Water Content of Soil by Oven Drying Method

1

AIM :

To determine the water (moisture) content of a given soil sample expressed as a percentage of the oven dry weight.

SCOPE & APPLICATION OF THE TEST :

Moisture content plays an important role in understanding the behavior of fine grained soils and field compaction control.

THEORY :

The soil has a porous structure with a skeleton of solid particles and the voids or pore spaces being mostly filled with water and /or air. The moisture content is defined as the ratio of mass / weight of water to the mass / weight of solids and may be expressed as

$$w = \frac{W_W}{W_S} = \frac{M_W}{M_S}$$

where M_w or W_w = mass or weight of water

M_s or W_s = mass or weight of soil solids

The mass of water used in the above expression is the mass of free pore water only. So for the determination of moisture content, the soil samples are dried to a temperature at which only pore water is evaporated. For fine grained soils, this temperature may be 105°C to 115°C where the pore water is subjected to appreciable surface tension in capillaries. But for granular soils this may happen at a lower temperature or it may take less time .However, for soils containing gypsum or other minerals having loosely bound water of hydration or for soils containing significant amounts of organic material, drying may be done at approximately 60- 80°C.

There are several laboratory and field methods for determination of moisture content namely oven drying method, pycnometer method, torsion balance or infra-red moisture meter, calcium carbide or alcohol burning method.

APPARATUS REQUIRED :

(1) Containers (non- corrodible, air tight) for soil sample.
(2) Balance of accuracy 0.04 percent of the weight of the soil taken for the test.
(3) Oven – thermostatically controlled with interior of non–corroding material to maintain temperature at 110° ± 5°C.
(4) Desiccators – with any suitable desiccating agent.
(5) A pair of tongues.

SPECIMEN / MATERIALS REQUIRED :

The quantity of soil sample to be taken for the determination of moisture content depends upon the gradation and maximum size of particles as well as accuracy of weighing. The following quantities are recommended for the laboratory use.

Soil type	Size of particles more than 90% passing	Minimum quantity of soil specimen to be taken for the test
Silt & clays	75µ	10 – 25g
Fine sand	425µ	25g
Medium sand	2 mm	50g
Coarse sand	4.75 mm	200g
Fine gravel	9.5 mm	300g
Medium gravel	19 mm	500g
Course gravel	37.5 mm	1000g

However, drier the soil, the greater shall be the quantity of the soil to be taken for the test.

PROCEDURE :

(1) The container is cleaned, dried and weighed with lid (M_1).

(2) The required quantity of soil specimen is taken in the container, crumbled and placed loosely and weighed with lid (M_2).

(3) Then it is kept in an oven with the lid removed and the temperature of the oven is maintained at 110 ± 5°C or 60 – 80°C for organic soil or for soils containing gypsum.

(4) The specimen is dried in the oven for 16 – 24 hours in normal condition, so that it attains a constant mass.

(5) After drying, the container is removed from the oven, the lid is replaced and it is cooled in the desiccator.

(6) The dried soil in the container with lid is weighed (M_3).

PRECAUTIONS :

(1) The wet soil specimen should be placed loosely in the metal container.

(2) Over heating of soil specimen is to be avoided to guard against breaking of soil structure.

(3) Dried soil specimen in the container should not be left uncovered before weighing as it is likely to catch moisture from the surrounding atmosphere.

OBSERVATION AND CALCULATION :

The percentage moisture or water content is calculated as follows :

$$w = \frac{M_2 - M_3}{M_3 - M_1} \times 100$$

It is reported to two significant figures.

Sl No.	Particulars	Container No. 1	2	3
1.	Mass of the container with lid (M_1)g			
2.	Mass of the container with lid + wet soil (M_2)g			
3.	Mass of the container with lid + dry soil (M_3)g			
4.	Mass of water $M_w = (M_2 - M_3)$g			
5.	Mass of dry soil $M_S = (M_3 - M_1)$g			
6.	Moisture content $w = \frac{M_2 - M_3}{M_3 - M_1} \times 100$			

Specific Gravity of Fine Grained Soils 2

AIM :

To determine the specific gravity of the soil particles passing 4.75 mm IS sieve.

SCOPE & APPLICATION OF THE TEST :

Specific gravity finds application in the determination fo the degree of saturation and unit weight of moist soils, which, in turn are needed in pressure, settlement and stability problems in soil engineering.

THEORY :

Specific gravity of soil is the ratio of the mass/weight of a given volume of dry soil particles in air to the mass /weight of an equal volume of distilled water at a temperature of 4°C. The specific gravity of a soil is widely used in the derivation of weight volume relationships. Although specific gravity may be employed in the identification of minerals, it is of little importance for identification or classification of soils because the specific gravity values of most soils fall within a narrow range. It is an important factor required for computing most of the soil properties i.e void ratio of soil, unit weight, and particle size determination by hydrometer method, degree of saturation of soil etc.

Mathematically, it is expressed as;

$$\text{Specific gravity of soil particles } G = \frac{G_L(W_2 - W_1)}{(W_2 - W_1) - (W_3 - W_4)} = \frac{G_L(M_2 - M_1)}{(M_4 - M_1) - (M_3 - M_2)}$$

where G_L = specific gravity of liquid used ,at constant temperature.

M_1 or W_1 = mass or weight of the density bottle.

M_2 or W_2 = mass or weight of the bottle + dry soil.

M_3 or W_3 = mass or weight of the bottle +soil+ liquid.

M_4 or W_4 = mass / weight of the bottle when full of liquid only.

APPARATUS REQUIRED :

(1) Two density bottles of approximately 50ml capacity with stoppers or pycnometer of 1 litre capacity.
(2) A water bath maintained at a constant temperature to within ±0.2°C.
(3) A vaccum desiccator (a convenient size is one about 200 mm to 250 mm in diameter).
(4) A desiccators (a convenient size is one about 200 mm to 250 mm in diameter) containing anhydrous silica gel.
(5) A thermostatically controlled drying oven, capable of maintaining a temperature of 105 to 110°C.
(6) A balance readable and accurate to 0.01g.
(7) A source of vacuum, such as a good filter pump or a vacuum pump.
(8) A spatula (a convenient size is one having a blade 150 mm long and 3mm wide ; the blade has to b small enough to go through the neck of the density bottle) or a piece of glass rod about 150 mm lo and 3 mm diameter.
(9) A wash bottle preferably made up of plastics, containing air–free distilled water.

(10) A sample divider of the multiple slot type (riffle box) with 7 mm width of opening.
(11) Length of rubber tubing to fit the vacuum pump and the desiccator.
(12) 2 mm / 4.75 mm I.S sieve.
(13) Balance accurate to 0.5g and 0.001g.
(14) Thermometer (0-50°C).

MATERIALS REQUIRED :

(1) Sample of soil.
(2) Distilled water / kerosene / white spirit.

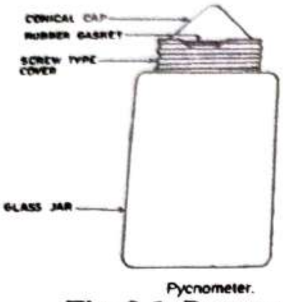

Fig. 2.1 Pycnometer

Fig. 2. 2 Specific Gravity Bottle

Fig. 2.3 Desicator

PROCEDURE :

(1) The complete density bottle with stopper or the pycnometer with cap is dried at 105°C to 110°C cooled in the desiccator and weighed to the nearest 0.001g (M_1).

(2) About 50g of soil sample (in case of density bottle or 500gm of soil sample (incase of pycnometer) sieved through 4.75mm I.S. sieve and dried in an oven is taken and if necessary is ground to pass a 2 mm I.S sieve.

(3) A 5 to 10 g of sub sample (in case of density bottle) or 200g to 250 g of sub sample (in case of pycnometer) is obtained by riffling (sample divider) and oven dried at 105 to 110°C.

(4) This sample is transferred to the density bottle /pycnometer direct from the desiccator in which it has been cooled. The bottle (pycnometer) and contents together with the stopper (cap) is weighted to the nearest 0.001g (M_2).

(5) Sufficient air free distilled water is added so that the soil in the bottle/pycnometer is just covered.

(6) The bottle/pycnometer containing the soil and liquid, but without the stopper /cap, is placed in the vaccum desiccator, which is then evacuated gradually. The pressure is reduced to about 20mm Hg .In case of pycnometer, it may be shaken well before connecting to the vacuum pump.

(7) When using a water pump, because of variation in mains pressure, care is taken to ensure that the required vaccum is maintained. Care is also taken during this operation to see that the air trapped in the soil does not bubble too violently, so as to prevent small drops of suspension being lost through the mouth of the bottle /pycnometer.

(8) The bottle is allowed to remain in the desiccator for at least 1 hour until no further loss of air is apparent. The vacuum is released and the lid of the desiccator removed.

(9) The soil in the bottle /pycnometer is stirred carefully with the spatula /glass rod or the bottle/pycnomete is vibrated. Before removing the spatula /glass rod from the bottle/pycnometer, the particles of soi adhering to it is washed off with a few drops of air-free liquid. The lid of the desiccator is agai replaced and the desiccator evacuated again.

(10) The above procedure is repeated until no more air is evolved from the soil. Alternatively, the entrapped air can be removed by getting heated the pycnometer placed on a water bath or sand bath.

(11) The bottle (pycnometer) and its contents are then removed from the desiccators and further air–free liquid is added until the bottle /pycnometer is full. The stopper/ cap is then inserted.

(12) The stoppered bottle or capped pycnometer is immersed up to the neck in the constant–temperature bath for approximately one hour or until it has attained the constant temperature of the bath. However, if the constant temperature room or cabinet is available, then this procedure need not be carried out in a water bath.

(13) If there is an apparent decrease in the volume of the liquid, further liquid added up to the tip of the pycnometer or by removing the stopper of the density bottle to fill it and the stopper replaced.

(14) The bottle is then returned to the bath and sufficient time is allowed to elapse after this operation to ensure that the bottle and its contents again attain the constant temperature of the bath.

(15) This process is repeated till the bottle /pycnometer is full. The stoppered bottle /capped pycnometer is then taken out of the bath ,wiped dry and the whole weighed to the nearest 0.001g (M_3).

(16) Then the bottle /pycnometer is cleaned out and filled completely with air free liquid (the stopper being inserted in case of density bottle) and the whole immersed in the constant temperature bath for 1 hour or until it has attained the constant temperature of the bath.

(17) If there is an apparent decrease in the volume of the liquid, further liquid is added to fill the bottle or pycnometer (up to the tip of the cap or removing and replacing the stopper).

(18) The stoppered bottle /capped pycnometer is then returned to the bath and sufficient time is allowed to elapse after this operation to ensure that the bottle / pycnometer and its contents again attain the constant temperature. If the bottle /pycnometer is still not completely full, this process is repeated.

(19) The bottle /pycnometer is then taken out of the bath, wiped dry and the whole weighed to the nearest to 0.001g (M_4). If this method is used to find the volume of the density bottle /pycnometer, then the test may be carried out at any temperature provided it is constant throughout the test.

(20) Two determinations of specific gravity of the same soil sample are made.

PRECAUTIONS :

(1) If a density bottle is used, then in order to avoid distortion, it should not be dried by placing it in an oven. It may be dried by rinsing with acetone or an alcohol–ether mixture and then blowing warm air through it.

(2) Oven drying of the soil is done for convenience at about 105°C to 110°C. If there is possibility of change of specific gravity due to loss of water of hydration, the soil should be dried at not more than 80°C.This fact is to be reported.

(3) The soil grains whose specific gravity is to be determined should be completely dry and the dried soil taken for testing should have the soil grains of its original size. So if on drying, soil lumps are formed, they should be broken to its original size.

(4) For the soils containing water soluble salts or for very fine grained soils kerosene (paraffin oil) or white spirit is used in place of water. If one of these is used, the fact is recorded and a separate experiment is carried out to determine the specific gravity of the liquid at the room temperature of the test.

(5) Inaccuracies in weighing and failure to completely eliminate the entrapped air are the main sources of error. Both should be avoided by careful working.

(6) To obtain reliable results, the sample should be left under vacuum for several hours (to ensure complete removal of air) preferably over night. Shaking the bottle in hand once or twice interrupting the

vacuum gives quicker result. Also the rubber tubing should be held tightly with the pycnometer so that there is no leakage when the vaccum pump works.

(7) In case of pycnometer, cap should be properly screwed with washer to avoid any leakage. Also the cap should be screwed up to the same mark throughout the test.

(8) Many soils may have a substantial proportion of heavier or lighter particles. Such soils give erratic values for the specific gravity and a number of repeated tests may be needed to obtain a good average value.

OBSERVATION AND CALCULATION :

The specific gravity of the soil particles G is measured at room temperature. If water has been used as the air free liquid then the following equation is used

$$G = \frac{M_2 - M_1}{(M_4 - M_1) - (M_3 - M_2)}$$

If some other air free liquid in place of water is used, the numerator of the above expression is multiplied with G_L, the specific gravity of the liquid concerned.

The specific gravity is calculated at 27 °C. If the room temperature is different from 27°C, the following correction is to be done.

G′= KG / where G′ = corrected specific gravity at 27 °C

$$\text{and } K = \frac{\text{Relative density of water at room temperature}}{\text{Relative density of water at 27°C}}$$

The average of the values obtained is taken as the specific gravity of the soil particles and is reported to the nearest 0.01. If the two results differ by more than 0.03, the tests are to be repeated.

OBSERVATION SHEET :

(i) Test temperature T_t, °C =

(ii) Relative density of water at T_t, °C =

(iii) Relative density of water at 27 °C =

(iv) Correction factor due to temperature,

$$K = \frac{(ii)}{(iii)} =$$

Sl. No.	Particulars	Test No. - 1	Test No. - 2
1.	Mass of density bottle or pycnometer (M_1)		
2.	Mass of density bottle or pycnometer with dry soil (M_2)		
3.	Mass of density bottle or pycnometer with soil & water (M_3)		
4.	Mass of density bottle or pycnometer full of water (M_4)		
5.	Mass of dry soil = $(M_2 - M_1)$		
6.	Mass of equal volume of water = $(M_2 - M_1)$ - $(M_3 - M_4)$		
7.	Sp. Gravity of soil at T_t°C, $G = \frac{(5)}{(6)}$		
8.	Sp. Gravity of soil at 27 °C = (7) × K		

Field Density of Soil by Core Cutter Method

3

AIM :

To determine the dry density of soil in –place using the core cutter.

SCOPE & APPLICATION OF THE TEST :

This method is used for determination of the in-place density of fine grained (not less than 90 percent passing 4.75 mm I.S. sieve) natural or compacted soils free from aggregates using a core cutter.

THEORY :

The in-place density of soil is needed for the stability analysis and for the determination of the degree of compaction of compacted soil etc. The core cutter method is suitable for fine grained soils free from aggregations .It is less accurate than the sand replacement method and is not recommended , unless the speed is essential or unless the soil is well compacted .

In this method, bulk density of soil is obtained by dividing the weight of the soil inside the core cutter by volume of the core cutter. The water content of the soil sample is determined which is used to find the dry density of soil.

APPARATUS REQUIRED :

(1) Cylindrical core cutter – of seamless steel tube 130 mm long and 100mm internal diameter, with a wall thickness of 3mm, beveled at one end as shown in the figure. The cutter shall be kept properly greased or oiled.

(2) Steel dolly – 2.5 cm length high and 10 cm internal diameter with a wall thickness of 7.5 mm with a lip to enable it to be fitted on the top of the core cutter.

(3) Steel rammer – with solid mild steel foot 140 mm diameter and 75 mm in height with a concentrically screwed 25mm diameter solid mild steel staff. The overall length of the rammer including the foot as well as the staff is approximately 900 mm. The rammer (foot and staff together) weighs about 9 kg.

(4) Balance- accurately to 1 g.

(5) Palette knife – A convenient size is one having a blade approximately 20 cm long and 3cm wide .

(6) Steel rule.

(7) Grafting tool or spade or pick axe.

(8) Straight edge –A steel strip about 30 cm long, 2.5 cm wide and 3 to 5 mm thick, with one beveled edge.

(9) Apparatus for determination of water content (Drying oven and container for water content determination, rapid moisture meter etc.)

(10) Apparatus for extracting samples from the cutter – optional.

Fig. 3.1 Core Cutter Apparatus

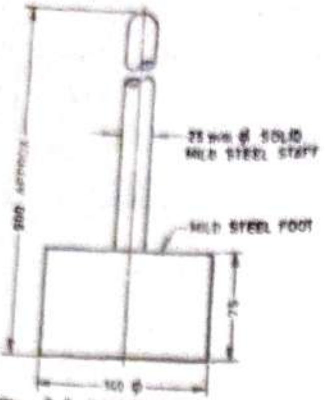

Fig. 2.2 RAMMER

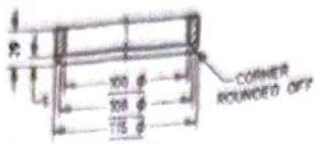

Fig. 2.3 DOLLEY

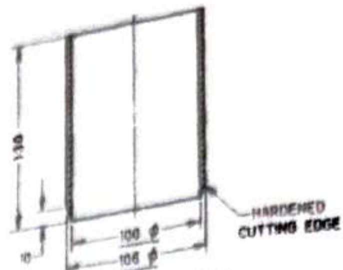

Fig. 3.2 Cutter

MATERIALS REQUIRED :

(1) Grease.

PROCEDURE :

(1) The inside dimensions of the core cutter are measured to the nearest 0.25 mm and the internal volume (V_c) of the core cutter in cubic centimeters is calculated.

(2) The core cutter (with out dolly) is weighed to the nearest gram (W_c).

(3) A small area, approximately 30 cm square of the soil layer to be tested is exposed and leveled.

(4) The steel dolly is placed on the top of the cutter ,and the assembly is rammed down vertically into the soil layer until only about 15mm of the dolly protudes above the surface, care being taken not to rock the cutter.

(5) The cutter is then dug out of the surrounding soil, care being taken to allow some soil to project from the lower end of the cutter.

(6) The ends of the soil core are then trimmed flat to the ends of the cutter by means of the straight edge.

(7) The cutter containing the soil core is weighed to the nearest gram (W_s).

(8) The soil core is removed from the cutter and a representative sample is placed in an air –tight container and its water content (w) determined.

(9) The test is repeated at least at three locations nearby to average the results to take into account the density variation of soil from point to point.

PRECAUTIONS :

(1) Essential dimensions of the core cutter are to be accurately measured.

(2) The cutting edge is to be kept sharp and to avoid damage it should not be used in stony soil.

(3) The number of the repeat determinations should be such that an additional one would not alter the average significantly.

OBSERVATION, CALCULATION & REPORTING :

The bulk density γ_b; that is the weight / mass of the soil per cubic centimeter is calculated from the following formula

$$\gamma_b = \frac{(W_S - W_C)}{V_C} g/cm^2$$

where W_s = weight of the soil and core cutter in g.

W_c = weight of the core cutter in g.

V_c = volume of the core cutter in cm^3.

The dry density γ_d, that is the weight of the dry soil per cubic centimeter is calculated from the following formula.

$$\gamma_d = \frac{100\gamma_b}{100 + w} g/cm^3$$

where γ_b = bulk density.

w = water content of the soil (%).

The dry density of the soil is reported to the second place of decimal in g/cm^3 and water content of the soil (%) to two significant figures.

OBSERVATION SHEET

Sl. No.	Particulars of the test	1	2	3
	Bulk Density			
1	Determination No.			
2.	Weight of core cutter + wet soil (W_s),g			
3.	Weight of core cutter (W_c),g			
4.	Weight of wet soil ($W_s - W_c$),g			
5.	Volume of core cutter (V_c),cm^3			
6.	Bulk density, $\gamma_b = \frac{W_s - W_c}{V_c} g/cm^3$			
	Water content			
7.	Moisture can or container No.			
8.	Weight of the container with lid (W_1),g			
9.	Weight of the container with lid + wet soil (W_2),g			
10.	Weight of the container with lid + dry soil (W_3),g			
11.	Water content, $w = \frac{(W_2 - W_3)}{(W_3 - W_1)} \times 100(\%)$			
	Dry Density			
12.	Dry density, $\gamma_d = \frac{100\gamma_b}{100 + w}$, g/cm^3			

RESULT :

(1) The water content of the soil = _________.

(2) The dry density of the soil = ___________.

CONCLUSION :

(Comment on the result by comparing with standard values).

DISCUSSION :

Generally this method is adopted for field control of compaction in predominantly cohesive soil (claye soil) and not suitable for cohesionless soils (sandy soils) because of retention problem of such soils in th

Praticle Size Gradation of Sand / Gravel by Sieve Analysis

4

AIM :

To determine the grain size distribution of soil by sieve analysis.

SCOPE & APPLICATION OF THE TEST :

It is applicable to coarse grained soils and the results of grain size analysis are widely used in soil classification.The data obtained from grain size distribution curves is used in the design of filters for earth dams & to determine the suitability of soils for road construction .

THEORY :

Grain size analysis quantitatively expresses the proportions by mass of the various sizes of particles present in the soil. In a soil, the gravel, sand, silt and clay fractions are recognized as containing particles of decreasing magnitude. The actual range of dimensions of particles for boulders are more than 300mm, for cobbles 80mm to 300mm ,for gravel 4.75mm to 80mm ,for sand 4.75mm to 75μ and for silt & clay fractions less than 75μ. Thus soil particles larger than 75μ size are termed as coarse grained soils.

There are two methods for finding the distribution of grain sizes larger than 75μ IS sieve ; the first method, wet sieving is applicable to all soils and the second dry sieving is applicable only to soils which do not have an applicable amount of clay (say less than 5%) . Sieving consists of shaking the soil by a mechanical device through sieves of known aperture size .The particle size, therefore, is defined by the dimensions of square hole of the sieve .The soil particles being generally flaky in shape, in this analysis only the width of the flake is measured .The results of grain size analysis are represented graphically in the form of a grain size distribution curve in which the cumulative percentages finer than the known equivalent grain sizes are plotted against these sizes, the later being on a logarithmic scale.

For convenience, the course fraction (>75μ) is divided into two broad categories for sieve analysis i.e. fraction retained on 4.75 mm I.S sieve (Dry sieving) and the fraction passing 4.75 mm I.S sieve and retained on 75μ IS sieve (Dry sieving or wet sieving).

(I) Sieve Analysis of Soil Fraction Retained on 4.75 mm I.S Sieve

APPARATUS REQUIRED :

(1) I.S sieves of sizes (450 mm or 300 mm dia. preferably)-100 mm,75 mm, 40 mm, 25mm, 19mm, 12.5mm, 10 mm, 6.5mm and 4.75mm.

(2) Rubber pestle and mortar.

(3) Balance – Sensitive to 0.1 percent of the weight of sample to be weighed .

(4) Oven

(5) Desiccator

(6) Tray etc.

MATERIALS OR SPECIMEN REQUIRED :

The soil sample received from the field is prepared as per IS: 2720 (Part -1) [Methods of test for soils; Preparation of dry soil samples for various tests]. The soil fraction retained on and passing 4.75 IS sieve is taken separately for the analysis .

PROCEDURE :

(1) A suitable quantity of oven dried soil sample depending upon the maximum particle size contained in it is taken for analysis as per the following table:

Max^{m}. size of material present in substantial quantities (mm)	Mass to be taken for the test (kg)
75	60
40	25
25	13
19	6.5
12.5	3.5
10	1.5
6.5	0.75
4.75	0.4

(2) The portion of the soil sample retained on 4.75 mm IS sieve is weighed and the mass recorded as the mass of the sample uncorrected for hygroscopic moisture.

(3) The sample is separated into various fractions by sieving through the specified set of IS sieves. While sieving through each sieve ,the sieve is agitated so that the sample rolls in regular motion over the sieve.

(4) Any particle may be tested to see if it falls through but it is not to be pushed thorough.The material from the sieve may be rubbed ,if necessary ,with the rubber pestle in the mortar taking care to see that individual soil particles are not broken and re-sieved to make sure that only individual particles are retained .

(5) The quantity taken each time for sieving on each sieve is to be such that the maximum weight of the material retained on each sieve at the completion of sieving does not exceed the values given in the following table:

I.S. sieve Designation (mm)	450 mm dia. sieves (kg)	300 mm dia. sieves (kg)
80	15	6
20	4	2
4.75	1	0.5

(6) The mass of the material retained on each sieve is recorded .

(7) If the sample appears to contain over 5% moisture , the water content of the material is determined and the masses corrected accordingly .When the sample contains less than 5% moisture, it is not necessary to determine the water content for dry weight computations and all the determinations may be made on the basis of wet weight only.

(8) If the soil contains more than about 20% gravel particles and the fines are very cohesive with considerable amounts adhering to the gravel after separation, the gravel is to be washed on 4.75 mm IS sieve using sodium hexametaphosphate solution, if necessary, with a concentration of 2 grams / liter of water used.

(9) For further analysis, a fresh portion of the fraction passing 4.75 mm IS sieve is to be taken.

SERVATION AND CALCULATION :

The percentage of soil retained on each sieve is calculated on the basis of total mass of soil sample taken from the results; the percentage passing through each of the sieves is calculated.

Praticle Size Gradation of Sand / Gravel by Sieve Analysis

Mass of total soil sample / taken for analysis = ________

Water content = ________

I.S. sieve designation (mm)	Mass of soil retained+mass of container	Mass of container	Mass of soil retained	Cumulative mass of soil retained	Soil retained as % of sample taken	Soil passing as % of sample taken	Combined % passing as % of total soil sample	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
100								
75								
40								
25								
19								
12.5								
10								
6.5								
4.75								

(II) Sieve Analysis of Soil Passing 4.75 mm IS Sieve and Retained on 75μ I.S. Sieve.

APPARATUS REQUIRED :

(1) IS sieves of sizes (200mm dia.) – 2mm, 850μ,600 μ,425μ,300μ,150μ and 75μ.

(2) Balance – sensitive to 0.1 percent of the mass of sample to be weighed.

(3) Oven – Thermostatically controlled to maintain the temperature between 105 to 110°C with interior of non- corroding material.

(4) Trays or bucket – two or more large metal or plastic water tight trays or a bucket about 30cm in diameter and 30 cm deep. (tray 45 to 90 cm^2 and 8 to 15 cm deep)

(5) Brushes – Sieve brushes and wire brush or similar stiff brush.

(6) Mortar with a rubber covered pestle.

(7) Mechanical sieve shaker.

(8) Riffler

(9) Rubber pestle & mortar.

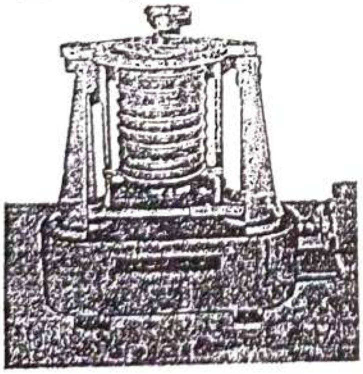

Fig. 4.1 Mechanical sieve shaker

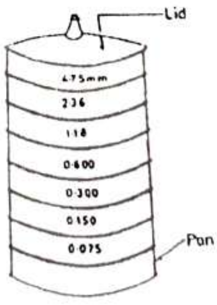

Fig. 4.2 Sleve Set

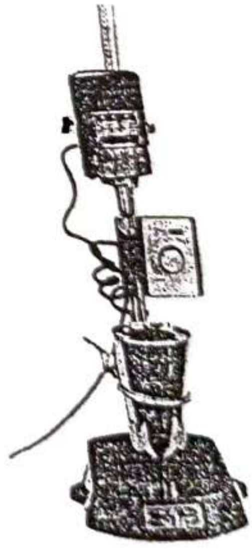

Fig. 4.3 Stirring Apparatus

REAGENTS AND MATERIALS REQUIRED :

(1) Sodium hexa metaphosphate (chemically pure) or a mixture of sodium hydroxide and sodium carbonate (analytical grade) or any other suitable dispersing agent.

(2) Water

(3) Sample of soil.

PROCEDURE :

[A] ANALYSIS BY WET SIEVING [for clayey soils or soils having substantial fines]

(1) The portion of the soil passing 4.75 mm I.S sieve is oven dried at 105 to 110° C.

(2) The oven dried material is then riffled so that a fraction of convenient mass is obtained .This is to be 200g if a substantial proportion of the material only, just passes the 4.75 mm IS sieve or less if the largest size is smaller .

(3) The fraction is to be weighed to an accuracy of 0.1 percent of its total mass and the mass recorded.

(4) The riffled and weighed fraction is spread out in a large tray or bucket and covered with water.

(5) 2g of sodium hexametaphosphate or 1g of sodium hydroxide and 1g of sodium carbonate per liter of water used is then added to the soil, if required. The mix is thoroughly stirred and left for soaking.

(6) The soil soaked specimen is washed thoroughly over the specified set of sieves nested in order of their fineness with the finest sieve (75 μ IS sieve) at the bottom . Washing is continued until the water passing each sieve is substantially clean.

(7) Care is taken to see that the sieves are not overloaded in the process for which the permissible maximum mass of sample on the 200 mm diameter sieve is to be as follows :

I.S. sieve Designation	Max^{m} mass of the sample
2 mm	200g
425μ	50g
75μ	25g

(8) The fraction retained on each sieve should be carefully emptied without any loss of material in separate trays.

(9) Then it is oven dried at 105 to 110°C and each fraction weighed separately and the masses recorded.

Alternatively :

(6) The soaked soil specimen is washed on the 75μ IS sieve until the water passing the sieve is substantially clean.

(7) The fraction retained on the sieve is tipped without loss of material in a tray, dried in the oven and sieved through the nest of specified sieves either by hand or by using mechanical sieve shaker.

(8) The fraction retained on each sieve is weighed separately and the masses recorded.

[B] ANALYSIS BY DRY SIEVING :

(1) The portion of the soil passing 4.75 mm I.S sieve is oven dried at 105 to 110°C and weighed to 0.1 % of its total mass.

(2) The sieve or sieves are agitated so that the sample rolls in irregular motion over the sieves.

(3) No particle is pushed through the sieve. However the material retained on the sieve may be rubbed with the rubber pestle in mortar and re–sieved to ensure that only individual particles are retained on the sieve.

(4) The amount retained on the sieve is weighed.

(5) The material retained in the receiver is transferred to a steel tray and the receiver fitted to the next largest sized sieve.

(6) The contents of the steel tray is placed on this sieve and the operations indicated above are repeated. Also these operations are repeated through all the sieves specified.

(7) However, these steps may be performed in one operation in a mechanical sieve shaker.

(8) Care is taken to ensure that the sieving is complete. Hence a minimum of 10 minutes shaking is used.

(9) The soil fraction retained on each sieve is carefully collected in containers and the mass of each fraction determined and recorded.

PRECAUTIONS :

(1) While drying the soil, the temperature in the oven should not exceed 105°C because higher temperature may cause some permanent changes in the material finer than 75µ.

(2) During shaking, the soil sample should not spill over the rim of the sieve and the sieving should be done for sufficient time so that it is complete.

(3) In wet analysis, all cohesive soil adhering to the large size particles should be removed by water. Also, while removing the clear water from the bucket, care should be taken so that no soil particle flows with water out of the bucket.

(4) While calculating, the percentage finer should be determined with respect to the total soil taken for the initial analysis.

OBSERVATION AND CALCULATION :

The cumulative mass of soil fraction retained on each sieve is calculated. The percentage of soil fraction retained on each sieve is calculated on the basis of the mass of the sample passing 4.75 mm IS sieve taken for the initial analysis. The combined gradation on the basis of the total soil sample taken for analysis is then calculated.

Mass of partial soil sample taken for analysis = __________

Water content = ________

I.S. sieve designation (mm)	Mass of soil retained+mass of container	Mass of container	Mass of soil retained	Cumulative mass of soil retained	Mass of soil retained as % of partial sample taken	Mass of soil passing as % of partial sample taken	Combined % passing as % of total soil sample	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	**(8)**	**(9)**
2mm								
850µ								
600 µ								
425µ								
300µ								
150µ								
75µ								

RESULT :

A grain size distribution curve is drawn on a semi- logarithmic chart, plotting the particle size on the lo scale against the % finer than the corresponding size on the ordinary scale.

Cobble % = __________ D_{60} = __________

Gravel % = __________ D_{30} = __________

Sand % = __________ D_{10} = __________

Silt & clay % = __________ C_C = __________

C_U = __________

Gradation & classification = __________

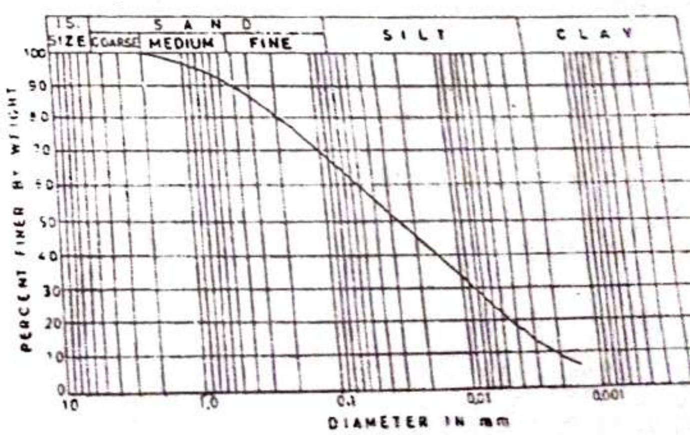

Fig. 4.4 Particle size Distribution curve.

Liquid Limit of Soil by Casagrande's Apparatus

6

AIM :

To determine the liquid limit of soil by mechanical method.

SCOPE OF THE TEST :

It indicates the cohesive properties or plasticity characteristics o soil.

THEORY :

Liquid limit is the water content corresponding to the arbitrary limit of transition between the liquid state (zero shear strength)and initiation of plastic state (infinitesimal strength) of consistency of a soil . Thus it may be defined as the minimum water content at which the soil is at the margin of the liquid state having a small shearing strength of about 0.17 N/cm^2 (17.6 g/cm^2) against flowing which can be measured by standard available means. For determination purpose, liquid limit is that water content at which a part of soil ,cut by a groove of standard dimensions ,will flow together for a distance of 12 mm under an impact of 25 blows in a standard liquid limit device . For all soils, shear strength at liquid limit is constant .i.e. the critical shear strength at liquid limit water content arises out of force field equilibrium and is independent of soil type.

There are three methods, namely mechanical method , one point method and the cone method for the determination of liquid limit .One point method may be an approximate method and may be applicable for which constants are obtained based upon test results of a particular region. The Casagrarde's apparatus is suitable for predominantly clayey soils and is not suited to soils of low plasticity (sandy soils) due to difficulty of cutting groove in such soils and the tendency of soils to slip rather than flow. Cone penetrometer forms an alternative method to overcome these inherent short comings.

NOTE : *Liquid limits over about 120 percent is obtained either by Casagrandes method or cone penetrometer method. One point method is not used for highly organic soils.*

APPARATUS REQUIRED :

(1) Mechanical liquid limit device (Casagrande's type)
(2) Grooving tools Type A (BS types),Type B (ASTM type), Type-C (Casagrande's type)
(3) Porcelain evaporating dish –about 12 to15 cm in diameter.
Or Flat glass plate -10 mm thick and about 45 cm square or larger (for mixing soil and water).
(4) Spatula –flexible ,with the blade about 8cm long and 2 cm wide for mixing soil and water in the porcelain evaporating dish .
Or, Palette knives – two ,with the blade about 20 cm long and 3cm wide for mixing soil and water on flat glass plate .
(5) Balance – sensitive to 0.01g.
(6) Oven – thermostatically controlled with interior of non – corroding material to maintain temperature between 105° to 110° C.
(7) Wash bottle or beaker – containing distilled water
(8) Moisture can or containers – air tight and non-corrodible for determination of moisture content.
(9) Measuring cylinder
(10) Desiccator.

Liquid Limit of Soil by Casagrande's Apparatus

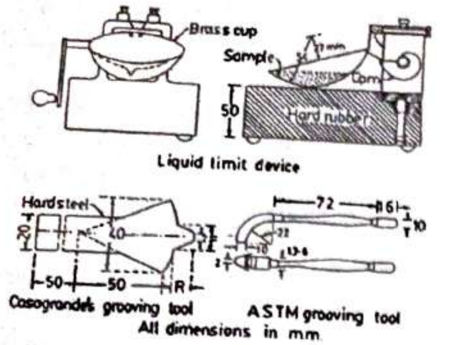

Fig. 6.1 Casagrande's liquid limit aparatus

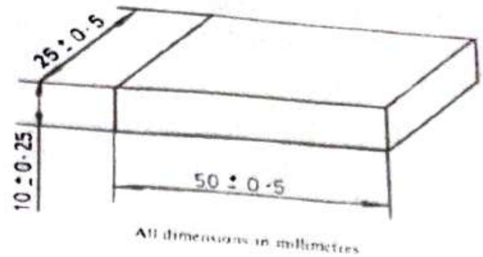

Fig.6.2 Gauge Block

Fig. 6.3 Closing of groove.

MATERIALS REQUIRED :

Sample of soil weighting about 120 g from the thoroughly mixed portion of material passing 425μ IS sieve.

PROCEDURE :

(1) The height through which the cup of liquid limit apparatus is lifted and dropped is adjusted by spacer block and the adjustment plate so that the point on the cup which comes in contact with the base falls through exactly one centimeter for one revolution of the handle.

(2) About 120 gm. of air dried sample passing 425μ I.S sieve is thoroughly mixed with distilled water in the evaporating dish or on flat glass plate to from a uniform paste.

(3) The soil is left for sufficient time so that water may permeate throughout the soil mass. In case of fat clays, this maturing time may be up to 24 hours. Light textured soils (of low clay content) may be tested immediately after thorough mixing with water. For average soil thorough mixing of about 15 to 30 minutes may be sufficient, but for clayey soil, it should be remixed before the test after maturing.

(4) A portion of the paste is taken with the spatula and placed in the cup above the spot where the cup rests on the base, squeezed down and spread with a few strokes of spatula to level off the top of the wet soil symmetrically so that it is parallel to the rubber base .At the same time, it is trimmed to a depth of one centimeter, at the point of maximum thickness, returning the excess soil to the dish .

(5) The soil in the cup is divided by firm strokes of the grooving tool along the diameter through the center line of the cam follower holding the tool normal to the surface of the cup so that a clean ,sharp groove of proper dimensions (2mm wide at the bottom ,11mm at the top and 8mm deep) is formed.In case where grooving tool type A does not give a clear groove as in sandy soils , grooving tool type B or type C are to be used .

(6) The cup is lifted and dropped by turning the crank at the rate of two revolutions per second until the two halves of the soil cake come in contact with the bottom of the groove along a distance of about 12mm. This length is measured with the end of the grooving tool or a ruler. The number of drops required to cause the groove to close for the length of 12 mm is recorded.

(7) A little extra of the soil mixture is added to cup and mixed with the soil in the cup. The pat is made in the cup and the test is repeated. In no case, the dried soil is to be added to the thoroughly mixed soil that is being tasted.

(8) The procedure given in (6) & (7) are repeated until two consecutive runs give the same number of drops for the closure of the groove. Some soils tend to slide on the surface of the cup instead of flowing. If this occurs, the result is discarded and the test is repeated.

(9) A representative slice of the soil of approximately the width of the spatula, extending from about edge to edge of the soil cake at right angles to the groove and including that portion of the groove in which the soil flowed together, is taken in a suitable container and its moisture content determined. The remaining soil in the cup is transferred to the evaporating dish and the cup and the grooving tool cleaned thoroughly.

(10) The operations specified above[(4) to(9)] is repeated for at least three more additional trials (minimum of four in all) with the soil collected in the evaporating dish or flat glass plate , to which required water is added to bring the soil to a more fluid condition .In each case , the number of blows is recorded and the moisture content determined as before.

NOTE : *The amount of water to be added to the soil depends upon the type of soil and the paste is to have such consistency that requires 25 ±10 drops of the cup to cause required closure of the standard groove. The test should always proceed from the dryer (more blows) to the wetter (less blows) condition of soil. The test may also be conducted from the wetter to drier condition provided drying is achieved by kneading the wet soil and not by adding dry soil.*

PRECAUTIONS :

(i) To avoid tearing of the sides of the groove or slipping of the soil cake on the cup, up to six strokes of grooving tool, from front to back or from back to front counting as one strokes is permitted .Each stroke penetrates a little deeper until the last stroke from back to front scraps the bottom of the cup clean .The groove is made with as few strokes as possible.

(ii) When grooving tool type B is used , it inserts a wedge into the pat of soil causing the two halves of the pat to slide at the cup – soil interface .Hence during the test ,the tendency is then for the soil to slide back again on this same face instead of flowing as it should do. It should therefore be used with caution.

(iii) Care is taken to see that the soil paste does not dry out too rapidly between repeat tests as the number of blows for closure will increase gradually as the sample dries out.

(iv) The soil used for liquid limit determination should not be oven dried prior to testing and only distilled water is to be used in order to minimize the possibility of ion exchange between the soil and any impurities in water.

OBSERVATION AND CALCULATION :

Moisture contents are determined from the following table;

Sl. No.	Particulars	Determination			
1.	No of blows	1	2	3	4
2.	Container No.				
3.	Mass of container + wet soil (M_1) (M_2)				
4.	Mass of container + dry soil (M_2) (M_3)				
5.	Mass of water ($M_2 - M_1$) ($M_3 - M_2$)				
6.	Mass of container, M_3 (M_1)				
7.	Mass of dry soil, ($M_2 - M_3$) ($M_3 - M_1$)				
8.	Moisture content $w = \frac{M_2 - M_1}{M_2 - M_3} \times 100$				

$$\frac{M_3 - M_2}{M_3 - M_1} \times 100$$

Points are plotted on a semi logarithmic graph representing water content on the arithmetic scale and the number of drops on the logarithmic scale .The flow curve is a straight line drawn as nearly as possible through the four or more plotted points .The moisture content corresponding to 25 drops as read from the curve shall be rounded off to the nearest whole number and reported as the liquid limit (w_L) of the soil.

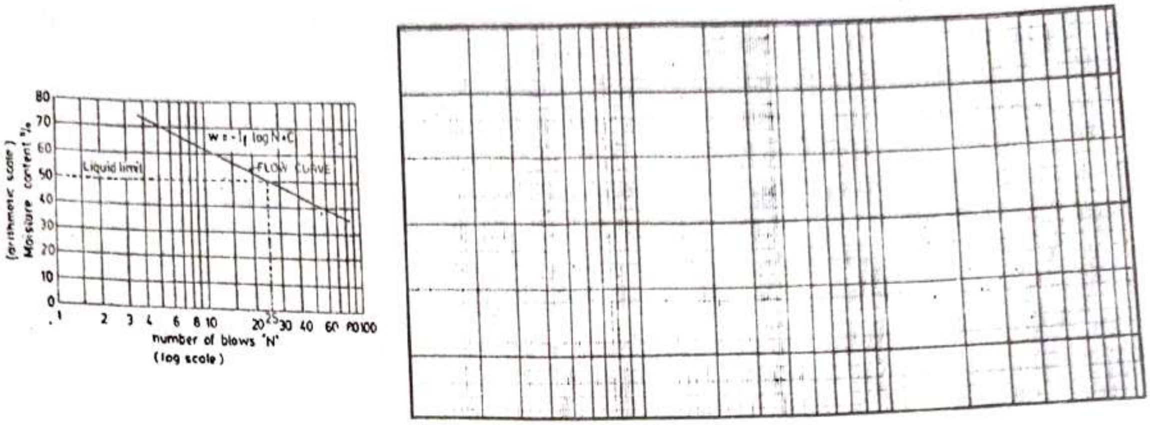

Fig. 6.4 Determination of liquid limit

Flow index I_f – The flow curve (straight line) plotted in the semi logarithmic graph is extended at either end so as to intersect the ordinates corresponding to 10 and 100 drops .The slope of this line expressed as the difference in water contents at 10 drops and at 100 drops is reported as the flow index .Also it may be calculated form the following equation

$$I_f = \frac{w_1 - w_2}{\log_{10} \frac{N_2}{N_1}}$$

where w_1= water content corresponding to N_1 drops (%)

and w_2= water content corresponding to N_2 drops (%)

RESULT :

(1) Liquid limit of the given sample of soil = ________.

(2) Flow index (I_f) = ________.

CONCLUSION :

(Comment on the result by comparing with standard values).

DISCUSSION :

Liquid limit of the soil depends upon the type of clay particles present in the soil .Liquid limit of mixed sandy soil ranges up to 30- 35% and that of clayey soil is generally more than 40%. Organic clays possess liquid limit greater than 50%. Expansive clays like black cotton soils have liquid limit not less than 70 %. A liquid limit greater than 100 is uncommon for inorganic clays of non- volcanic origin. Bentonite, a material consisting of chemically disintegrated volcanic ash has a liquid limit ranging from 400 to 600 because it contains considerable amount of scale like particles of colloidal size.

REFERENCE :

IS: 2720 (Part -5) Method of test for soils -Determination of liquid and plastic limit.

Plastic Limit of Soil

7

AIM :

To determine the plastic limit of soil.

SCOPE & APPLICAITON OF THE TEST :

It indicates the cohesive properties or plasticity characteristic of soil.

THEORY :

Plastic limit is the water content corresponding to an arbitrary limit between the plastic and the semisolid states of consistency of a soil .It is defined as the minimum water content at which a soil will just begin the crumble when rolled into a thread approximately 3mm in diameter. Shearing strength though constant at liquid limit varies at plastic limit for all clays. A high plastic (fat) clay has higher shearing strength at plastic limit and the threads at this limit are rather hard to roll where as a low plastic (lean) clay can be rolled easily at plastic limit and there by possess low shearing strength .Cohesion-less soils for which plastic limit cannot be determined are called non – plastic soils .The range of water content between the liquid and plastic limit ,which is an important measure of plastic behavior, is called the plasticity index (I_p) = L.L –P.L

APPARATUS REQUIRED :

(1) Porcelain evaporating dish – About 12 cm in diameter.
Or, Flat glass plate -10mm thick and about 45 cm square or larger.

(2) Spatula: - Flexible, with the blade about 8cm long and 2 cm wide (for use with porcelain dish for mixing soil and water).
Or, Palette knives – two, with the blade about 20 cm long and 3cm wide (for use with flat glass plate for mixing soil and water).

(3) Surface for rolling –ground glass plate about 20 x 15 cm.

(4) Moisture can / containers –air tight to determine moisture content.

(5) Balance – sensitive to 0.01 g.

(6) Oven – thermostatically controlled with interior of non-corroding material to maintain the temperature between 105 to 110°C.

(7) Rod – 3mm diameter and about 10cm long.

PLASTIC LIMIT SET

Fig. 7.1

MATERIALS REQUIRED :

Sample of soil weighing about 20 g from the thoroughly mixed portion of the material passing 425μ IS sieve.

PROCEDURE :

(1) The soil sample is mixed thoroughly with distilled water in an evaporating dish or on a flat glass plate till the soil mass becomes plastic enough to be easily moulded with fingers.

(2) In case of clayey soils, the plastic soil mass is left to stand for sufficient time (24 hours) to ensure uniform distribution of moisture throughout the soil.

(3) A ball is formed with about 8 g of this plastic soil mass and rolled between the fingers and the glass plate with just sufficient pressure to roll the mass into a thread of uniform diameter through out its length.

(4) The rate of rolling is to be between 80 to 90 strokes /min counting a stroke as one complete motion of the hand forward and back to the starting position again. The rolling is done till the threads are of 3mm diameter.

(5) The soil shall then be kneaded together to a uniform mass and rolled again. This process of alternate rolling and kneading is continued until the thread crumbles under the pressure required for rolling and the soil can no longer be rolled into a thread.

(6) The crumbling may occur when the thread has a diameter greater than 3mm. This is considered a satisfactory end point, provided the soil has been rolled into a thread 3mm in diameter immediately before.

(7) At no time an attempt is to be made to produce failure exactly at 3mm diameter by allowing the thread to reach 3mm, then reducing the rate of rolling or pressure or both and continuing the rolling without further deformation until the thread falls apart.

(8) The process of crumbled soil thread shall be collected in an air tight container and the moisture content determined.

PRECAUTIONS :

(1) The distilled water is to be used in order to minimise the possibility of ion exchange between the soil and any impurities in water.

(2) Soil used for plastic limit determination should not be oven dried prior to testing as heating of a soil may alter its plastic limit by causing the particles to subdivide or agglomerate by driving off adsorbed water which is not completely regained on rewetting or by effecting a chemical change in any organic matter in the soil.

(3) Wet soil taken in the containers for moisture content determination should not be left open in the air even for some time and the container with dry soil samples should either be placed in the desiccator or immediately weighed after cooling.

OBSERVATION AND CALCULATION :

The plastic limit is determined for at least three portions of the soil passing 425μ I.S sieve. The average of the results calculated to the nearest whole number is reported as the plastic limit of the soil.

Sl. No.	Particulars	Determination No.		
		1	2	3
1.	Container No.			
2.	Mass of container + wet soil (M_1)			
3.	Mass of container + dry soil (M_2)			
4.	Mass of water, ($M_1 - M_2$)			
5.	Mass of container, M_3			
6.	Mass of dry soil (M_2- M_3)			
7.	Plastic limit, $w_p = \frac{(4)}{(6)} \times 100 = \frac{M_1 - M_2}{M_2 - M_3} \times 100$			

Plasticity Index (I_p) – It is calculated as the difference between its liquid limit and plastic limit.

i.e. Plasticity Index (I_p) = Liquid limit w_L – plastic limit w_p

NOTE:

(1) *In case of sandy soils, plastic limit is determined first. When plastic limit can not be determined, the plasticity index (I_p) is reported as (non plastic) N_p.*

(2) *When the plastic limit is equal to greater than liquid limit , the plasticity index is reported as zero .*

RESULT :

(1) The plastic limit of given soil sample w_p = ______.

(2) The plasticity index PI value = I_p = ______.

CONCLUSION :

(Comment on the result by comparing with standard values)

DISCUSSIONS :

Liquid limit and plastic limit are determined on soil fractions smaller than fine sand size i.e. passing 425μ I.S. sieve, because surface activity of particles are supposed to start below this range although particles < 75μ come under the category of silt and clays.

The liquid limit and plastic limits of soil are both dependent on the amount (quantity) and the type (quality) of clay particles present in the soil and forms the basis of the soil classification system for cohesive soils based on plasticity tests. Besides their use for identification, these tests give information concerning the cohesive properties of soil and the water retentive capacity (the amount of capillary water which it can hold) .They are also used directly in specifications for controlling soil for use in the fill .These index properties of soil have also been related to various other properties of soil .

Plasticity index (PI) value indicates the degree of plasticity of soil i.e the range of water content over which the soil remains in plastic state .Thus , liquid limit value gives an idea regarding quality of clay particles (qualitative measure of cohesive properly of soil) whereas PI value indicates the quantitative measure (amount) of clay particles present in the soil. For embankment or subgrade, soils having liquid limit exceeding 70 and PI value exceeding 45 are not permitted. Similarly, the maximum permissible limit of LL and PI value for granular sub-base layers are 25 and 6 percent respectively. Cohesionless soils have zero plasticity index. For soils like rock flour (fine grained but not really plastic, at border line of plastic and non plastic soils) the LL is practically identical with PL and there are cases when LL is even lower than PL giving there by a negative PI value which are reported as N_P (non- plastic) .Two soils having same plasticity index (PI) value may differ in their physical properties if they possess different flow indices . Fat clays (highly plastic) have a lower flow index (flatter slope) and lean clays (low plastic) have a higher flow index (steeper slope), thus indicating larger cohesive strength at plastic limits in case of the former. Also the flow curve of the former is located above the flow curve in the case of later. Inorganic clays are characterized by high values of w_L and I_P whereas organic clays through have high values of w_L possess low value of I_p, since their plastic limit w_P values are also equally higher .The correlation between the plasticity index, soil type, degree of plasticity and degree of cohesiveness is as follows :

P.I. Value	Soil type	Degree of plasticity	Degree of cohesiveness
0	Sand	Non Plastic	Non cohesive
< 7	Silt	Low-Plastic	Partly cohesive
7-17	Silty clay	Medium-Plastic	Cohesive
>17	clay	High-Plastic	Highly cohesive

10

MDD & OMC of Soil by Light / heavy Compaction

AIM :

To determine the optimum moisture content and maximum dry density of soil by light or heavy compaction method.

SCOPE & APPLICATION OF THE TEST :

The purpose of a laboratory compaction test is to be determine the proper amount of mixing water to be used, when compacting the soil in the field and the resulting degree of denseness which can be expected from compaction at optimum moisture content.

THEORY :

Compaction is the process of densification of soil mass by reducing the air voids; but water plays a vital role in the soil compaction. Up to certain water content, water acts as a lubricant and helps in closer packing of soil particles and when it exceeds certain limit, water starts to occupy the space of soil grains and hinders in the closer packing of grains .

The degree of compaction of a soil is measured in terms of its dry density , which mainly depends upon its moisture content,compaction energy and type of soil .For a given compaction energy ,every soil attains the maximum dry density at a particular water content which is called optimum moisture content .

APPARATUS REQUIRED :

(1) Compaction mould –A cylindrical mould (capacity 1000 cc, internal diameter 100 mm, effective height 127.3mm) or (capacity 2250cc ,internal diameter 150 mm, effective height 127.3mm)

(2) Metal rammer – for light compaction (face diameter 50mm, mass of 2.6 kg ,free drop of 310 mm) & for heavy compaction (mass = 4.89kg, free fall 450 mm)

(3) Mould accessories – (detachable base plate, removable collar)

(4) I.S sieves – 4.75 mm and 19mm .

(5) Steel straight edge – a steel straight-edge about 30cm in length and having one beveled edge.

(6) Mixing tools – tray or pan, scoop, trowel and spatula or a suitable mechanical device for thoroughly mixing the sample of soil with water.

(7) Graduated jar for measuring water.

(8) Moisture can or drying crucibles.

(9) Balances – one of capacity 10kg , sensitive to 1g and other of capacity 200g ,sensitive to 0.01g .

(10) Oven – thermostatically controlled for temperature of 105 to 110°C.

(11) Desiccator.

(12) Sample extruder (optional) – for extruding compacted specimen from the mould .

MDD & OMC of Soil by Light / heavy Compaction

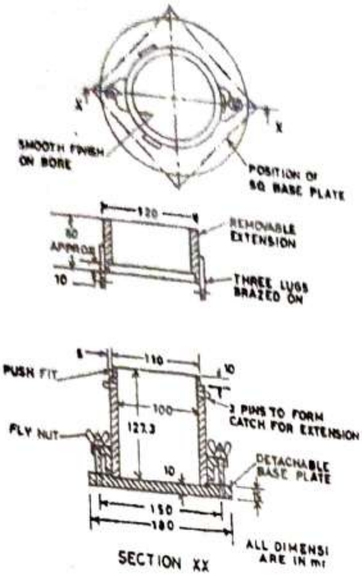

Fig. 10.1 Line sketch of Proctor mould

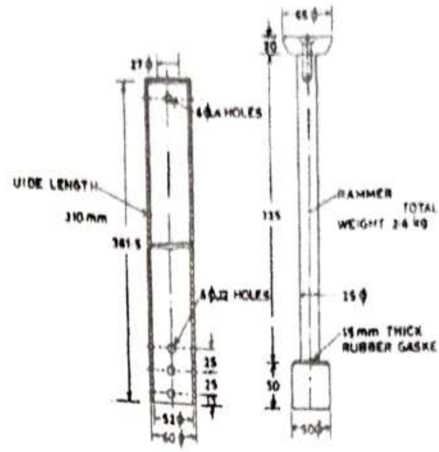

Fig. 10.2 Layout of Typical metal rammer for compaction

MATERIAL REQUIRED :

Sample of soil, water

PROCEDURE :

[A] *Preparation of soil specimen :*

(1) A representative portion of air dried soil material large enough to provide about 6 kg of material passing a 19mm I.S sieve (for soils not susceptible to crushing during compaction) or about 15 kg of material passing a 19mm I.S sieve (for soils susceptible to crushing during compaction) is taken .

(2) This portion is sieved on a 19m m IS sieve and the coarse fraction rejected after its proportion of the total sample has been recorded.

(3) Aggregations of particles is broken down so that, if the sample is sieved on a 4.75 mm IS sieve, only separated individual particles would be retained.

[B] Compaction test in small size mould:

(i) Soil not susceptible to crushing during compaction;

(1) A 5 kg sample of air dried soil passing the 19 mm IS test sieve is taken and it is mixed thoroughly with suitable amount of water depending on the soil type (a moisture content of 4 to 6 percent with sandy and gravelly soils and about 8 to 10 percent below the plastic limit of cohesive soils) in a pan or tray.

(2) With clays of high plasticity or where hand mixing is employed, it may be difficult to distribute the water uniformly through the air dried soil by mixing alone and it may be necessary to store the mixed sample in a sealed container for a minimum period of about 16 hours for maturing .

(3) The mould with the base plate attached is weighed to nearest 1 g (M_1)

(4) It is placed on a solid base such as concrete floor or plinth and the moist soil is compacted into it, with the extension collar attached, in three layers of approximately equal mass, each layers being given 25 blows from the 2.6kg rammer dropped from a height of 310 mm above the soil for light compaction or in five layers, each layer being given 25 blows from the 4.89 kg rammer dropped from a height of 450mm for heavy compaction.

(5) The blows are disturbed uniformly over the surface of each layer ensuring that the tube of the rammer is kept clear of soil so that the rammer always falls freely.

(6) The amount of soil used is to be sufficient to fill the mould leaving not more than about 6mm to be struck off when the extension collar is removed.

(7) The extension collar is removed and the compacted soil is leveled off carefully to the top of the mould by means of a straight edge.

(8) The mould and soil is then weighed to 1g accuraly (M_2).

(9) The compacted soil specimen is removed from the mould and placed on the mixing tray .The water content of representative sample of specimen is determined.

(10) The reminder of the soil specimen is broken up, rubbed through the 19 mm IS test sieve and then mixed with the remainder of the original sample.

(11) Suitable increments of water (1to2 percent for sandy and gravelly soils and 2 to 4 percent for cohesive soils) is added successively and mixed into the sample repeating the above procedure for each increment of water added.

(12) The total number of determinations made is at least five and the range of moisture content is such that, the optimum moisture content at which the maximum dry density occurs, is within that range.

(ii) Soil susceptible to crushing during compaction:

(1) Five or more 2.5 kg samples of air dried soil passing the 19mm I.S. test sieve is taken.

(2) Each sample is mixed thoroughly with different amounts of water to give a suitable range of moisture contents (depending upon the type of soil) so that the moisture content at which the maximum dry density occurs is within that range.

(3) The procedure same as for soil not susceptible to crushing is followed.

(4) The remainder of each soil specimen is discarded.

[C] Compaction test in large size mould:

(1) For soil containing larger proportion of gravel i.e.coarse material up to 37.5 mm size and when the percentage retained on 19mm sieve is more than 5, the 2250 ml mould is used.

(2) A sample weighing about 6 kg and passing the 40mm I.S sieve is used for the test.

(3) Soil is compacted in there layers ,each layer being given 55 blows of the 2.6kg rammer in case of light compaction or in five layers , each layer being given 55 blows from the 4.89 kg rammer for heavy compaction .

(4) Rest of the procedure is same as for the small size mould.

PRECAUTIONS :

(1) Each layer of the compacted soil is to be scratched with a sharp tool before pouring the soil for the next layer for proper bond between the layers .

(2) If the sample contains granular materials of a soft nature, such as soft lime stone, sand stone etc.which are reduced in size by the action of the rammer, it is considered as susceptible to crushing and separate sample method is used.

(3) The removal of small amounts of stone (upto 5 percent) retained on a 19mm IS sieve does not affect the density appreciably, but if there is a larger proportion of stone coarser than 19 mm, it has a major effect on density and in such case bigger mould is to be used .

(4) The water is to be mixed thoroughly and adequately with the soil, since inadequate mixing gives rise to variable test results. This is particularly important in cohesive soils where a substantial quantity of water is added to the air dried soil.

(5) It is necessary to control the total volume of soil compacted because if the amount of soil struck off after removing the extension is too great, the test results are likely to be in accurate.

(6) The water added for each stage of the test is to be such that a range of moisture content is obtained which includes the optimum moisture. Also to increase the accuracy of the test, the increments of water is reduced in the region of the optimum moisture content.

(7) While ramming, blows should be uniformly distributed over the surface of each layer manually or in auto-compactor.

OBSERVATION, CALCULATION AND REPORTING:

CALCULATION :

Bulk density – γ in each compacted specimen is calculated from the equation $\gamma = \frac{M_2 - M_1}{V}$ (g/cc)

where M_1 = mass in g of the mould and base.
M_2 = mass in g of mould, base and soil.
V = volume of the mould in ml.

Dry density;

γ_d is calculated from the equation $\gamma_d = \frac{\gamma}{1+w}$ where w is the water content of soil expressed as decimal.

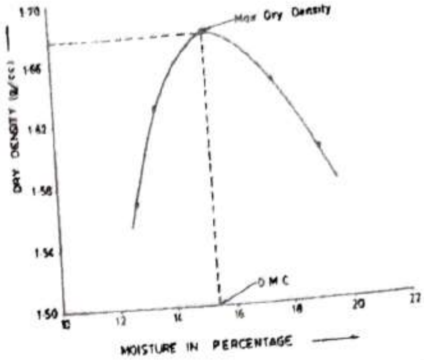

Fig. 10.3 Dry density v/s moisture content

Moisture – density curve :

The dry density γ_d obtained in a series of determinations is plotted against the corresponding moisture content w. A smooth curve is drawn through the resulting points and the position of the maximum on this curve is determined.

Reporting of results:

(1) The dry density corresponding to the maximum point is reported as the maximum dry density to the nearest 0.01 g.

(2) The percentage moisture content corresponding to the maximum dry density is reported as optimum moisture content and quoted to the nearest 0.2 for values below 5 percent , to the nearest 0.5 for values from 5 to 10 percent and to the nearest whole number for values exceeding 10 percent .

(3) The amount of stone retained on the 19 mm IS sieve is reported to the nearest 1percent.

(4) The method used (light / heavy compaction) and the procedure used (single sample or separate sample) along with the size of the mould is also reported.

Observation sheet :

Method of test = light / heavy compaction. Procedure used = single / separate sample.

Volume / size of the mould = 1000cc/ 2250cc Soil retained on 19 mm sieve = ________ %

Determination No.	1	2	3	4	5	6
1. Mass of mould + base (M_1)						
2. Mass of mould +base + wet soil (M_2)						
3. Mass of wet soil (M_2-M_1)						
4. Bulk density $\gamma_t = (M_2 - M_1)/V$						
5. Moisture can No						
6. Mass of empty can (m_1)						
7. Mass of can +wet soil (m_2)						
8. Mass of can +dry soil (m_3)						
9. Mass of water = (m_2-m_3)						
10. Mass of dry soil = (m_3 –m_1)						
11. Water content (%) $w = \frac{m_2 - m_3}{m_3 - m_1} \times 100$						
12. Dry density $\gamma_d = \frac{\gamma_t}{1+w}$						