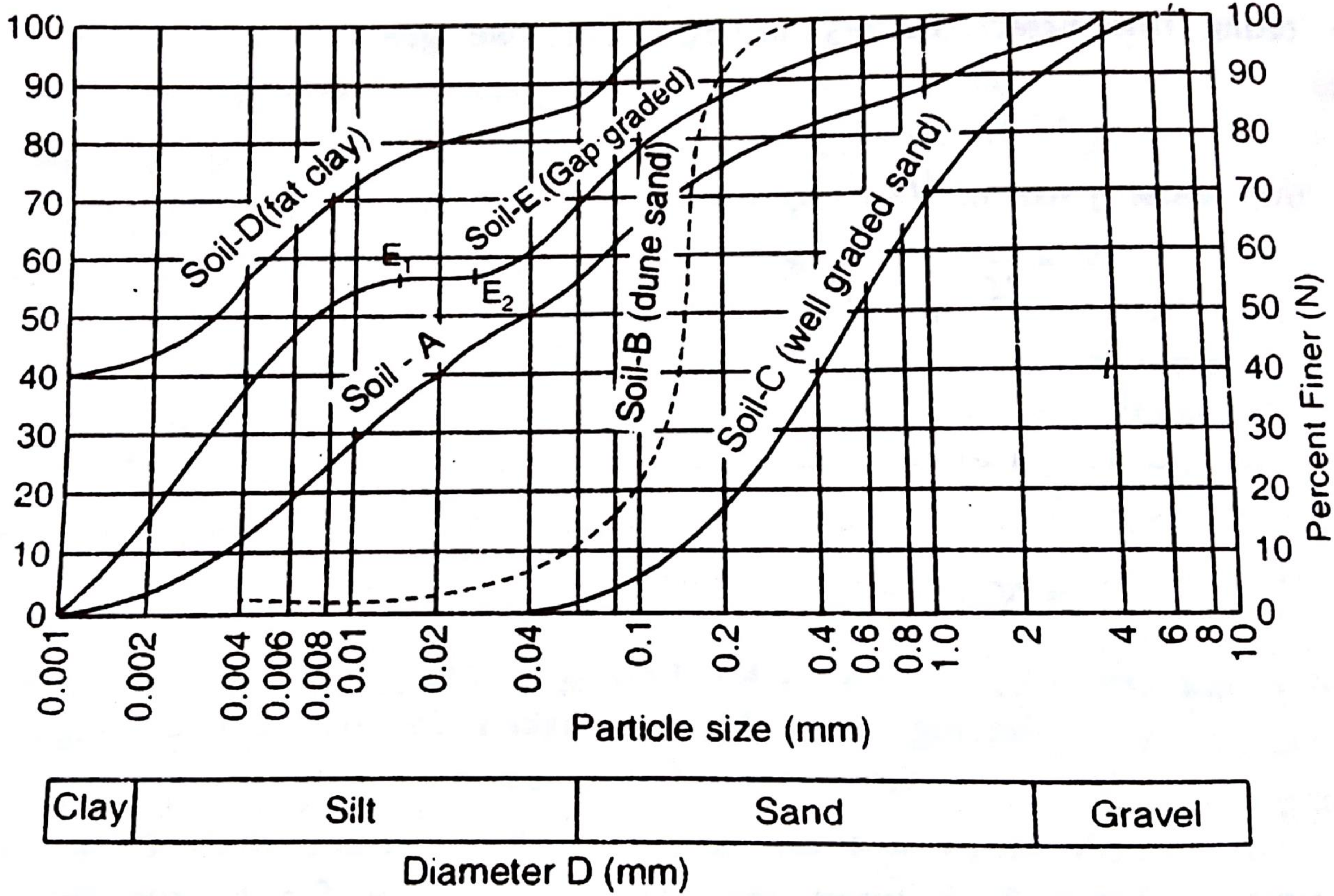

FIG. 3.8. PARTICLE SIZE DISTRIBUTION CURVE

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Module – 1: Introduction

Particle – Size Distribution:

Particle Size Distribution Curve:

- The result of the mechanical analysis are plotted to get a particle size distribution curve with the percentage finer N as the ordinate and the particle diameter as the abscissa, the diameter being plotted on a logarithmic scale.
- Figure 3.8 shows some typical curves for various soils.
- A particle size distribution curve gives an idea about the type and gradation of the soil.

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Module – 1: Introduction

Particle – Size Distribution:

Particle Size Distribution Curve:

- A curve situated higher up or to the left represents a relatively fine grained soil while a curve situated to the right represents a coarse grained soil.
- A soil is said to be well graded when it had good representation of particles of all sizes.
- On the other hand, a soil is said to be poorly graded if it has an excess of certain particles and deficiency of other.

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Module – 1: Introduction

Particle – Size Distribution:

Particle Size Distribution Curve:

- Soil contains most of the particles of about the same size, it is known as a uniformly graded soil.
- Thus, soil A is well graded while the soil B is uniformly graded.
- A curve with a flat portion represent a soil in which some intermediate size particles are missing i.e., soil E is known as gap graded or skip graded.

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Module – 1: Introduction

Particle – Size Distribution:

Particle Size Distribution Curve:

- For coarse grained soil, certain particle sizes such as D_{10}, D_{30} and D_{60} are important.
- D_{10} = diameter of particles corresponding to 10% finer. This is also called as Effective size or diameter.
- D_{30} = diameter of particles corresponding to 30% finer.
- D_{60} = diameter of particles corresponding to 60% finer.

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Module – 1: Introduction

Particle – Size Distribution:

Particle Size Distribution Curve:

- C_u = uniformity coefficient or coefficient of uniformity

$$C_u = (D_{60} / D_{10})$$

- C_c = coefficient of curvature

$$C_c = ((D_{30})^2 / D_{10} \times D_{60})$$

For a uniformly graded soil, C_u is nearly 1. For a well graded soil, C_c must be between 1 to 3 and in addition C_u must be greater than 4 for gravels and 6 for sands.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Consistency of Soils:

- By consistency is meant the relative ease with which soil can be deformed.
- This term is mostly used for fine grained soils for which the consistency is related to a large extent to water content.
- Consistency denotes degree of firmness of the soil which may be termed as soft, firm, stiff or hard.
- Fine grained soil may be mixed with water to form a plastic paste which can be moulded into any form by pressure.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Consistency of Soils:

- The addition of water reduces the cohesion making the soil still easier to mould.
- Further addition of water reduces the cohesion until the material no longer retains its shape under its own weight, but flows as a liquid.
- If water is evaporated from such a soil suspension, the soil passes through various stages or states of consistency.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Consistency of Soils:

- In 1911, the Swedish agriculturist Atterberg divided the entire range from liquid to solid state into four stages: (i) the liquid state, (ii) the plastic state, (iii) the semi-solid state and (iv) the solid state.
- He set arbitrary limits, known as consistency limits or Atterberg limits, for these divisions in terms of water content.
- Thus, the consistency limits are the water contents at which the soil mass passes from one state to the next.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Consistency of Soils:

- Figure 3.9 shows the four states of consistency, with the appropriate consistency limits.
- The Atterberg limits which are most useful for engineering purposes are: liquid limit, plastic limit and shrinkage limit.
- These limits are expressed as percent water content.

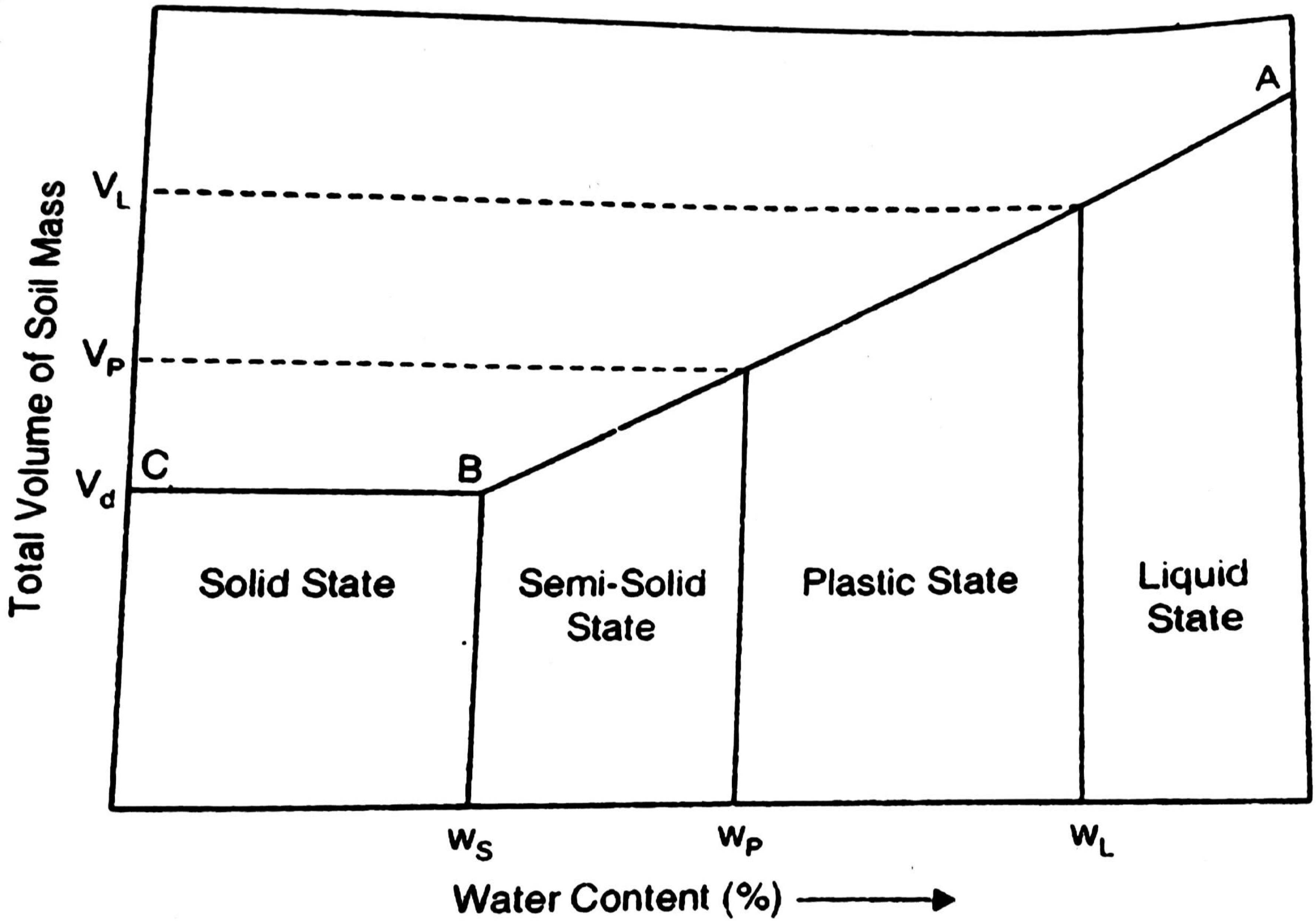

FIG. 3.9. CONSISTENCY LIMITS

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Module – 1: Introduction

Consistency of Soils:

Liquid Limit (w_L):

- Liquid limit is the water content corresponding to the arbitrary limit between liquid and plastic state of consistency of a soil.
- It is defined as the minimum water content at which the soil is still in the liquid state, but has a small shearing strength against flowing which can be measured by standard available means.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Consistency of Soils:

Liquid Limit (w_L):

- With reference to the standard liquid limit device, it is defined as the minimum water content at which a part of soil cut by a groove of standard dimensions, will flow together for a distance of 12mm under an impact of 25 blows in the device.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Consistency of Soils:

Plastic Limit (w_P):

- Plastic limit is the water content corresponding to an arbitrary limit between the plastic and the semi-solid states of consistency of a soil.
- It is defined as the minimum water content at which a soil will just begin to crumble when rolled into a thread approximately 3mm in diameter.

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Module – 1: Introduction

Consistency of Soils:

Shrinkage Limit (w_S):

- Is defined as the maximum water content at which a reduction in water content will not cause a decrease in the volume of a soil mass. It is lowest water content at which a soil can still be completely saturated.

Plasticity Index (I_P):

- Is defined as the numerical difference between the liquid limit and the plastic limit of a soil.

$$I_P = w_L - w_P$$

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Consistency of Soils:

Plasticity:

- Is defined as that property of a soil which allows it to be deformed rapidly, without rupture, without elastic rebound and without volume change.

Consistency Index or Relative Consistency (I_C):

- Is defined as the ratio of the liquid limit minus the natural water content to the plasticity index of a soil

$$I_C = (w_L – w) / I_P$$

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Consistency of Soils:

Liquidity Index (I_L):

- Is defined as the ratio, expressed as a percentage, of natural water content of soil minus its plastic limit, to its plasticity index.

$$I_L = (w - w_P) / I_P$$

Shrinkage Index (I_S):

- Is defined as the difference between the plastic limit and shrinkage limit of a soil.

$$I_S = (w_P - w_S)$$

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Consistency of Soils:

Toughness Index (I_T):

- Is defined as the ratio of plasticity index to flow index of soil

$$I_T = (I_P / I_F)$$

Flow Index (I_F):

$$I_F = (W_1 - W_2) / Log_{10} (N_2 / N_1)$$

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Consistency of Soils:

Determination of Liquid Limit:

The liquid limit is determined by two methods:

- Casagrande Liquid Limit Method
- Static Cone Penetration Method

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Consistency of Soils:

Casagrande Liquid Limit Method:

- The liquid limit is determined in the laboratory with the help of the standard liquid limit apparatus designed by Casagrande.
- The apparatus consists of a hard rubber base of B.S. hardness, over which a brass cup drops through a desired height.
- The brass cup can be raised and lowered to fall on the rubber base with the help of a cam operated by a handle.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Consistency of Soils:

Casagrande Liquid Limit Method:

- The height of fall of the cup can be adjusted with the help of adjusting screws.
- Before starting the test, the height of fall of the cup is adjusted to 1cm.
- Two types of grooving tools are used (i) the Casagrande tool and (ii) ASTM tool.
- The Casagrande tool cuts a groove of size 2mm wide at the bottom, 11mm wide at the top and 8mm high.

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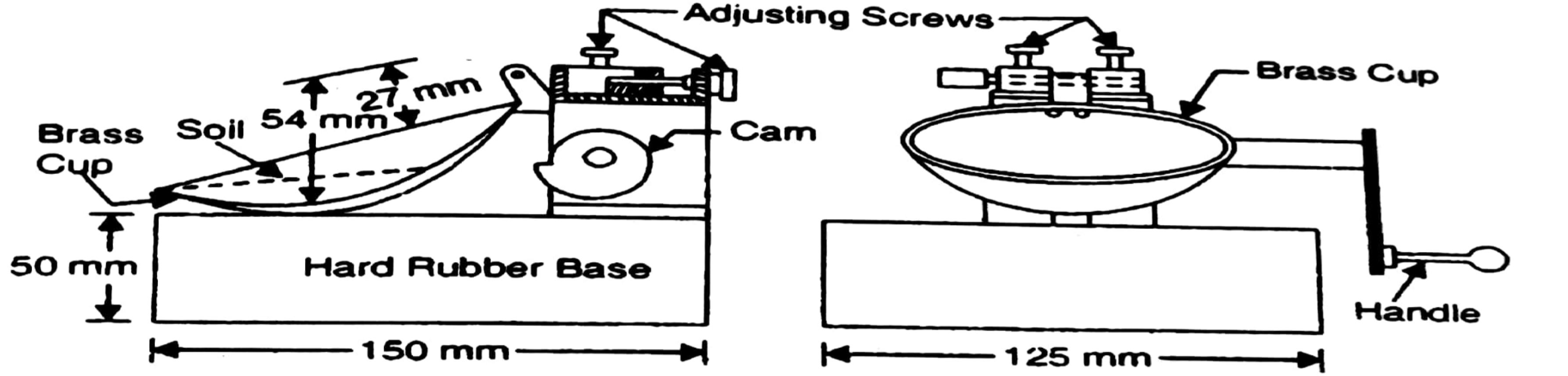
Module – 1: Introduction

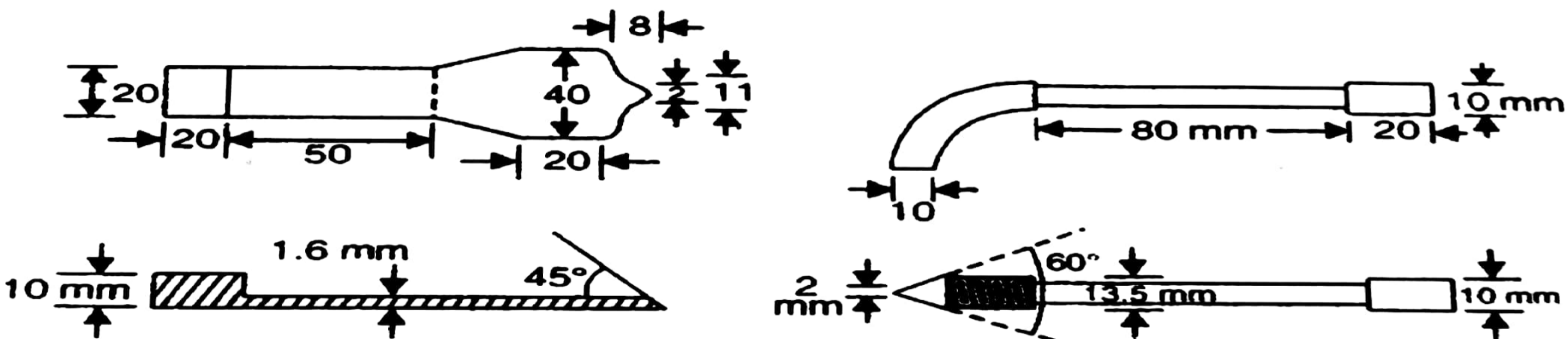
Consistency of Soils:

Casagrande Liquid Limit Method:

- The ASTM tool cuts a groove 2mm wide at the bottom, 13.6mm at the top and 10mm deep.
- The ASTM tool is used only for more sandy soils where the Casagrande tool tends to tear the sides of the groove.



(i) Liquid Limit Apparatus



(a) Casagrande (BS) Tool

(b) Tool

(ii) Grooving Tools

Divided soil cake before test

Soil cake after test

(iii) Closing of Groove

FIG. 3.10. LIQUID LIMIT APPARATUS.

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Module – 1: Introduction

Consistency of Soils:

Procedure:

- About 120 g of the specimen passing through 425 micron sieve is mixed thoroughly with distilled water in the evaporation dish or on a marble plate to form a uniform paste.
- A portion of the paste is placed in the cup over the spot where the cup rests on the base, squeezed down and spread into position and the groove is cut in the soil pat.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Consistency of Soils:

Procedure:

- The handle is rotated at a rate of 2 revolutions per second, and the number of blows are counted until the two parts of the soil sample come into contact at the bottom of the groove along a distance of 10mm.
- Some soil tend to slide on the surface of the cup instead of the flowing.
- If this occurs, the result should be discarded and the test repeated until flowing does not occur.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Consistency of Soils:

Procedure:

- After recording the number of blows, approximately 10 g of soil from near the closed groove is taken for water content determination.
- The liquid limit is determined by plotting a graph between number of blows as abscissa on a logarithmic scale and the corresponding water content as ordinate.
- Such graph is known as the flow curve, is a straight line.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Consistency of Soils:

Procedure:

- For plotting the flow curve, at least four to five sets of reading in the range of 10 to 50 blows should be taken.
- The water content corresponding to 25 blows is taken as the liquid limit
- Flow index can also be determined form the same flow curve.
- If the flow curve is extended at either end so as to intersect the ordinates corresponding to 10 and 100 blows, the numerical difference in water contents at 10 and 100 blows gives directly the flow index.

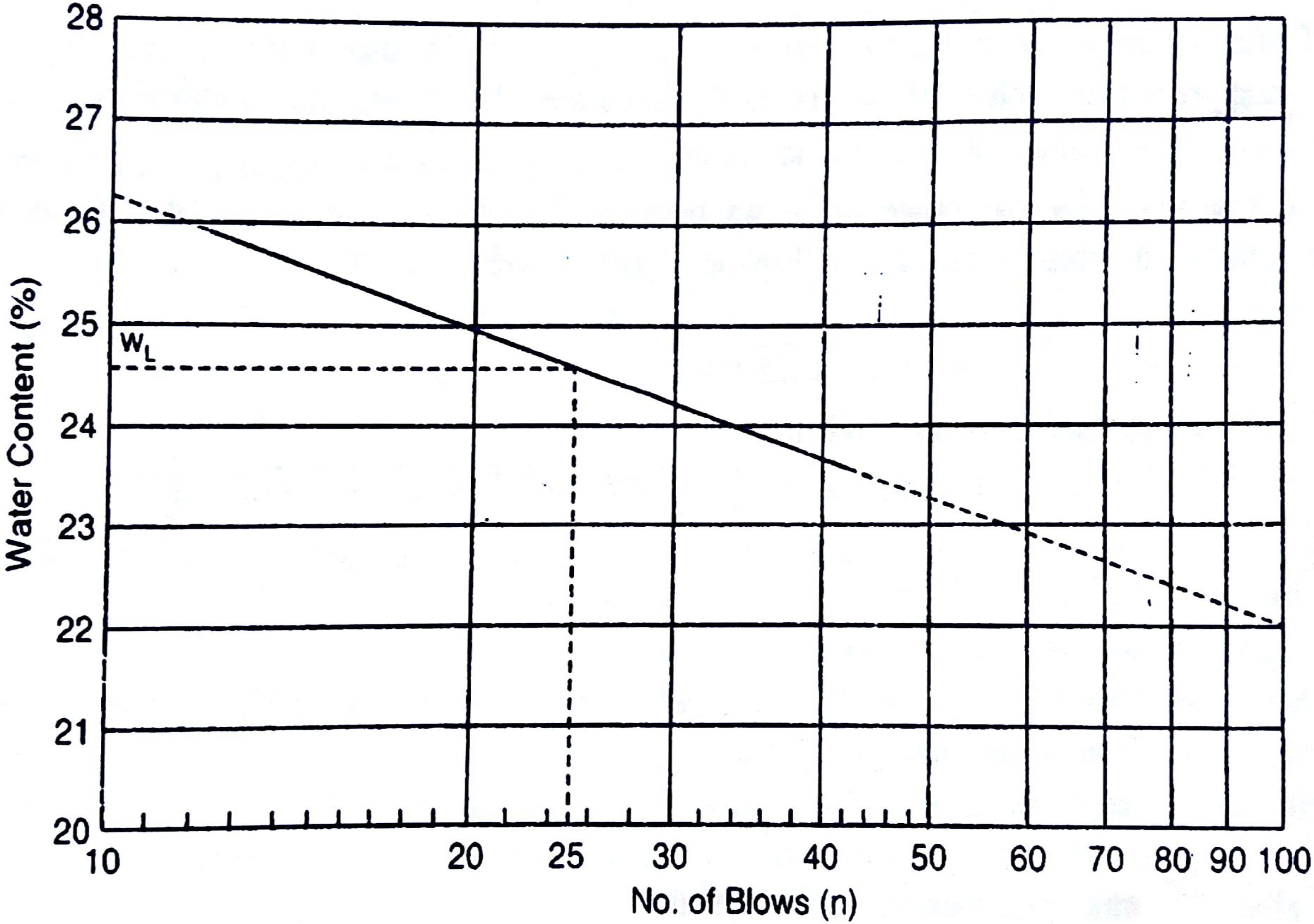

FIG. 3.11. FLOW CURVE.

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Module – 1: Introduction

Consistency of Soils:

Static Cone Penetration Method:

- The Soviet liquid limit device is based on the principle of static penetration.
- A 30° cone of stainless steel is made to penetrate the soil pat, under a mass of 75 g inclusive of the mass of the cone.
- If the cone penetrates through a depth of 1cm in 5 seconds, the soil pat is at the liquid limit.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Consistency of Soils:

Static Cone Penetration Method:

- IS : 2720 (Part V) : 1985 specifies a similar penetrometer for the determination of liquid limit.
- The cone has a central angle of 31° and total sliding mass of 80 g.
- The soil pat is kept in a cylindrical trough, 5cm in a diameter and 5cm high, below the cone.
- The liquid limit of the soil corresponds to the water content of a paste which would give 20mm penetration of the soil.

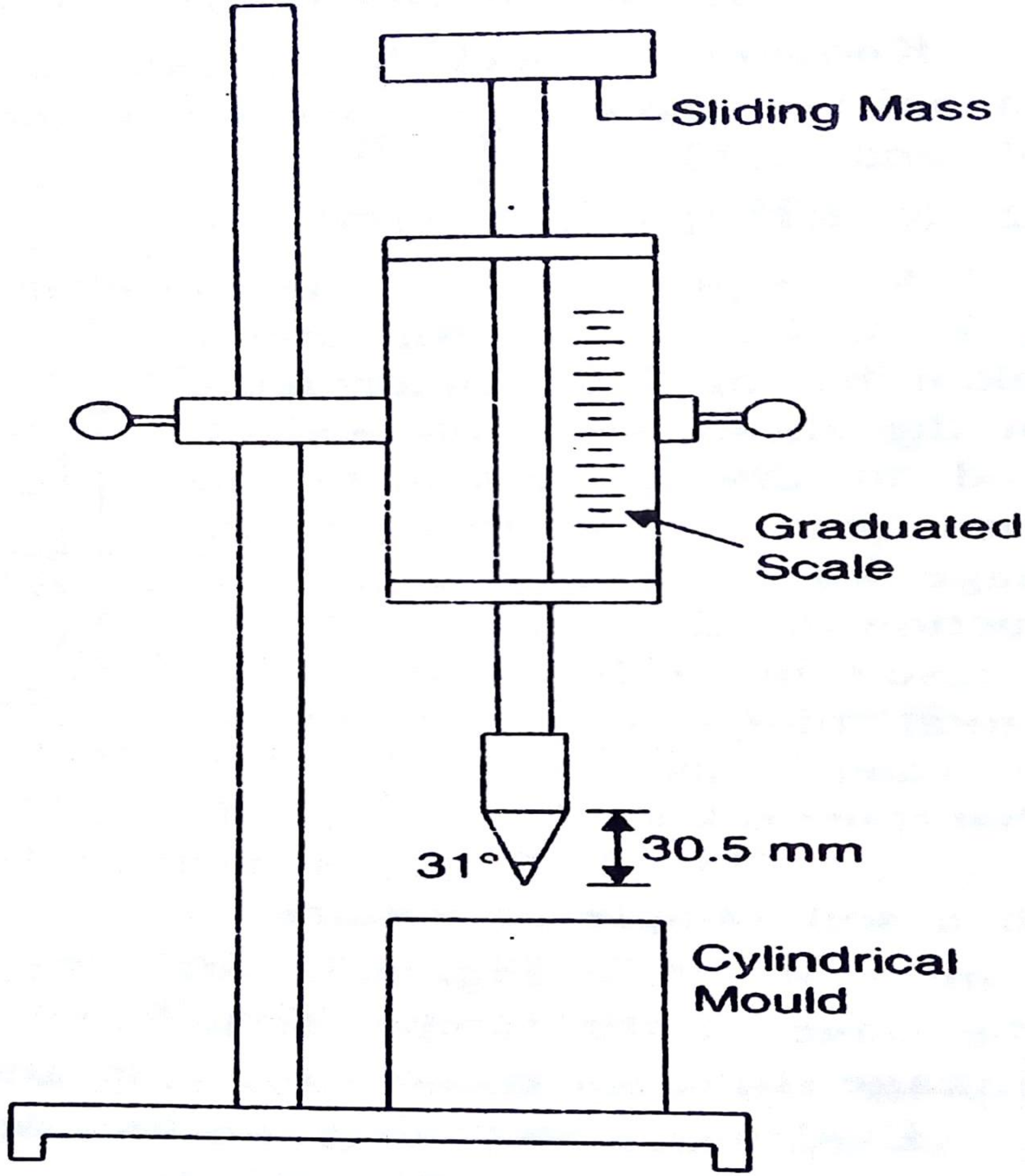

FIG. 3.12. CONE PENETRATION.
IS : 2720 (PART V)-1965.

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Module – 1: Introduction

Consistency of Soils:

Static Cone Penetration Method:

- Soil pats are prepared at various water contents and depth of penetration (x) for each pat is noted.
- A graph is plotted representing water content (w) on the y-axis and cone penetration (x) on the x-axis.
- The best fitting straight line is then drawn.
- The water content corresponding to a cone penetration of 20mm is then taken as the liquid limit.
- The sets of values used for the graphs should be in the range of 14 to 28mm.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Consistency of Soils:

Plastic Limit Determination:

- The soil sample passing 425 micron sieve, is mixed thoroughly with distilled water until the soil mass becomes plastic enough to be easily moulded with fingers.
- The plastic soil mass should be left for enough time to allow water to permeate through the soil mass.
- A ball is formed with about 8 g of this plastic soil mass and rolled between the fingers and a glass plate with just sufficient pressure to roll the mass into a thread of uniform diameter throughout the length.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Consistency of Soils:

Plastic Limit Determination:

- When a diameter of 3mm is reached, the soil is remoulded again into a ball.
- This process of rolling and remoulding is repeated until the thread starts just crumbling at a diameter of 3mm.
- The crumbled threads are kept for water content determination.
- The test is repeated twice or more with fresh samples.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Consistency of Soils:

Plastic Limit Determination:

- The plastic limit is then taken as the average of three water contents.
- The plasticity index and toughness index are also calculated.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Consistency of Soils:

Shrinkage Limit Determination:

Shrinkage limit is determined by anyone of the following methods:

- Determination of shrinkage limit, when the specific gravity of the soil is unknown.
- Determination of shrinkage limit, when the specific gravity of the soil is known.

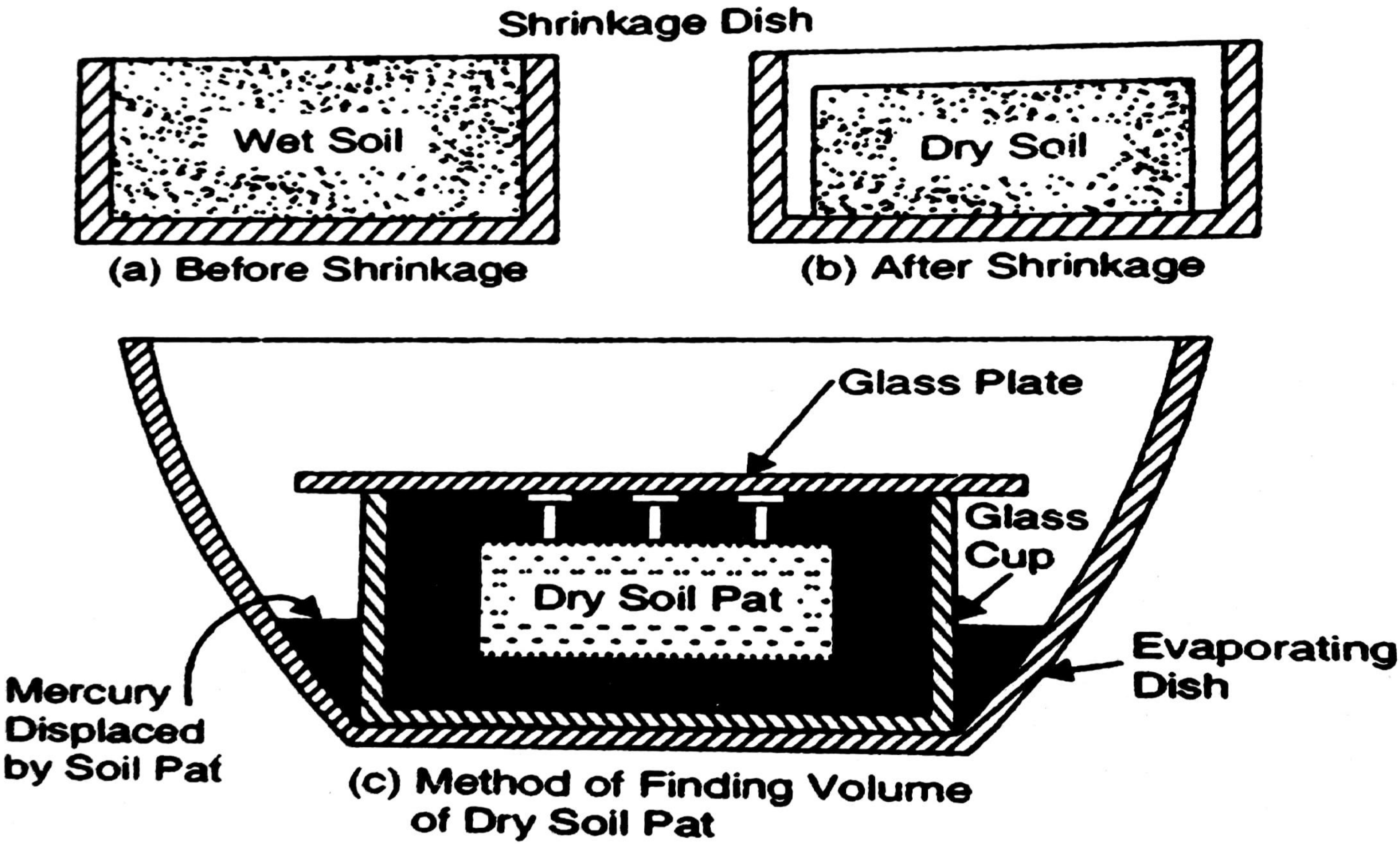

FIG. 3.14. APPARATUS OF SHRINKAGE LIMIT DETERMINATION.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Consistency of Soils:

Procedure:

- The apparatus consists of a porcelain evaporating dish of about 12cm diameter, a stainless steel shrinkage dish 45mm in diameter and 15mm high, two glass plates of each 75mm x 75mm one is a plain glass and the other having three metal prongs, a glass cup of 50mm in diameter and 25mm high, straight edge, spatula, oven, mercury, desiccator, balance and sieves.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Consistency of Soils:

Procedure:

- The volume of the shrinkage dish is first determined by filling it with mercury, remove the excess mercury by pressing a flat glass plate over the top and then take the mass of the dish filled with mercury.
- The mass of the mercury divided by its unit weight i.e., 13.6 gives the volume of the dish V_1.
- Take about 50 g of oven dry soil passing through 425 micron IS sieve.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Consistency of Soils:

Procedure:

- The soil is mixed with sufficient quantity of water to bring the soil to a consistency.
- The inside layer of the shrinkage dish is coated with a thin layer of vaseline.
- The soil mixture is placed in the shrinkage dish in three equal quantities so as to fill the dish.
- The excess soil is removed with straight edge and the dish is weighed with soil.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Consistency of Soils:

Procedure:

- The dish is then placed in an oven at 110°C and the soil pat is allowed to dry up.
- The weight of dry soil mass is founded.
- In order to find the volume of dry soil pat, V_2 the glass cup is filled with mercury and excess is removed by pressing the glass plate with three prongs firmly over the top.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Consistency of Soils:

Procedure:

- Then place the glass cup in the evaporating dish.
- The dry soil pat is placed on the surface of the mercury in the cup and carefully pressed by means of the glass plate with prongs.
- The mass of mercury so displaced divided by its density gives the volume of dry soil pat as V_2.
- The shrinkage limit is determined by using the relation:

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Consistency of Soils:

Procedure:

$$w_S = \{ w_1 - ((V_1 - V_d) \gamma_w / W_d) \} \times 100$$

Where,

w_1 = water content of the original saturated sample of volume V_1

V_d = dry volume of the soil sample

W_d = dry weight of the soil sample

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Consistency of Soils:

Shrinkage Ratio (SR):

- Is defined as the ratio of a given volume change expressed as a percentage of dry volume, to the corresponding change in water content above the shrinkage limit expressed as percentage of the weight of the oven dried soil.

$$SR = \{ (V_1 – V_2 / V_d) \text{ x } 100 / (w_1 – w_2) \}$$

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Consistency of Soils:

Shrinkage Ratio (SR):

Where,

V_1 = volume of soil mass at water content w_1

V_2 = volume of soil mass at water content w_2

V_d = volume of dry soil mass

w_1 & w_2 = water content, expressed as percentage

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Consistency of Soils:

Volumetric Shrinkage (VS):

- Is defined as the decrease in the volume of a soil mass, expressed as a percentage of the dry volume of the soil mass, when the water content is reduced from a given percentage to the shrinkage limit.

$$VS = (V_1 - V_d / V_d) \times 100$$

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Consistency of Soils:

Linear Shrinkage (VS):

- Is defined as the decrease in one dimension of a soil mass expressed as a percentage of the original dimension, when the water content is reduced from a given value to the shrinkage limit.

$$L_S = 100 \left[1 - \{100 / (V S + 100)\}^{1/3} \right]$$

Geotechnical Engineering (18CV54)

Module – 1: Introduction

In-Situ Density of Soils:

The field density of a natural soil deposit or of a compacted soil can be determined by the following methods:

- Sand replacement method
- Core cutter method
- Water displacement method
- Rubber balloon method

Geotechnical Engineering (18CV54)

Module – 1: Introduction

In-Situ Density of Soils:

Sand Replacement Method:

- The equipment consists of (i) sand pouring cylinder mounted above a pouring cone and separated by a value or shutter, (ii) calibrating container, (iii) tray with central circular hole, and (iv) chisel, scoop, balance etc.
- The procedure consists of (a) calibration of the cylinder, (b) measurement of a soil density, and (c) determination of water content and dry density.

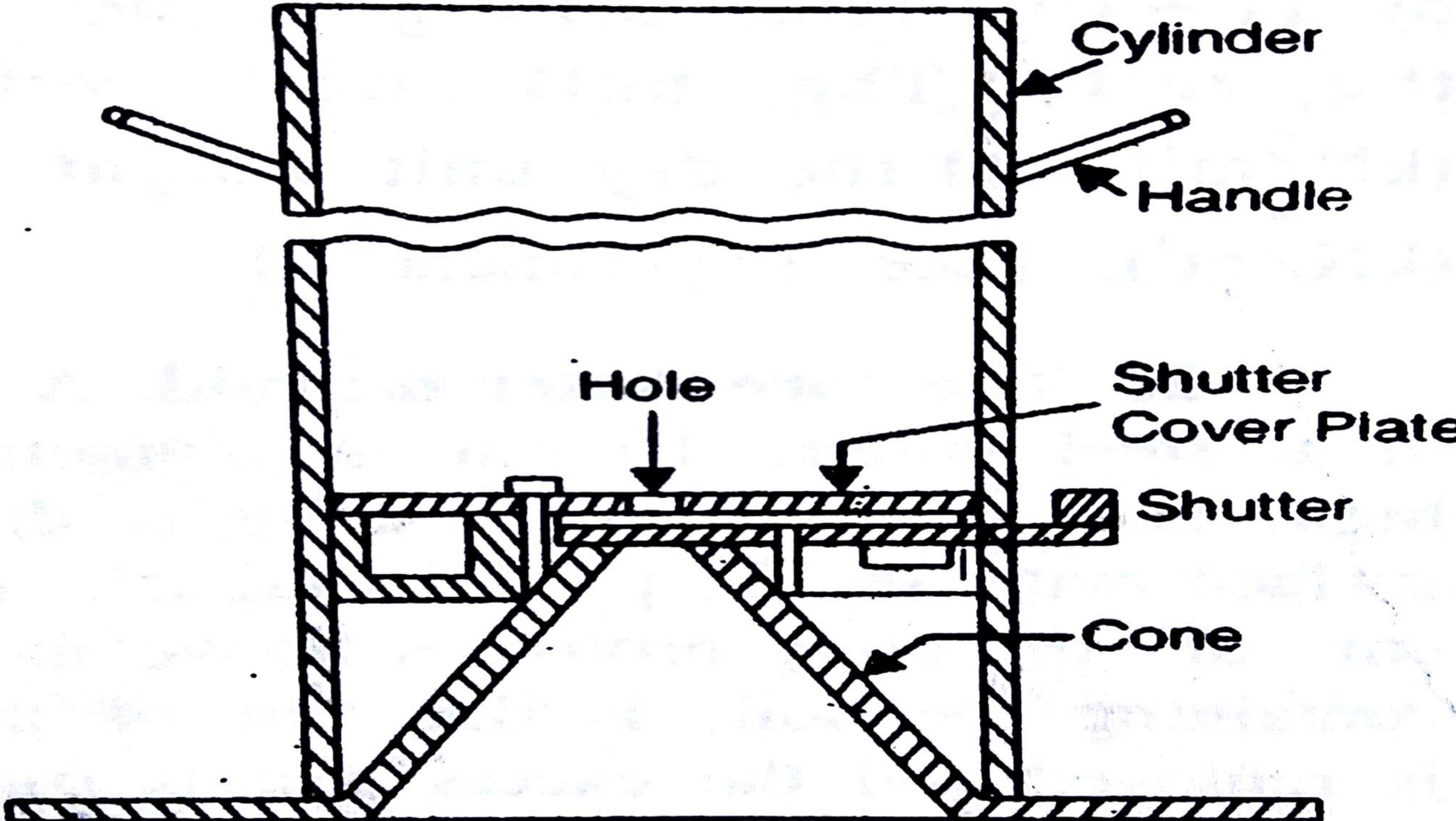

FIG. 3:19. SAND REPLACEMENT CYLINDER.

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Module – 1: Introduction

In-Situ Density of Soils:

Procedure:

- The calibration of the cylinder consists of the determination of the weight of sand required to fill the pouring cone of the cylinder, and the determination of the bulk density of sand.
- Uniformly graded, dry, clean sand preferably passing a 600 micron sieve and retained on 300 micron IS sieve is used in the cylinder.

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Module – 1: Introduction

In-Situ Density of Soils:

Procedure:

- The cylinder is filled upto a height 1cm below the top, and its initial mass M_1 is taken.
- The sand is run out of cylinder, equal in volume to that of the calibrating container.
- The cylinder is then placed over a plane surface and the sand is allowed to run out to fill the cone below.
- When no further sand runs out, the valve is closed.

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Module – 1: Introduction

In-Situ Density of Soils:

Procedure:

- The sand filled in the cone is collected, and its mass M_2 is found.
- All the sand is then refilled in the cylinder so that the total mass of sand and cylinder is equal to the original mass M_1.
- The cylinder is then put centrally above the calibrating container, and the sand is allowed to run into the calibrating container.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

In-Situ Density of Soils:

Procedure:

- The valve is closed when there is no further movement of sand.
- The mass of cylinder with sand is found M_3.
- The mass M' of the sand required to fill the calibrating container will be equal to $M_1 - M_3 - M_2$
- The mass M' divided by the volume of the calibrating container gives the bulk density of the sand.
- All the sand is then refilled in the cylinder.

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Module – 1: Introduction

In-Situ Density of Soils:

Procedure:

- For measurement of soil density, the site is cleaned and levelled, and the tray placed over it.
- A test hole, approximately of a depth equal to that of the calibrating container is excavated in the ground, and the soil is collected in the tray.
- The mass M of the excavated soil is found.
- The cylinder is centrally placed over the hole, and the sand is allowed to run in it.

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Module – 1: Introduction

In-Situ Density of Soils:

Procedure:

- The valve is closed when no further movement of sand takes place.
- The mass M_4 of the cylinder and the remaining sand in it is measured.
- The mass M'' run into the hole, upto level ground surface, will evidently be equal to $M_1 – M_2 – M_4$.
- Dividing M'' by the bulk density of sand, the volume of the hole and hence the volume V of the excavated soil is known.

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Module – 1: Introduction

In-Situ Density of Soils:

Procedure:

- Dividing the mass M by the volume V, the bulk density ρ of the soil excavated is known.
- In order to find the dry density, a suitable sample of the excavated soil is kept for water content determination.
- The dry density of the soil will be equal to the bulk density divided by (1+w).

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Module – 1: Introduction

In-Situ Density of Soils:

Core Cutter Method:

- A core cutter, consisting of a steel cutter, 10cm in diameter and about 13cm high and a 2.5cm dolly is driven in the cleaned surface with the help of a suitable rammer, till about 1cm of the dolly protrudes above the surface.
- The cutter, containing the soil, is dug out of the ground, the dolly is removed and the excess soil is trimmed off.

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Module – 1: Introduction

In-Situ Density of Soils:

Core Cutter Method:

- The mass of the soil in the cutter is found.
- By dividing it by the volume of the cutter the bulk density is determined.
- The water content of the excavated soil id found in the laboratory, and the dry density is computed.

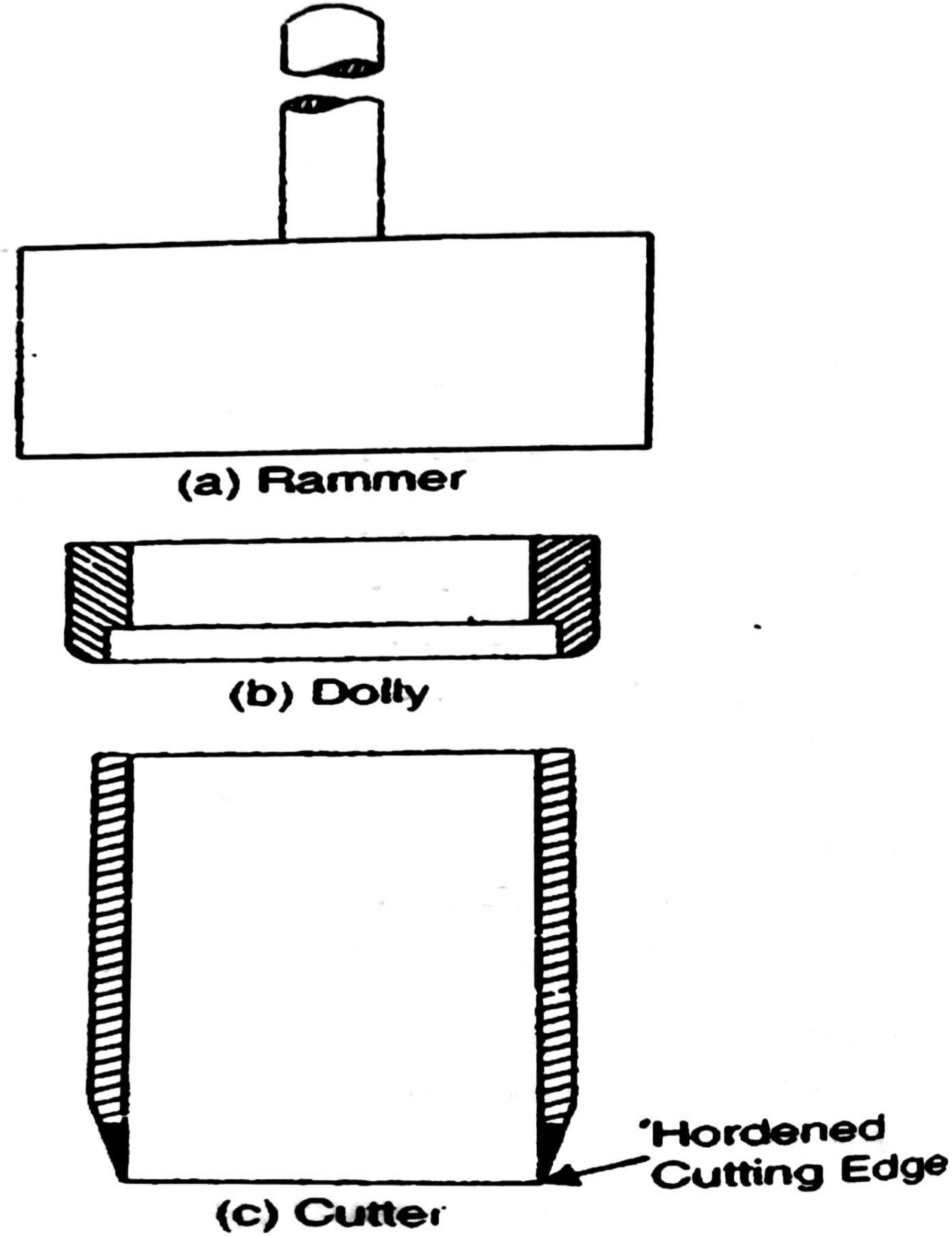

FIG. 3.20. CORE CUTTER.

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Module – 1: Introduction

In-Situ Density of Soils:

Water Displacement Method:

- The method is suitable only for cohesive soil samples brought from the field.
- A small specimen is trimmed to a more or less regular shape, from a larger sample, and its mass M_1 is found.
- The specimen is covered with a thin layer of paraffin wax and the mass M_2 of the coated specimen is taken.
- A metal container is filled above the overflow level, and excess water is allowed to runoff through the overflow outlet.

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Module – 1: Introduction

In-Situ Density of Soils:

Water Displacement Method:

- The coated specimen is then slowly immersed in the container, and the overflow water is collected in a measuring jar.
- The volume V_w of the displaced water is thus known.
- The volume V of the uncoated specimen is then calculated from the relation:

$$V = V_w - \{ (M_2 - M_1) / G_P \}$$

G_P = density of paraffin wax (g/ml) = 0.908 g/ml

Module – 1: Introduction

In-Situ Density of Soils:

Rubber Balloon Method:

- In this method, the volume of the excavated hole is measured with the help of an inflated rubber balloon.
- The apparatus consists of (i) a graduated glass enclosed in an air tight aluminium case, with an opening in the bottom, and (ii) a tray with central circular hole of 10cm diameter.
- The cylinder is partially filled with water
- Pressure or vacuum can be applied to the bottom of the cylinder with the help of a double acting rubber bulb.

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Module – 1: Introduction

In-Situ Density of Soils:

Rubber Balloon Method:

- The ground surface, where the density is to be determined is cleaned and levelled, and tray is placed over it.
- The cylinder is then placed centrally over the tray.
- The air valve is opened and air is pumped into the cylinder until the balloon is completely inflated against the surface of the soil in the opening of the tray.
- The water level is read in the cylinder.

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Module – 1: Introduction

In-Situ Density of Soils:

Rubber Balloon Method:

- The cylinder is then removed, and a hole is excavated in the ground.
- The excavated soil is weighed, and a sample is kept for water content determination.
- The cylinder is then placed over the opening in the tray, air valve is opened and air is forced in the cylinder to inflate the bottom, until the base of the instrument is raised off the tray at least by 1cm.

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Module – 1: Introduction

In-Situ Density of Soils:

Rubber Balloon Method:

- The air valve is closed and both feet are placed firmly on the base plate so that the balloon is forced into any irregularities in the hole.
- The water level is read in the cylinder.
- The volume of hole is found from the difference between the initial and final water level, in the glass cylinder.
- Knowing the mass, volume and water content, bulk density and dry density can be computed.

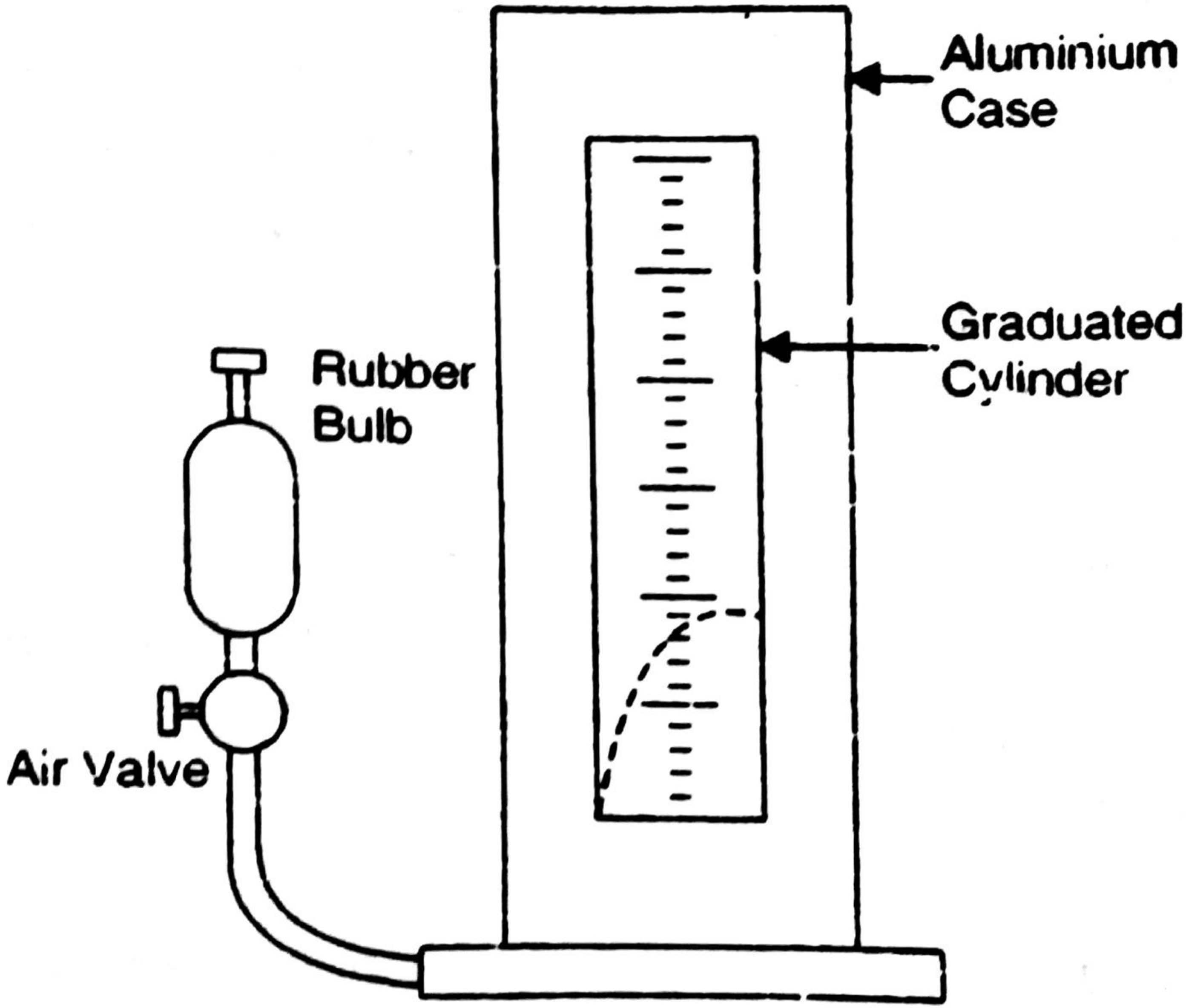

FIG. 3.21. RUBBER BALLOON CYLINDER.

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Module – 1: Introduction

Index Properties:

Activity of Clays:

- The properties of clays and their behaviour is influenced by presence of certain clay minerals even in small quantities.
- The thickness of the oriented water around a clay particle is dependent on type of clay mineral.
- Thus, the plasticity of a clay depends on (i) the nature of clay mineral present, and (ii) amount of clay mineral present.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Index Properties:

Activity of Clays:

- On the basis of lab test, Skempton observed that for a given soil the plasticity index is directly proportional to the percent of clay-size fraction.
- He introduced the concept of activity, by relating the plasticity to the quantity of clay-size particles, and defined the activity as the ratio of plasticity index to the percent by weight of soil particles of diameter smaller than two microns present in the soil.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Index Properties:

Sensitivity of Clays:

- The consistency of an undisturbed sample of clay is altered, even at the same water content, if it is remoulded.
- It is because the original structure of clay is altered by remoulding.
- Since the strength of a clay soil is related to its structures, remoulding results in decrease of it strength.

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Module – 1: Introduction

Index Properties:

Sensitivity of Clays:

- The degree of disturbance of undisturbed clay sample due to remoulding is expressed by sensitivity.
- Which is defined as the ratio of its unconfined compression strength in the natural or undisturbed state to that in the remoulded state, without change in the water content.

$$S_t = q_u \text{ (undisturbed)} / q_u \text{ (remoulded)}$$

- The sensitivity of most clays generally falls in a range of 1 to 8.

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Module – 1: Introduction

Index Properties:

Thixotropy of Clays:

- When sensitivity clays are used in construction, they loose strength due to remoulding during construction operations.
- However, with passage of time, the strength again increases, though not to the same original level.
- This phenomenon of strength loss-strength gain with no change in volume or water content is called thixotropy.

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Module – 1: Introduction

Index Properties:

Thixotropy of Clays:

- The loss of strength due to remoulding is partly due to (i) permanent destruction of the structure due to in-situ layers, and (ii) reorientation of the molecules in the adsorbed layers.
- The gain in strength is due to rehabilitation of the molecular structure of the soil, and is due to its thixotropic property.

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Module – 1: Introduction

Classification of Soils:

Unified Soil Classification System (USCS):

- Originally developed by Casagrande (1940), the USCS was used for air field construction during World War II.
- It was later (1952) modified slightly by the Bureau of Reclamation and Crops of Engineers of USA, to make it applicable to other construction like foundations, earth dams, earth canals, earth slopes etc.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Classification of Soils:

Unified Soil Classification System (USCS):

- The system has also been adopted by American Society of Testing Materials (ASTM) and later by Bureau of Indian Standards (1970).
- According to the USCS, the coarse grained soils are classified on the basis of their grain size distribution while the fine grained soils, whose behaviour is controlled by plasticity, are classified on the basis of their plasticity.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Classification of Soils:

Unified Soil Classification System (USCS):

- Various soils are classified into four major groups: (i) Coarse grained, (ii) Fine grained, (iii) Organic soils, and (iv) Peat.
- Coarse grained soils: if more then 50% of the soil is retained on No. 200 US sieve or 0.075mm, it is designated as coarse grained soil.
- A coarse grained soil is designates as gravel (G) if 50% or more of the coarse fraction, otherwise it is termed as sand (S).

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Classification of Soils:

Unified Soil Classification System (USCS):

- Coarse grained soils, containing less than 5% fines, are designated by symbols GW and SW if they are well graded and by symbol GP and SP if they are poorly graded.
- If however the percentage of fines is more than 12%, the coarse grained soils are designated by symbols GM, GC, SM and SC.
- Similarly, if percentage of fines lie between 5 to 12%, coarse grained soils are designated by dual symbols GW-GM or SP-SM.

Geotechnical Engineering (18CV54)

Module – 1: Introduction

Classification of Soils:

Unified Soil Classification System (USCS):

- Fine grained soils: A soil is termed as fine grained if more than 50% of the soil sample passes No. 200 US sieve.
- Fine grained soils are subdivided into silt (M) and clay (C), based on their liquid limit and plasticity index.
- Organic soil (O) are also included in this group.
- Figure shows the plasticity chart devised by Casagrande and used for the USCS system.

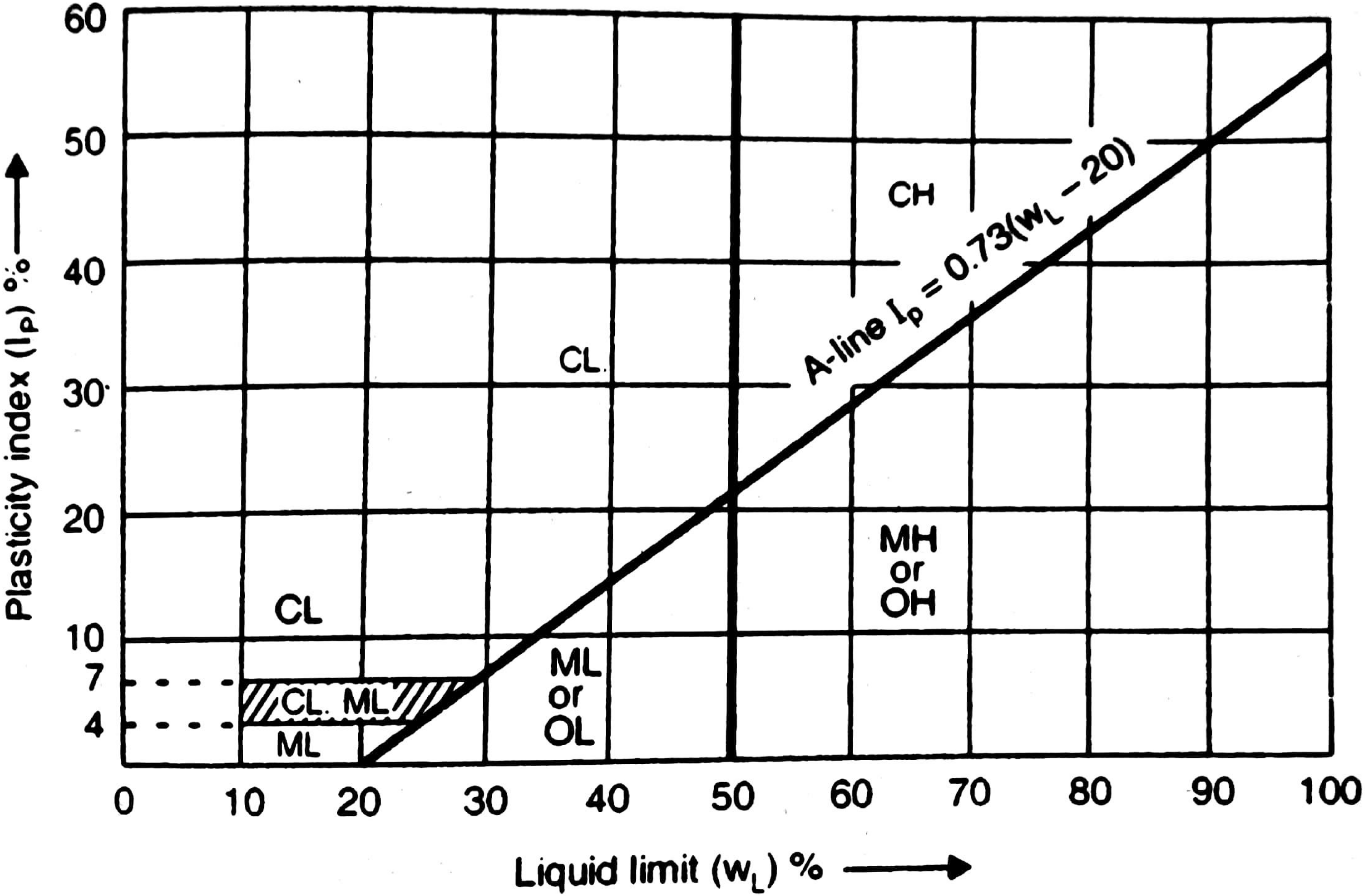

FIG. 4.3 CASAGRANDE'S PLASTICITY CHART (USCS)

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Module – 1: Introduction

Classification of Soils:

Indian Standard Classification System ISCS (IS : 1498-1970):

- First developed in 1959, was revised in 1970.
- This revised version is essentially based on USCS with the modification that the fine grained soils have been subdivided into three groups.

Soils are broadly divided into three divisions:

- Coarse grained soil
- Fine grained soil
- Highly organic and other miscellaneous soil materials

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Module – 1: Introduction

Classification of Soils:

Indian Standard Classification System ISCS (IS : 1498-1970):

Coarse grained soils: (i) Gravels (G), (ii) Sands (S)

- In these soils, more than half the coarse fraction is larger then 4.75mm IS sieve size.
- In these soils, more than half the coarse fraction is smaller than 4.75mm IS sieve size.

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Module – 1: Introduction

Classification of Soils:

Indian Standard Classification System ISCS (IS : 1498-1970):

Fine grained soils: (i) Inorganic silts and very fine sands (M), (ii) Inorganic clays (C) and, (iii) Organic silts and clays and organic matter (O)

Fine grained soils are further divided into three groups on the basis of values of liquid limit: (i) Silts and clays of low compressibility (<35, L), (ii) Silts and clays of medium compressibility (>35 and <50, I) and, (iii) Silts and clays of high compressibility (>50, H).

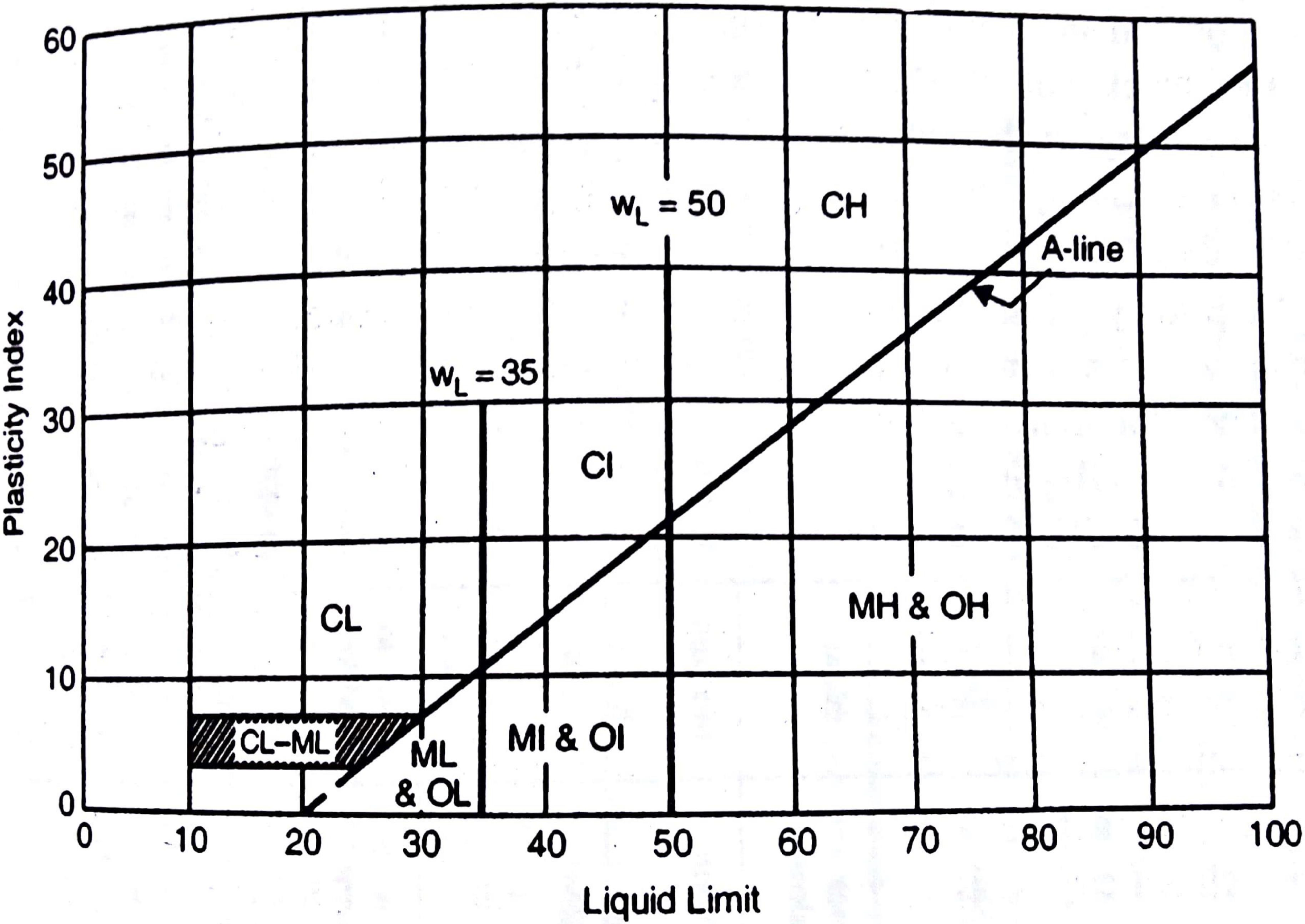

FIG. 4.4. PLASTICITY CHART (IS SOIL CLASSIFICATION SYSTEM).