SESHADRI RAO GUDLAVALLERUENGINEERINGCOLLEGE
(An Autonomous Institute with Permanent Affiliation to JNTUK, Kakinada)
Seshadri Rao Knowledge Village, Gudlavalleru

DEPARTMENT OF CIVIL ENGINEERING

GEOTECHNICAL ENGINEERING LABORATORY

III B.Tech - I Sem

2021 – 2022

GEOTECHNICAL ENGINEERING LABORATORY

Name : ……………………………………………………………………………..

Regd. No : ……………………………………………………………………………..

Year & Semester : …………………………………………………………………………….

Academic Year : ……………………………………………………………………………..

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DEPARTMENT OF CIVIL ENGINEERING

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Course objectives:

- To conduct the tests for determining the dry density of soils.
- To familiarize with different tests procedures for obtaining shear strength of soils.
- To appraise the soil properties by compaction and consolidation process.
- To familiarize with the tests for finding out the permeability of soils.

Course Outcomes:

Students will be able to

- Conduct index tests and classify the soils.
- Determine in-situ density and compaction control of soils.
- Determine the compaction and consolidation parameters of soils.
- Determine the engineering properties of the soils.

Expt. No: **Date:**

DETERMINATION OF SPECIFIC GRAVITY OF SOLIDS

As per IS 2720 (Part III/Sec-1)-1980

AIM: To determine the Specific gravity of solids by Density Bottle method.

THEORY: Density Bottle method is suitable for both coarse-grained and fine-grained soils. As the capacity of the Density Bottle is larger, about 200-300g of oven-dry soil is required for the test.

APPARATUS:

1. A Density bottle of 50ml capacity with stopper,
2. 4.75 mm (or 2mm) IS sieve,
3. A Thermostatically controlled drying Oven capable of maintaining a temperature of 105^{o} to 110^{o}C,
4. A water-bath maintained at constant temperature (27^{0}C) to within $\pm$ 0.2%^{o}C,
5. Desiccator of size about 200mm to 250mm in diameter,
6. Vacuum pump,
7. A Weighing balance (accuracy 0.001g),
8. Thermometer
9. Spatula/ Glass rod.

PROCEDURE:

1. Dry the Density Bottle thoroughly and weighed it with cap (W1.)
2. Density Bottle is filled with aggregate to about 1/3rd and weights it again (W2.)
3. Add sufficient water up to the top and allow the entrapped air to escape.
4. Gently tight the cap to avoid leakage of water.
5. Fill the Density Bottle with water slowly up to top of cap without spilling (W3) through pipe .
6. Clean the Density Bottle by washing it with water thoroughly.
7. Fill the Density Bottle with only water and weighed it as (W4)
8. Repeat the test twice and take the average for 2 trials.

   The procedure is repeated by taking about 200-300g of oven-dry soil.

OBSERVATIONS AND CALCULATIONS:

The specific gravity at test temperature shall be calculated as follows:

Mass of dry soil = M_s= (M_2- M_1)

Mass of water in the observation (iii) = (M_3- M_2)

Mass of water in the observation (iv) = (M_4- M_1)

Mass of water having the same volume as that of solids = (M_4-M_1) - (M_3 -M_2)

$$\text{Sp. gr. of solids @ test temperature} = \frac{\text{Mass of solids}}{\text{Mass of water equivalent to volume of the solids}}$$

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

S.NO	Observations and Calculations	Trail No.		
		1	2	3
	Observations:			
1	Density Bottle No.			
2	Mass of empty Density Bottle (M_1), in g			
3	Mass of Density Bottle with dry soil (M_2), in g			
45	Mass of Density Bottle, dry soil & water (M_3), in g			
	Mass of Density Bottle with water (M_4), in g			
6	**Calculations:**			
	Specific gravity of solids at test temperature (G_T) $= \frac{(M_2 - M_1)}{(M_4 - M_1) - (M_3 - M_2)}$			

The specific gravity shall be calculated at 27°C. If the room (test) temperature is different than 27°C, the following correction shall be done:

$$\text{Average Sp. gr. of solids corresponding to } 27^oC = G_{27} = \frac{\text{Sp. gr. of water at } T^0C}{\text{Sp. gr. of water at } 27^0 C} \times G_T$$

(or)

$$G^1 = k \times G_T$$

Where, G^1= Corrected Sp. gr. of solids at 27°C

$$K = \frac{\text{Relative Density of water at test temperature}}{\text{Relative Density of water at } 27^0 C}$$

ALTERNATIVE LIQUIDS FOR SPECIFIC GRAVITY: With certain soils, for example those containing soluble salts, *kerosene (paraffin oil) or white spirit* may be proffered. If one of these is used, record the fact and carry out a separate experiment to determine the specific gravity of at test temperature $(G_L)_T$.

$$(G_s)_T = (G_L)_T \times \frac{(M_2 - M_1)}{(M_4 - M_1) - (M_3 - M_2)}$$

RESULT: The average Specific gravity of solids corresponding to 27°C =

APPLICATIONS: The specific gravity of solids helps up to some extent in identification and classification of soils. It is used in finding out the degree of saturation, void ratio and unit weight of moist soils. The unit weights are needed in pressure, settlement and stability problems in soil engineering. It is used in computing the particle size by means of hydrometer analysis. It is also used in estimating hydraulic gradient in soil when a sand boiling condition being studied. It is further used in zero air-void calculations in the compaction theory of soils.

Note: The average value obtained shall be taken as sp. gr. of the soil particles and shall be reported as nearest 0.01. If the two results differ by 0.03 the test shall be repeated.

Expt. No: **Date:**

ATTERBERG'S LIMITS

DETERMINATION OF LIQUID LIMIT, PLASTIC LIMIT AND SHRINKAGE LIMIT OF THE SOIL

As per IS 2720 (Part V)-1985

Part-A: Determination of Liquid Limit of the Soil

AIM:

To determine the liquid limit of the given soil sample.

THEORY:

Liquid limit is the water content at which the soil changes from liquid state to plastic state. For determination purpose liquid limit may be defined as the water content at which a standard groove (25mm wide) made in a part of soil placed in the cup of a standard liquid limit device, closes over a distance of about 13 mm when the cup drops 25 times from a height of 10mm on hard rubber base.

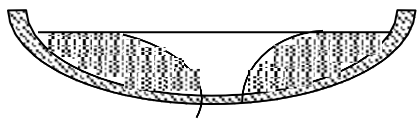
APPARATUS:

1. Casagrande's liquid limit device
2. 425 microns IS sieve
3. Porcelain evaporating dish
4. Distilled water
5. Grooving tool
6. Spatula
7. Balance (sensitive to 0.01 g)
8. Water content cans and
9. Oven.

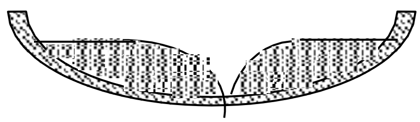
PROCEDURE:

1. Take about 250 g of air-dried soil sample passing 425µ IS sieve in a porcelain evaporating dish.
2. Add a small quantity of distilled water and carefully mix it thoroughly distilled water to form a uniform paste.
3. Adjust the cup of the liquid limit apparatus to give a drop of exactly 10mm on the point of contact on base.
4. Place a portion of the paste in the cup. Smooth the surface with spatula to a maximum depth of 10mm. By using a grooving tool, cut a clean, straight groove that completely separates the soil pat into two parts.

5. Rotate the handle at a rate of 2 revolutions per second and count the number of blows until the two parts of the sample come in contact at the bottom of the groove over a distance of 13mm (≈1/2”). Record the number of blows.
6. Take about 25g of soil from the closed part of the groove for determination of water content.
7. Transfer the remaining soil in the cup to the main soil sample in the evaporating dish. Then mix thoroughly after adding a small amount of water.
8. Repeat the steps 4 to 7. Obtain at least five sets of readings in the range of not less than 10 or more than 40 blows.



DIVIDED SOIL CAKE BEFORE TEST



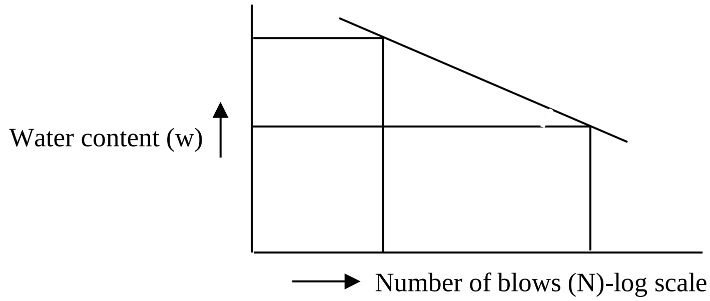
SOIL CAKE AFTER TEST

OBSERVATIONS:

Determination No.	**1**	**2**	**3**	**4**	**5**
Number of blows (N)					
Container number					
Weight ofcontainer, g (W_1)					
Weight ofcontainer + Wet soil, g (W_2)					
Weight ofcontainer + Oven dry soil, g(W_3)					
Weight of water, g(W_2-W_3)					
Weight of oven dry soil, in g (W_3-W_1)					
Water content (%)((W_2-W_3)/ (W_3-W_1))*100					

GRAPH:

Plot a straight-line graph between number of blows (Log scale) and water content (natural/arithmetical scale). The water content corresponding to 25 blows as read from the curve shall be rounded off to the nearest whole number and reported as the liquid limit of the soil.



PRECAUTIONS:

i. Consistency limits are greatly affected by the layer of adsorbed water present in the form of a thin film surrounding the soil particles. Oven drying destroys this thin film.Therefore, consistency limits tests should be performed only on *air-dried soil samples*.
ii. Use distilled water in order to minimize the possibility of ion exchange between the soil and any impurities in the water.
iii. After mixing distilled water to the soil sample, sufficient time should be given to permeate the water throughout the soil mass.
iv. The test may also be conducted from the wetter to the drier condition; the drying is achieved by kneading (rub) the wet soil and not by adding dry soil.
v. In liquid limit test, the groove should be closed by a flow of soil and not by slippage between the soil and cup.
vi. Wet soil taken in the container for moisture content determination should not be left open in air even for some time, the containers with soil samples should either placed in desiccator or immediately weighted.
vii. For each test, cup and groove tool, should be clean.

RESULT:

Liquid limit of the given soil sample (W_L) =

If the Liquid limit of the soil (W_L) < 35%, soil is Low Compressible (L)

W_L= 35%-50%, soil is Intermediate Compressible (I)

W_L> 50%, soil is Highly Compressible (H)

Part-B: Determination of Plastic Limit of the Soil

AIM:

To determine the plastic limit of given soil sample.

THEORY:

Plastic limit is the water content at which the soil changes from plastic state to semi-solid state. For the determination purpose, the plastic limit is defined as the water content at which a soil will just begin to crumble when rolled into a thread of 3mm in diameter.

The numerical difference in water contents between the liquid limit and plastic limit is termed as plasticity index. Knowing the liquid limit and plasticity index, soil may be classified with the help of plasticity chart according to Indian standard soil classification (IS 1498-1970).

APPARATUS:

1. Flat Glass plate,
2. Distilled water,
3. Rod of 3mm in diameter and 100mm length,

Balance (sensitive to 0.01 g),5.Oven, and

6. Water content cans.

PROCEDURE:

1. Take about 20 g. of air-dried sample passing through 425 micron IS sieve.
2. Mix thoroughly with distilled water on the glass plate until it is plastic enough to be shaped into a small ball.
3. Take about 10 g of the plastic soil mass and roll it between the hand and the glass plate to form the soil mass into a thread. If the diameter of thread becomes less than 3 mm without cracks, it shows that water added is more than its plastic limit; hence the soil is kneaded further and rolled into thread again.
4. Repeat this rolling and remoulding process until the thread starts just crumbling at a diameter of 3mm.
5. If crumbling starts before 3mm diameter thread, it shows that water added is less than the plastic limit of the soil, hence some more water should be added and mixed to a uniform mass and rolled again, until the thread starts crumbling at a diameter of 3mm.
6. Collect the pieces of crumbled soil thread at 3mm diameter in an air tight container and determine moisture content.
7. Repeat the test two to three times and take the average value.

Determination No.	**1**	**2**	**3**
Container number			
Weight of container, g (W_1)			
Weight of container + Wet soil, g (W_2)			
Weight of container + Oven dry soil, g(W_3)			
Weight of water, g (W_2-W_3)			
Weight of oven dry soil, in g (W_3-W_1)			
Water content (%) ((W_2-W_3)/ (W_3-W_1))*100			

RESULT:

Average plastic limit of the given soil (W_P) =

∴ Plasticity Index of the given soil = I_p = (Liquid Limit – Plastic Limit) = (W_L- W_p) =

$I_p$of A-line $(I_p)_A = 0.73\ (W_L - 20)$ =

If $I_p > (I_p)_A$, i.e. above A-line, soil is Clay (C)

If $I_p < (I_p)_A$, i.e. below A-line, soil is Silt (M) and Organic soil (O)

∴ Type of soil as per the Plasticity chart of ISSCS =

DETERMINATION OF SHRINKAGE LIMIT OF THE SOIL
As per IS 2720 (Part VI)-1972

AIM:

To determine shrinkage limit of given soil sample.

THEORY:

Shrinkage Limit (Undisturbed Soil) (w_{su}) is maximum water content expressed as percentage of oven-dry weight at which any further reduction in water content will not cause a decrease in volume of the soil mass, the soil mass being prepared initially from undisturbed soil.

Shrinkage Limit (Remoulded Soil) (w_u) is maximum water content expressed as percentage of oven-dry weight at which any further reduction in water content will not cause a decrease in volume of the soil mass, the soil mass being prepared initially from remoulded soil.

Shrinkage Ratio (R) is the ratio of a given volume change, expressed as a percentage of the dry volume, to the corresponding change in water content above the appropriate shrinkage limit, expressed as a percentage of the weight of the oven-dried soil.

Volumetric Shrinkage (Volumetric Change) (V_s) is the decrease in volume, expressed as a percentage of the soil mass when dried, of a soil mass when the water content is reduced from a given percentage to the appropriate shrinkage limit.

APPARATUS:

Evaporating Dish- two, porcelain, about 12cm in diameter with a pour out and flat bottom, the diameter of flat bottom, being not less than 55mm,

Spatula- flexible, with the blade about 8 cm long and 2 cm wide

Shrinkage Dish- circular, porcelain or non-corroding metal dish inert to mercury having a flat bottom and 45mm in diameter and 15mm height internally. The internal corner between the bottom and the vertical sides shall be rounded into a smooth concave curve.

Straight Edge- steel, about 15cm in length

Glass Cup- 50 to 55mm in diameter and 25mm in height, the top rim of which is ground smooth and level

Glass Plates- two, each 75mmx75mm, and 3mm thick, one plate shall be of plain glass and other shall have three metal prongs inert to mercury (see Fig. 1).

Oven- thermostatically controlled to maintain the temperature between 105 and 110^{0}C, with interior of non-corroding material.

Sieve- 425-micron IS sieve,

Balances- sensitive to 0.1 g and 0.01 g,

Mercury- clean**,** sufficient to fill the glass cup to overflowing,

Desiccator- with any dessicating agent other than sulfuric acid, and

Distilled water

SOIL SAMPLE FOR TEST:

For Shrinkage Limit (Remoulded Soil) Test:

Take a sample weighing about 100g from the thoroughly mixed portion of the material passing through 425 micron IS Sieve.

For Shrinkage Limit (Undisturbed Soil) Test:

(i) Preserve the undisturbed soil received from the field in its undisturbed state.

(ii) Trim from the undisturbed soil sample, sample soil pats approximately 45mm in diameter and 15mm in height. Round off their edges to prevent entrapment of air.

PROCEDURE:

PROCEDURE FOR DETERMINING SHRINKAGE LIMIT (REMOULDED SOIL):

Preparation of Soil Paste:

Place about 30g of soil sample (obtained from remoulded soil) in the evaporating dish and thoroughly mix with distilled water in an amount sufficient to fill the soil voids completely and to make the soil pasty enough to be readily worked into shrinkage dish without entrapping air bubbles.

Weight and Volume of shrinkage Dish:

(i) Determine the weight of the clean empty shrinkage dish and record.

(ii) Determine the capacity of the shrinkage dish in cubic centimeters, which is also the volume of the wet soil pat.

By filling the shrinkage dish to overflowing with mercury, removing the excess by pressing the plain glass plate firmly over the top of the shrinkage dish in such a way that the plate is flush with the top of the shrinkage dish and no air is entrapped, weighing the mercury held in the shrinkage dish to an accuracy of 0.1g and dividing this weight by the unit weight of mercury to obtain the volume. Record this volume as the volume of wet soil pat, V.

Filling the Shrinkage Dish:

(i) Coat inside of the shrinkage dish with a thin layer of silicone grease or vaseline or some other heavy grease to prevent the adhesion of soil to the dish.

(ii) Place in the center of the shrinkage dish an amount of the soil paste equal to about one-third the volume of the shrinkage dish, and allow the soil paste to flow to the edges by tapping (beating) the shrinkage dish on a firm surface cushioned by several layers of blotting paper, rubber sheet or similar material.

(iii) Add an amount of the soil paste approximately equal to the first portion, and tap the shrinkage dish as before until the paste is thoroughly compacted.

(iv) Add more soil paste and continue the tapping until the shrinkage dish is completely filled and excess soil paste and excess soil paste stands out about its edge. Then strike off the excess soil paste with as traight edge, and wipe off all soil adhering to the outside of the shrinkage dish.

Weigh immediately after filling the oven with wet soil. Record the weight as weight of shrinkage dish wet soil pat.

Allow the soil pat to dry in air until the colour of the soil pat turns from dark to light.

Then dry the soil pat in shrinkage dish by keeping in the oven, cool in a dessiccator and weigh immediately after removal from the desiccator. Record the weight as weight of shrinkage dish dry soil pat.

Volume of the Dry Soil Pat:

(i) Fill the glass cup to overflowing with mercury and remove the excess mercury by pressing the glass plate with the three prongs (see Fig. 1), firmly over the top of the glass cup, collecting the excess mercury in a suitable container. Carefully wipe off any other mercury which may be adhering to the outside of the cup.

(ii) Place the glass cup, filled thus with mercury, in the evaporating dish taking care not to spill any mercury from the glass cup

(iii) Place the oven-dried soil pat on the surface of the mercury in the glass cup. Then carefully force the dry soil pat under the mercury by means of the glass plate with three prongs and press plate firmly over the top of the cup, the displaced mercury being collected in the evaporating dish without slipping out of it. Care shall be taken to ensure that no air is trapped under the soil pat.

(iv) Weigh the mercury so displaced by the dry soil pat to an accuracy of 0.1g and determine its volume by dividing this weight by the unit weight of mercury. Record this volume as the volume of the oven-dry soil pat, V_o.

PROCEDURE FOR DETERMINING SHRINKAGE LIMIT (UNDISTRUBED SOIL):

- Keep the undisturbed soil specimen in a suitable small dish and air-dry it.
- Then dry the specimen in the dish to constant weight in an oven at 105 to 110^{0}C. Remove the specimen from the oven and smoothen the edges by sand papering. Brush off the soil dust from the specimen by a soft paint brush.
- Place the specimen again in the cleaned dish and dry it in an oven at constant weight. Cool the oven-dry specimen in desiccator and weigh it with the dish. Determine the oven-dry weight of the specimen, W_{su}.
- Determine the volume of the oven-dry specimen V_{su} as described in 5.1.7.
- Determine the specific gravity of soil in accordance with IS: 2720 (Part-3)-1964.

CALCULATIONS:

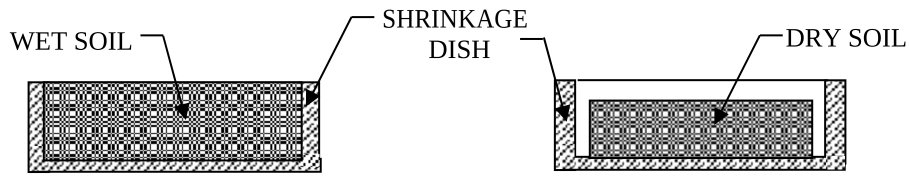
Water/Moisture content (%) of soil pat (w): **The moisture content of wet soil pat as a percentage of the dry weight of the soil as follows:**

$$\text{Water/Moisture content (\%) of soil pat} = w = \frac{(W - W_o)}{W_o} \times 100$$

where

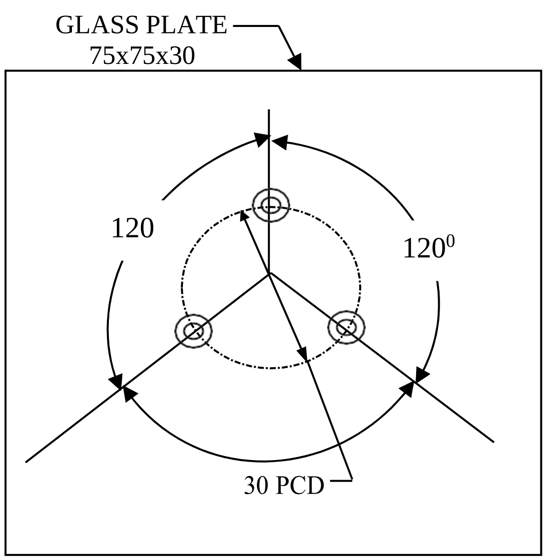
W = Weight of wet soil pat obtained by subtracting the weight of shrinkage dish from the Weight of shrinkage dish and wet soil pat, and

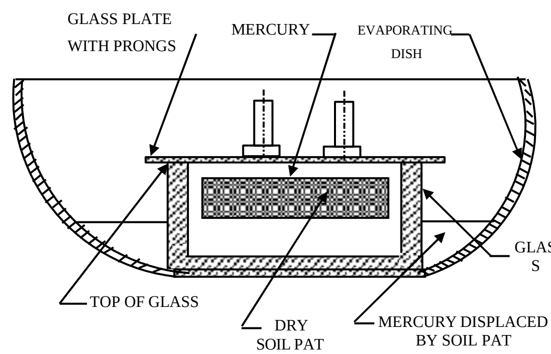
W_o = Weight of dry soil pat obtained by subtracting the weight of shrinkage dish from the Weight of shrinkage dish and dry soil pat.



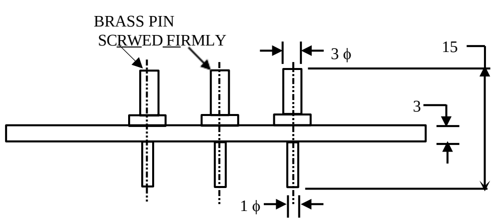
BEFORE SHRINKAGE

AFTER SHRINKAGE





METHOD OF OBTAINING DISPLACED MERCURY



DETAILS OF GLASS PLATE WITH

NOTE: All dimensions are in millimeters

Fig. APPARATUS FOR DETERMINING VOLUMETRIC

Shrinkage Ratio (R):

$$\text{Shrinkage Ratio} = \frac{W_o}{V_o}$$

where

W_o = Weight of oven-dry soil pat, in g, and

V_o = Volume of oven-dry soil pat in ml.

Shrinkage Limit (Remoulded Soil) (w_s):

Shrinkage Limit (Remoulded soil) = $w_s = w - [(V - V_0)/ W_o] \times 100$

Where w = Water/Moisture content of wet soil pat (in %), V = Volume of wet soil pat in ml,

V_o = Volume of oven-dry soil pat in ml, and

W_o = Weight of oven-dry soil pat, in g.

NOTE: When the specific gravity of the soil is known the shrinkage limit may also be calculated by the following formula:

Shrinkage Limit (Remoulded soil) = w_s = **[(1/ R) - (1/G)] x100**

Where

R = Shrinkage Ratio, and

G = Specific gravity of the soil (can be determined in accordance to IS: 2720 (Part-3)).

Shrinkage Index (I_s) (in %):

Shrinkage Index (I_s) = (Plastic Limit- Shrinkage Limit)

Plastic Limit can be determined in accordance to IS: 2720 (Part-5).

Volumetric Shrinkage/ Volumetric Change (V_s):

Volumetric Shrinkage (V_s) = (w_1-w_s) x R

Where

w = given Water/Moisture content (in %),

w_s =Shrinkage limit (in %), and

R = Shrinkage Ratio

Shrinkage Limit (Undisturbed Soil) (w_{su}):

Shrinkage Limit (Undisturbed Soil) = w_{su} = **[(V_{cs}/ W_{cs}) - (1/G)] x100**

Where

V_{cs} = Volume of oven-dry specimen in ml,

W_{cs} = Weight of oven-dry specimen in g, and

G= Specific gravity of the soil (can be determined in accordance to IS: 2720 (Part-3).

Table: Shrinkage Limit (Remoulded Soil)

1. Determination No.	1	2	3
2. Shrinkage dish No.			
3. Weight of shrinkage dish, in g			
4. Weight of shrinkage dish + wet soil pat, in g			
5. Weight of shrinkage dish + dry soil pat, in g			
6. Weight of wet soil pat (W), in g			
7. Weight of oven-dry soil pat (W_o), in g			
8. Water/Moisture content (%) of soil pat =w = [(W- W_o)/ W_o x100]			
9. Evaporating dish No. (dish into which mercury filling shrinkage dish is transferred for weighing), in g			
10. Weight of mercury filling shrinkage dish + Weight of evaporating dish, in g			
11. Weight of evaporating dish, in g			
12. Weight of mercury filling shrinkage dish, in g			
13. Volume of soil pat (V), in ml			
14. Evaporating dish No.			
15. Weight of mercury displaced by the dry soil pat + Weight of evaporating dish, in g			
16. Weight of evaporating dish, in g			
17. Weight of mercury displaced by the dry soil pat, in g			
18. Volume of dry soil pat (V_0), in ml			
19. [(V- V_0)/ W_ox100]			
20. **Shrinkage Limit (Remoulded soil) = w_s = w-[(V- V_0)/ W_o]x100**			
21. Shrinkage Ratio = R = W_o /V_0x100			
22. Given moisture content = w (%)			
23. (w- w_s)			
24. Volumetric Shrinkage = V_s = (w- w_s)xR			

Table: Shrinkage Limit (Undisturbed Soil)

1. Determination No.	1	2	3
2. Shrinkage dish No.			
3. Weight of shrinkage dish + oven-dry soil specimen, in g			
4. Weight of shrinkage dish, in g			
5. Weight of oven-dry soil pat (W_o), in g			
6. Evaporating dish No.			
7. Weight of mercury displaced by the oven-dry specimen + Weight of evaporating dish, in g			
8. Weight of evaporating dish, in g			
9. Weight of mercury displaced by the oven-dry soil specimen, in g			
10. Volume of the oven-dry soil specimen (V_{cs}), in ml			
11. Weight of the oven-dry soil specimen (W_{cs}), in g			
12. Specific Gravity of the soil of the specimen= G			
13. **Shrinkage limit (Undisturbed Soil) = w_{su} = [(V_{cs}/ W_{cs})- (1/G)]x100**			

7. RESULT:

Shrinkage limit of the given soil sample =

Expt. No: **Date:**

FIELD DENSITY-CORE CUTTER AND SAND REPLACEMENT METHOD

Part A: Core Cutter Method

As per IS 2720 (Part XXIX)-1975

AIM:

To determine dry density of soils in-place/ in-situ/ in field by the core cutter method.

THEORY:

The in-place density of soil needed for determination of bearing capacity of soils, stability analysis, for the determination of degree of compaction of compacted soil, for the determination of pressures on underlying strata for calculation of settlement, for determination of lateral pressures etc.

The core-cutter method is suitable for fine-grained soils (soil 90% of which passes the 4.75mm-IS sieve) free from aggregations. It is less accurate than the sand-replacement method and is not recommended, unless speed is essential or unless the soil is well compacted.

APPARATUS:

- ✓ Cylindrical Core-cutter of 13cm long and 10cm internal diameter with a wall thickness of 3mm,
- ✓ Steel Dolly of 2.5 cm high and 10cm internal diameter with a wall thickness of 7.5mm,
- ✓ Steel Rammer,
- ✓ Crowbar/ Pick Axe or Spade,
- ✓ Trowel,
- ✓ Spatula or Straight edge,
- ✓ Sample extruder,
- ✓ Weighing balance (accurate to 1g), and
- ✓ Apparatus for Determination of Water content

PROCEDURE:

1. Clean the core-cutter and determine its internal volume (V_c) in cm^3 shall be calculated from its dimensions which shall be measured to the nearest 0.25mm.

2. The cutter shall be weighted to the nearest gram (W_c). The cutter shall be kept properly greased or oiled.
3. A small area of approximately 30 cm^2 of the soil layer to be tested shall be exposed and levelled. The steel dolly shall be placed the top of the core-cutter and latter shall be rammed down vertically into the soil layer until only about 15mm of the dollyprotrudes (projects) above the ground.
4. Dig the soil around the core-cutter with the help of crowbar and remove it. Remove the core-cutter by separating it from the soil with the help of a trowel and lifting it carefully.
5. Trim the top and bottom surfaces of the sample collected with a spatula or a straight edge. Determine the weight of the core-cutter with the soil (W_s).
6. Extrude the soil from the core-cutter with the help of a sample extruder; collect the soil in moisture cans taking out the soil from the middle of the soil cylinder. Keep the moisture cans in the oven for the determination of moisture content.

CALCULATIONS:

The bulk density of the soil shall be calculated as follows:

$$\text{Bulk density of the soil} = \gamma_b = \frac{\text{Weight of the wet soil}}{\text{Volume of the wet soil}} = \frac{W_s - W_c}{V_c}, g|cc$$

Where

W_s= Weight of soil and core-cutter in g,
W_c = Weight of core-cutter in g, and
V_c= Volume of core-cutter in cm^3.

The dry density of the soil shall be calculated from the following formula:

$$\text{Dry density of the soil} = \gamma_d = \frac{\gamma_b}{1+w}, g|cc$$

Where,

γ_b= Bulk density
w = water content of the soil (in decimals).

Determination No.	**1**	**2**
Weight of core-cutter (W_c), in g		
Weight of core-cutter + wet soil (W_s), in g		
Weight of wet soil (W_s - W_c), in g		
Volume of core-cutter (V_c), in cm^3		
Bulk density of the soil $= \gamma_b = \frac{W_s - W_c}{V_c}, g/cc$		
Water content container No.		
Weight of container with lid W_1, in g		
Weight of container with lid and wet soil W_2, in g		
Weight of container with lid and dry soil W_3, in g		
Water content (w) of the soil $= \frac{(W_2 - W_3)}{(W_3 - W_1)} \times 100\%$		
Dry density of the soil $= \gamma_d = \frac{\gamma_b}{1 + w}, g/cc$		

RESULT: The Average dry density of in-place soil =

NOTE: It is necessary to make a number of repeat determinations (at least three), and to average results, since the dry density of the soil vary appreciably from point to point.

Part-B: Sand-Replacement Method

As per IS 2720 (Part XXVIII)-1974

AIM:

To determine dry density of soils in-place/ in-situ/ in field by the sand-replacement method.

THEORY:

The in-place density of soil needed for determination of bearing capacity of soils, stability analysis, for the determination of degree of compaction of compacted soil, for the determination of pressures on underlying strata for calculation of settlement, for determination of lateral pressures etc.

The core-cutter method is suitable for fine-grained soils (soil 90% of which passes the 4.75mm-IS sieve) free from aggregations. It is less accurate than the sand-replacement method and is not recommended, unless speed is essential or unless the soil is well compacted. The sand-replacement method is suitable for fine, medium and coarse-grained soils. For fine and medium grained soils a small pouring cylinder is required. For fine and medium grained soils a large pouring cylinder is required.

APPARATUS:

1. Sand: Clean sand, uniformly graded natural sand passing the 1.00mm IS Sieve and retained on the 600µ IS Sieve shall be used. It shall be free from organic matter, and shall have been oven dried and stored for a 7 days period to allow its water content to reach equilibrium with atmospheric humidity. The sand should not be stored in air-tight containers and should be thoroughly mixed before use.
2. Sand-Pouring Cylinder,
3. Weighing balance (accurate to 1g),
4. Cylindrical calibrating container,
5. Plane Glass or Perspex Plate,
6. Metal Tray with hole,
7. Tools for excavating holes, and
8. Apparatus for Determination of Water content.

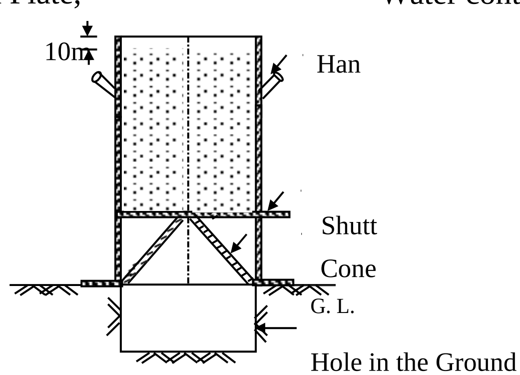


Fig. Sand-Pouring Cylinder for the Determination of

PROCEDURE:

(A) Determination of the Density of Sand used in the Sand-Pouring Cylinder:

1. Fill the sand pouring cylinder with sand up to about 10mm (1cm) below the top edge of the cylinder, weigh it with its shutter closed (W_{1S}).
2. Keep the cylinder on a plane glass plate; allow the sand to run out by opening the shutter when no further movement of sand is observed in the cylinder. Weigh the sand-pouring cylinder (W_{2S}).
3. Determine the volume of the cylindrical calibrating container (V_c) by measuring its internal dimensions.
4. Place the sand-pouring cylinder concentrically on the top of the calibrating container, open the shutter and allow the sand to run out. Close the shutter when no further movement of sand is observed in the cylinder.
5. Remove the cylinder and determine its weigh (W_{3S}).
6. Compute the **density of the dry sand** as given below:

Weight of the sand occupying the conical portion in the bottom of the cylinder = (W_{1S} - W_{2S})

Weight of the sand occupying the conical portion and the calibrating container = (W_{2S} – W_{3S})

Weight of the sand filling the calibrating container = W_{sand} = (W_{2S} – W_{3S}) - (W_{1S} - W_{2S})

Volume of the cylindrical calibrating container = V_c

$$\therefore \text{Density of the calibrated sand} = \gamma_{sand} = \frac{W_{sand}}{V_c}, g|cc$$

(B) Determination of the field density of the soil:

1. Fill the sand pouring cylinder with the calibrating sand up to 10mm below the top of the cylinder and determine its weight (W_1).
2. Weigh the tray with the central hole (W_2).
3. Place the tray on a prepared surface of the soil; make a pit by excavating the soil using the hole in the tray as a pattern, to a depth of about 125mm (12.5 cm). Collect the excavated soil carefully into the tray, leaving no loose material in the hole. Weigh the tray with the excavated soil (W_3).

4. Place the sand-pouring cylinder concentrically on the pit. Open the shutter and allow the sand to run out into the hole. After ensuring that no further sand is running out, close the shutter. Remove the cylinder and weigh it (W_4).
5. Collect a representative sample of the excavated soil in moisture can and keeps it in the hot-air oven for moisture content (%) determination.
6. The bulk density of the soil (γ_b) is determined as follows:

Weight of the soil excavated from the pit = W = (W_3 –W_2)

Weight of dry sand occupying pit and conical portion at the bottom of the cylinder = (W_1 –W_4)

We know that..

Weight of the sand occupying the conical portion in the bottom of the cylinder = (W_{1S} - W_{2S})

∴ Weight of the dry sand occupying the pit = (W_1 –W_4) - (W_{1S} - W_{2S})

$$\text{Volume of the pit} = V = \frac{\text{Weight of the dry sand occupying the pit}}{\text{Density of the calibrated sand}}$$

$$\therefore V = \frac{(W_1 - W_4) - (W_{1S} - W_{2S})}{\gamma_{sand}}, \text{ in cc}$$

$$\therefore \text{Bulk density of the in-situ soil} = \gamma_b = \frac{W}{V}, g/cc$$

7. The dry density of the soil shall be calculated from the following formula:

$$\text{Dry density of the soil} = \gamma_d = \frac{\gamma_b}{1 + w}, g/cc$$

Where, γ_b= Bulk density and w = water content of the soil (in decimals).

The observations are entered in the Tables 1 and 2.

PRECAUTIONS:

1. The field test holes being small, the error is likely to be large if any soil is lost during excavation. Therefore, any loss of soil should be avoided.
2. The excavation should be as rapid as possible to preserve the natural moisture-content of the soil. As soon as the excavation is completed, the natural soil should be taken for weight and water content determination.
3. Errors in water content determination can be minimized by drying the entire quantity of soil excavated from the test hole.

Table 1: Calibration of Sand

Determination No.	**1**	**2**
Weight of sand pouring cylinder + sand (W_{1S}), in g		
Weight of sand pouring cylinder after running down the sand on glass plate (W_{2S}), in g		
Diameter of calibrating container, d, in cm		
Height of calibrating container, h, in cm		
Volume of calibrating container (V_c), in cm^3		
Weight of sand pouring cylinder after running down the sand in calibrating container (W_{3S}), in g		
Weight of the sand occupying the conical portion in the bottom of the cylinder = (W_{1S} - W_{2S}), in g		
Weight of the sand occupying the conical portion and the calibrating container = (W_{2S} – W_{3S}), in g		
Weight of the sand filling the calibrating container = W_{sand} = (W_{2S} – W_{3S}) - (W_{1S} - W_{2S}), in g		
Density of the calibrated sand $= \gamma_{sand} = \frac{W_{sand}}{V_c}, g/cc$		

Table 2: Determination of Soil Density

Determination No.	**1**
Weight of sand pouring cylinder + sand (W_1), in g	
Weight of tray with central hole (W_2), in g	
Weight of tray + soil excavated from the pit (W_3), in g	
Weight of sand pouring cylinder after running down the sand into the pit (W_4), in g	
Weight of the soil excavated from the pit=W= (W_3-W_2), in g	
Weight of the sand occupying the pit and conical portion at the bottom of the cylinder = (W_1 - W_4), in g	
Weight of the dry sand occupying the pit = (W_1 –W_4) - (W_{1S} - W_{2S}), in g	
Volume of the pit $= V = \frac{(W_1 - W_4) - (W_{1S} - W_{2S})}{\gamma_{sand}}$, in cc	
Bulk density of the in-situ soil $= \gamma_b = \frac{W}{V}, g/cc$	
Water content container No.	
Weight of container with lid W_1, in g	
Weight of container with lid and wet soil W_2, in g	
Weight of container with lid and dry soil W_3, in g	
Water content (w) of the soil $= \frac{(W_2 - W_3)}{(W_3 - W_1)} \times 100\%$	
Dry density of the soil $= \gamma_d = \frac{\gamma_b}{1 + w}, g/cc$	

RESULT: The Average dry density of in-place soil =

Expt. No: Date:

COMPACTION TEST

STANDARD PROCTOR COMPACTION TEST (I. S. LIGHT COMPACTION)

As per IS 2720 (Part* VIII*)-1983

AIM:

To determine the moisture content - dry density relationship of a given soil under the Standard Proctor compaction effort.

THEORY:

Soil at a given site may not often ideal for construction of a civil engineering structure or a facility. It may be necessary to improve the engineering properties of such soils. Compaction is one of the methods of making such improvement and involves densification by applying mechanical energy on a soil mixed with suitable water content.

In 1933, proctor showed that there existed a definite relationship between the soil water content and degree of dry density to which the soil might be compacted. Optimum water content may be defined as the water content at which a particular soil attains a maximum dry density for a specific amount of compaction energy.

APPARATUS:

1. Proctor's cylindrical compaction mould of capacity 944 ml with base plate and collar
2. Compaction rammer weighing 2.50 kg and having a drop of 305 mm
3. 4.75mm IS sieve
4. Steel straight edge
5. Balance
6. Oven
7. Water content containers
8. Mixing equipment
9. Sample extruder

PROCEDURE:

1. Weigh the empty Proctor mould (W_1 g) and also determine its volume (V). Fix the mould to the base plate and attach the collar to the mould. Apply a thin layer of oil to inside surface of the mould and the collar.
2. Take about 2kg of air-dried soil which is pulverized and passed through 4.75mm sieve.
3. Add to this soil a certain initial percentage of water based on the dry weight. Sprinkle this water uniformly on the soil and mix it carefully.
4. Divide the wet soil into three equal parts. Fill the mould with one part of the soil and compact it with 25 evenly distributed blows with the standard rammer. Repeat the above process with the second and third parts of the soil.

   Before each subsequent layer of the soil is placed, the top of the previously compacted layer is scratched with a spatula. This ensures a thorough bonding of one layer with the other .The mould is thus filled with all the three soil layers.

   Detach the mould from the base plate, remove the collar and trim the soil on the top of the mould. If there is any difficulty in removing the collar, take a spatula and trim along the bottom edge of the collar until it comes off easily.
5. Weigh the mould with the compacted soil (W_2 g), after removing the soil sticking to the mould (trimmings).
6. To extrude the soil specimen from the mould use the sample extruder. After the sample has come out, split it and take a small quantity of soil from the middle layer of the sample for water content determination. After weighing the cans with soil samples, keep them in the hot-air oven for 24hours to determine the water content.
7. Repeat the procedure by taking fresh sample of soil each time and adding water to it with increments varying between 2% and 4% until; based on the wet weight, a peak value is obtained by at least two lesser compacted weights. The readings are to be recorded in Table 1.
8. The weight of the moisture cans with oven-dried soils is taken the next day and the average water content (w) determined for each test. The values are to be recorded in Table.
9. The dry density is calculated from the formula,

$$\text{Dry Density} = \rho_d = \frac{\rho}{1+w} = \frac{(W/V)}{1+w} = \frac{(W_2-W_1)}{V\,(1+w)}$$

Empty weight of mould =

Internal Diameter of mould=D=

Height of mould=H=

Volume of mould = Volume of the soil sample = $\Pi/4xD^2$ =

GRAPH:

Plot the water content on x-axis and dry density in y-axis, draw the smooth curve, called Compaction Curve.

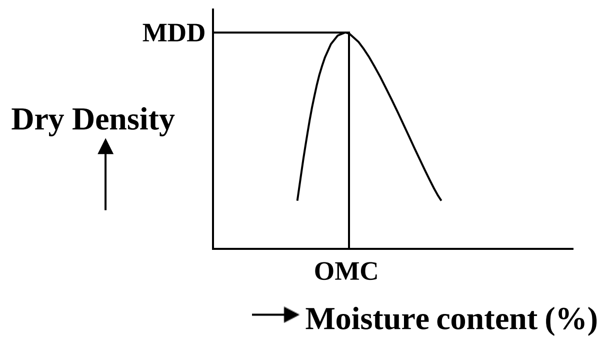


Table 1

Amount of water added				
Wt. of mould (W_1), in g				
Wt. of compacted soil + mould (W_2), in g				
Weight of wet soil (W_2 - W_1), in g				
Volume of mould (V), in cm^3				
Bulk density = $\rho = (W_2-W_1)/V$, in g/cc				
Water content container No.				
Weight of container with lid M_1, in g				
Weight of container with lid and wet soil M_2, in g				
Weight of container with lid and dry soil M_3, in g				
Water content (w) of the soil = $\frac{(M_2-M_3)}{(M_3-M_1)} \times 100$ %				
Dry density = $\rho_d = \rho / 1+w$, in g/cc				

RESULT:

Optimum moisture content (OMC) =

Max dry density (MDD) =

Expt. No: Date:

COMPACTION TEST

MODIFIED PROCTOR COMPACTION TEST (I. S. HEAVY COMPACTION)

As per IS 2720 (Part VIII)-1983

AIM:

To determine the moisture content - dry density relationship of a given soil under the Standard Proctor compaction effort.

THEORY:

Soil at a given site may not often ideal for construction of a civil engineering structure or a facility. It may be necessary to improve the engineering properties of such soils. Compaction is one of the methods of making such improvement and involves densification by applying mechanical energy on a soil mixed with suitable water content.

In 1933, proctor showed that there existed a definite relationship between the soil water content and degree of dry density to which the soil might be compacted. Optimum water content may be defined as the water content at which a particular soil attains a maximum dry density for a specific amount of compaction energy.

APPARATUS:

1. Proctor’s cylindrical compaction mould of capacity 2250 ml with base plate and collar
2. Compaction rammer weighing 4.85 kg and having a drop of 450 mm
3. 4.75mm IS sieve
4. Steel straight edge
5. Balance
6. Oven
7. Water content containers
8. Mixing equipment
9. Sample extruder

PROCEDURE:

1. Weigh the empty Proctor mould (W_1 g) and also determine its volume (V). Fix the mould to the base plate and attach the collar to the mould. Apply a thin layer of oil to inside surface of the mould and the collar.
2. Take about 5kg of air-dried soil which is pulverized and passed through 4.75mm sieve.
3. Add to this soil a certain initial percentage of water based on the dry weight. Sprinkle this water uniformly on the soil and mix it carefully.
4. Divide the wet soil into five equal parts. Fill the mould with one part of the soil and compact it with 55 evenly distributed blows with the rammer. Repeat the above process with the second, third, fourth and fifth parts of the soil.

   Before each subsequent layer of the soil is placed, the top of the previously compacted layer is scratched with a spatula. This ensures a thorough bonding of one layer with the other .The mould is thus filled with all the three soil layers.

   Detach the mould from the base plate, remove the collar and trim the soil on the top of the mould. If there is any difficulty in removing the collar, take a spatula and trim along the bottom edge of the collar until it comes off easily.
5. Weigh the mould with the compacted soil (W_2 g), after removing the soil sticking to the mould (trimmings).
6. To extrude the soil specimen from the mould use the sample extruder. After the sample has come out, split it and take a small quantity of soil from the middle layer of the sample for water content determination. After weighing the cans with soil samples, keep them in the hot-air oven for 24hours to determine the water content.
7. Repeat the procedure by taking fresh sample of soil each time and adding water to it with increments varying between 2% and 4% until; based on the wet weight, a peak value is obtained by at least two lesser compacted weights. The readings are to be recorded in Table 1.
8. The weight of the moisture cans with oven-dried soils is taken the next day and the average water content (w) determined for each test. The values are to be recorded in Table.
9. The dry density is calculated from the formula,

$$\text{Dry Density} = \rho_d = \frac{\rho}{1+w} = \frac{(W/V)}{1+w} = \frac{(W_2-W_1)}{V\,(1+w)}$$

Empty weight of mould =

Internal Diameter of mould=D=

Height of mould=H=

Volume of mould = Volume of the soil sample = $\Pi/4xD^2$ =

GRAPH:

Plot the water content on x-axis and dry density in y-axis, draw the smooth curve, called Compaction Curve.

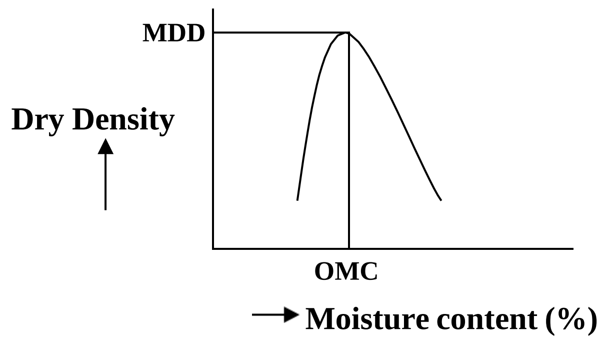


Table 1

Amount of water added				
Wt. of mould (W_1), in g				
Wt. of compacted soil + mould (W_2), in g				
Weight of wet soil (W_2 - W_1), in g				
Volume of mould (V), in cm^3				
Bulk density = $\rho = (W_2-W_1)/V$, in g/cc				
Water content container No.				
Weight of container with lid M_1, in g				
Weight of container with lid and wet soil M_2, in g				
Weight of container with lid and dry soil M_3, in g				
Water content (w) of the soil = $\frac{(M_2-M_3)}{(M_3-M_1)} x\ 100\ \%$				
Dry density = $\rho_d = \rho / 1+w$, in g/cc				

RESULT:

Optimum moisture content (OMC) =

Max dry density (MDD) =

Expt. No: **Date:**

GRAIN SIZE ANALYSIS

As per IS 2720 (Part IV)-1985

AIM:

Determining the Grain-Size Distribution for a given Coarse-Grained soil by dry sieving.

THEORY:

Grain size analysis expresses quantitatively the proportions by mass of various sizes of particles present in the soil. The results of a grain size analysis may be represented in the form of a Grain Size Distribution (GSD) curve/ Particle Size Distribution (PSD) curve/ Gradation curve. The grain-size distribution is universally used in the engineering classification of the soils. In addition, the suitability criteria of soils used for road and airfield construction, dam and other embankment construction and the design of filters for earth dams are based partly on the results of grain-size analysis.

Particle Size Analysis is accomplished by obtaining the quantity of material passing through the apertures of a given-sized sieve but retained on a sieve of smaller-sized apertures. The weight of the quantity of soil retained any particular sieve with reference to the overall weight of the soil sample taken for the analysis, expressed as a percentage, is termed as the percentage weight of the soil retained. The percentage of soil that passes through the sieve is termed as the percentage finer.

Dry Sieve Analysis is meant for coarse-grained soils having no or little fines (fines < 5%).

APPARATUS:

1. Sieves
2. Weighing balance
3. Wire brush
4. Thermostatically controlled oven
5. Mechanical Sieve Shaker
6. Mortar and Rubber pestle

PROCEDURE:

1. Keep the given representative sample of soil in the oven for 24 hours.
2. Pulverize the oven-dried sample by using the mortar and rubber pestle and sieve it on the 4.75 mm sieve. Take about 500 g of the fraction of the soil passing 4.75 mm sieve and retained on 75 mm sieve for the sieve analysis.

3.Take the following set of sieves and stack them one over the other in the order of arrangement shown (i.e. the sieve with the largest aperture at the top and smallest aperture size at the bottom).

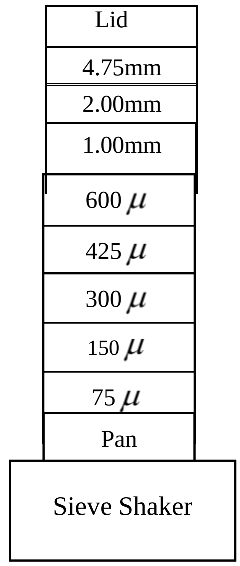


Fig. Set of Fine Sieves

1 micron = 1 μ = 1 x 10^{-6}m or 1 x 10^{-6} mm.

Place the soil in the top sieve, close the lid, transfer the set of sieves with the received pan at the bottom to a mechanical sieve shaker and fir them. Sieve the soil for a period of 10 minutes.

4. Remove the stack of sieves from the shaker and obtain the weight of the material retained on each sieve.
5. Compute the percentage retained on the each sieve by dividing the weight retained on each sieve by the original weight of the soil sample taken for the analysis.
6. Compute the percent finer by starting with 100 % and subtracting the percent retained on each sieve as accumulative procedure.
7. Draw a graph between the percentage finer, drawn to natural scale on the Y – axis and the particle (aperture) size drawn to logarithmic scale on the X – axis. Then the plot is called PSD Curve/ GSD Curve/ Gradation Curve.

Table: Particle Size Distribution

Gravel	Sand			Silt	Clay
	Coarse	Medium	Fine		
Grain size range in mm > 4.75	4.75 – 2.00	2.00 – 0.425	0.425 – 0.075	0.075 – 0.002	< 0.002

OBSERVATIONS:

S. No.	IS Sieve Size	Particle size D (mm)	Weight retained (g)	% Weight Retained	Cumulative % Weight Retained	Cumulative % Finer (% Passing)
1	4.75mm	4.75				
2	2.00 mm	2.00				
3	1.00 mm	1.00				
4	600 μ	0.600				
5	425 μ	0.425				
6	300 μ	0.300				
7	150 μ	0.150				
8	75 μ	0.075				
9	Pan	<0.075				

CALCULATION:

From the PSD Curve:

D_{60} = D_{30} = D_{10} =

$\therefore$ Co-efficient of uniformity = $C_u = \frac{D_{60}}{D_{10}}$

$\therefore$ Coefficient of curvature = $C_c = \frac{(D_{30})^2}{D_{60}\, D_{10}}$

RESULT:

According to C_u and C_c values obtained from graph, the soil may be termed as________graded.

The sample contains mostly_______. So the sample is________________________soil.

Expt. No: **Date:**

HYDROMETER ANALYSIS

As Per IS 2720 (Part 4)-1985

AIM:

To determine the percentages of various soil grains (finer that 75μ) by hydrometer analysis.

THEORY:

Grain size analysis expresses quantitatively the proportions by mass of various sizes of particles present in the soil. The results of a grain size analysis may be represented in the form of a Grain Size Distribution (GSD) curve/Particle Size Distribution (PSD) curve/ Gradation curve. The results of grain size analysis are widely used in soil classification. The data obtained from the GSD curves is used to determine the suitability of soils for road construction, used in the design of filters for earth dams, etc.

Sedimentation Analysis also called Wet Analysis is meant for fine-grained soils. Sedimentation Analysis is carried by using hydrometer. Hydrometer analysis is based on stoke's law which defines the velocity of a freely falling sphere through a liquid.

$$V = \frac{1}{18} \cdot \frac{g d^2 (G-1) \rho_w}{\mu} \longrightarrow (1)$$

Where, V = Terminal velocity

G = Sp. gr. of solids,

d = diameter of sphere = diameter of particle,

ρ_w = density of water=1g/cc,

g = acceleration due to gravity = 981 cm/s^2

μ = viscosity of water in g-s/cm^2

If a spherical particle falls through a height 'H_e' cm in 't' minutes.

$$V = \frac{H_e}{60t} \quad \frac{cm}{sec} \longrightarrow (2)$$

Equating (1) and (2)

$$\therefore \text{Particle size} = d \text{ (in cm)} = \sqrt{\frac{0.3\mu}{g(G-1)}} \sqrt{\frac{H_e}{t}}$$

$$\boxed{\therefore \text{Particle size} = d \text{ (in mm)} = \sqrt{\frac{30\mu}{g(G-1)}} \sqrt{\frac{H_e}{t}} = M\sqrt{\frac{H_e}{t}}} \longrightarrow (3)$$

If the W_s is the mass/ weight of the solids in a volume of 1000ml

$$\text{\% of particles finer than size 'd'} = N = \left[\frac{G}{G-1} \cdot \frac{R_c}{W_s} \cdot 100\right] \% \quad \rightarrow (4)$$

Where
G = Average specific gravity of soil grains
W_s = Weight of dry soil sample taken from the soil passing 75 sieve.
R_c = Corrected hydrometer reading

APPARATUS:

- Hydrometer (Calibrated at 27^0C, range 0.995 to 1.030 g/cc.),
- Graduated glass cylinders of capacity 1000 ml,
- Dispersing agent (containing 33g of Sodium Hexameta-Phosphate and 7g of Sodium carbonate in distilled water to make one liter of solution),
- 75 µ IS sieve,
- Mechanical stirrer (high speed 75000rpm),
- Balance,
- Stop watch,
- Filter paper
- Measuring cylinder of capacity 100ml, and
- Centimeter scale

PROCEDURE:
Calibration of Hydrometer:

1. **Volume of the Hydrometer (V_h):** Immerse the hydrometer in partly filled measuring cylinder and note down the displacement of water which is equal to the volume of hydrometer. Also weight of the hydrometer in grams (assuming sp. gr. to be unity) is approximately equal to the volume of hydrometer in ml.

2. **C/s Area of the measuring glass cylindrical jar (A_j):** Measure the distance in cm between two graduations on the cylinder. The C/s area of the cylindrical jar is then equal to the volume included between two graduations divided by the distance between them.

3. Keep the hydrometer, lying on a white paper. Draw its boundaries and mark the major calibration marks on the paper.

4. Measure the height of the bulb from the neck to the bottom of the bulb (h).

5. Measure the height between the neck and each major calibration marks (H_1).

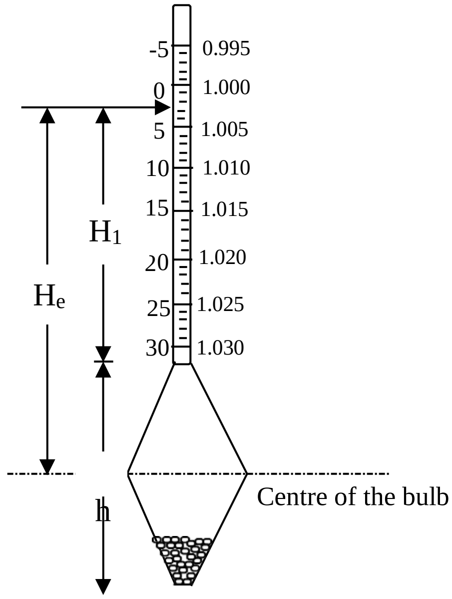


Fig. Hydrometer

NOTE: The hydrometer readings are recorded after subtracting unity from the value of density and multiplying the remaining digit by 1000. Thus a density of 1.015 is represented R_H of $(\rho_s-\rho_w)$ x 1000 $=(\rho_s-1)$ x1000 = (1.015-1.000) x1000 = 15.

V_h = Volume of the Hydrometer =

A_j = C/s Area of the measuring glass cylindrical jar =

h = Height of the bulb from the neck to the bottom of the bulb = length of hydrometer bulb=

Record the values of R_H and H_1 in Table 1 and calculate the effective height (H_e) corresponding to each of the major calibration marks $R_{H,}$ by the following expression:

$\therefore$ Effective height (in cm) = $H_e = H_1 + ½ (h - V_h/A_j) = H_1 + k$

Where, Constant = $k = ½ (h - V_h/A_j)$

Table 1:

Hydrometer Reading (R_H)	Measure the height between the neck and each major calibration marks (H_1)	Effective height (in cm) $H_e = H_1 + ½ (h - V_h/A_j)$

Draw the calibration curve between the H_e and R_H.

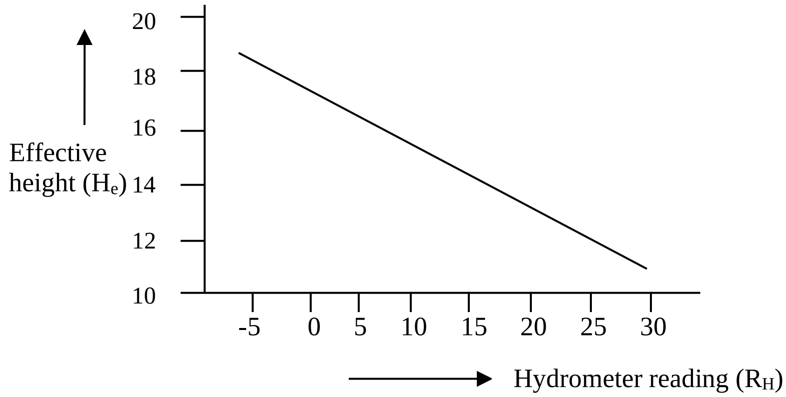


Fig. Calibration plot/chart

Sedimentation Test:

- About 50g of oven-dry soil is weighed accurately and transferred to an evaporating dish.
- To have a proper dispersion of soil, about 100ml of a dispersion solution is added to the evaporating dish to cover the soil.

NOTE: IS 2720: Part- IV recommends the use of dispersion solution obtained after adding 33g of sodium hexameta-phosphate and 7g of sodium carbonate to distilled water to make one liter of solution.

- **A**fter the dispersion solution has been added to soil, the mixture is warmed gently for 10minutes.
- The contents of the evaporating dish are then transferred to the cup of a mechanical stirrer.
- Distilled water is added to make the cup about ¾ th full.
- The suspension is stirred for 15 minutes. However, the stirring period is more for clayey soils.
- The suspension is then washed through 75µ IS sieve, using jet of distilled water.
- The portion of the suspension passing through the sieve is collected in 1000ml jar and enough water is added to make 1000 ml suspension for the sedimentation analysis The soil collected on 75µ IS sieve is oven-dried and weighed.
- The suspension in the jar is mixed thoroughly by firmly placing the palm of the hand on the open end and turning the jar upside and down and back.
- When the suspension is well mixed, the jar is placed on the table and the hydrometer is inserted.
- A stopwatch is started immediately and the readings of hydrometer (R_H) are taken after ¼, ½, 1, 2 and 4 minutes of the commencement of sedimentation.

- Remove the hydrometer from the jar and rinse it with distilled water and float it in a comparison jar (for finding composite correction) containing the distilled water with the dispersing agent to the same concentration as in the soil suspension.
- Re-immerse the hydrometer in the suspension and take hydrometer readings (R_H) after 5, 10, 15 and 30 minutes, 1, 2, 4, 8 and 24 hours, reckoned form the beginning of the sedimentation. Take out hydrometer after every reading and float it in the comparison cylinder (for finding composite correction).
- About 30 seconds before each hydrometer reading, the hydrometer is slowly inserted in suspension so that it is stable by the time the reading is due. The hydrometer is taken, with as little disturbance as possible.

Correction to Hydrometer Readings:

(a) Meniscus correction ($+C_m$): As the suspension is opaque, the hydrometer reading is corresponding to upper level of meniscus. It is the difference of readings between the top and bottom of the meniscus in the comparison cylinder. If R_H is the observed hydrometer reading in the suspension, the corrected hydrometer reading is given as follows:

$$\mathbf{R_H^1} = R_H + C_m$$

[Note: The reading R_H^1 is used for finding the effective height depth H_e from the Calibration chart**]**

(b) Temperature correction ($\pm C_t$): The hydrometers are calibrated at standard temperature (27^0C). In case the test temperature of the suspension is above the standard, the correction is added ($+\mathbf{C_t}$), if below it is subtracted **($-C_t$).** The temperature correction is obtained from the manufacturer.

(c) Dispersing agent correction ($-C_d$): The correction due to rise in density of soil suspension on account of the addition of dispersing agent is always negative.

Thus, the corrected hydrometer reading R_c is given as follows:

$$R_c = R_H + C_m \pm C_t - C_d$$

Composite correction ($C = C_m \pm C_t - C_d$): Instead of finding the corrections individually, it is convenient to find one composite correction. The composite correction is the algebric sum of all the corrections. Thus,

$$R_c = \text{Corrected hydrometer reading} = R_H + \mathbf{C}$$

Where R_H= Observed hydrometer reading.

The composite correction is found directly from the readings taken in a comparison cylinder of containing distilled water and the dispersing agent of the same concentration and has the same temperature as that of soil suspension. The negative of hydrometer reading in the comparison cylinder is equal to the composite correction. If the reading is +1 (i.e., 1.001), the correction is -1, and if the reading is -2 (i.e., 0.998) the correction is +2.

4 PRECAUTIONS:

(i) The insertion of the hydrometer should be gentle.

(ii) The hydrometer should not touch the walls of the jar.

(iii) Both the jars should be kept away from the any local sources of heat and direct sun light.

(iv) There should not be any vibration in the vicinity.

6 TABULATION:

Ws=Weight of dry soil sample taken from the soil passing 75 sieve =

C_m= Meniscus correction=

Test Temperature= T°C

G = Average specific gravity of soil grains =

μ = Viscosity of water at Test Temperature=T°C = g-s/cm^2

g = acceleration due to gravity= 981 cm/s^2

Factor = M= $\sqrt{\dfrac{30\mu}{g(G-1)}}$ =

Table: 2

Elapsed Time (in min) (t)	Hydrometer Reading (R_H)	$R_H^1 = R_H + C_m$	Effective Height (H_e) (in cm)	Particle size (in mm) (d) Equation 3 $d = M\sqrt{H_e/t}$	Composite correction (C)	Corrected Hydrometer Reading $Rc = R_H + C$	% of particles finer than size 'd' (N) Equation 4
1/4							
1/2							
1							
2							
4							
5							
10							
15							
30							
60							
120							
240							
480							
1440							

RESULT: Draw the plot between particle size and % finer

NOTE: As a soil contains the particles of coarse-grained and fine-grained soils, a combined sieve analysis comprising both Sieve Analysis and Sedimentation Analysis may be required for such soils.

Expt. No: **Date:**

LABORATORY CALIFORNIA BEARING RATIO (CBR) TEST

AS per IS 2720 (Part 16)-1992

AIM:

To determine California Bearing Ratio (CBR) of given soil specimen.

THEORY:

The CBR is a measure of resistance of material to penetration of standard plunger under controlled density and moisture conditions. The test procedure should be strictly adhered if high degree of reproducibility is desired. The CBR test may be conducted in remoulded or undisturbed specimens in the laboratory. Many methods exist today, which utilize mainly CBR test values for designing pavement thickness requirement.

APPARATUS:

1. **Loading machine:** This is compression machine, which can operate at a constant rate of 1.25 mm per minute. A metal penetration piston or plunger of diameter 50 mm is attached to the loading machine.
2. **Cylindrical mould:** Mould of 150 mm diameter and 175 mm height provided with a collar of about 50 mm length and a detachable base. A spacer disc of 148 mm diameter and 47.7 mm thickness is used to obtain a specimen of exactly 127.3 mm height.
3. **Compaction Rammer**
4. **Annular weight:** In order to simulate the effect of the overlying pavement weight, annular weights each of 2.5 kg weight and 147 mm diameter are placed on the top of the specimen, at the time of testing the sample, as surcharge.

PROCEDURE:

1. Remoulded soil specimen is compacted by dynamic compaction. The preparation of soil specimens by dynamic compaction or ramming is more commonly adopted and is explained below. About 4.5 kg material is dried and sieved in 20 mm sieve. If a noteworthy proportion of material is retained on 20 mm sieve, allowance for larger size materials is made by replacing it by an equal weight of material passing 20 mm sieve and retained on 4.75 mm sieve. The optimum moisture content and maximum dry density of

soil are determined by adopting either IS light compaction (Proctor compaction) or IS heavy compaction (modified Proctor or AASHTO compaction) as per the requirement 5.5 kg weight for granular soils and 4.5 kg weight for fine grained soils is mixed with water up to the optimum moisture content or the filed moisture content if specified so. The spacer disc is placed at the bottom of the mould over the base plate and a course filter paper is placed over the spacer disc. The moist soil sample is to be compacted over this in the mould by adopting either IS light compaction or IS heavy compaction.

(i) For *IS light compaction*, the soil to be compacted is divided in to three equal parts; the soil is compacted in three equal layers, each of compacted thickness about 44 mm by applying 56 evenly distributed blows of 2.6 kg rammer

(ii) For *IS heavy compaction*, the soil is divided in to five equal parts; the soil is compacted in five equal layers, each of compacted thickness about 26.5 mm by applying 55 evenly distributed blows of the 4.89 kg rammer. After compaction the last layer, the collar is removed and the excess soil above the top of the mould is evenly trimmed off by means of the straight edge. Any hole that develops on the surface due to the removal of coarse particles during trimming may be patched with smaller size material.

2. The clamps are removed and the mould with the compacted soil is lifted leaving below the perforated base plate and the spacer disc, which is removed.
3. The mould with the compacted soil is weighed. A filter paper is placed on the perforated over the base plate (such that the top of the soil sample is now placed over the base plate) and the clamps of the base plate are tightened. Another filter paper is placed on the top surface of the sample and the perforated plate with adjustable stem is placed over it.
4. Surcharge weights of 2.5 or 5.0 kg weight are placed over the perforated plate and the whole mould with the weights is placed under the penetration plunger of the loading machine. The penetration plunger is seated at the center of the specimen and is brought in contact with the top surface of the soil sample by applying a seating load of 40 kg.
5. The dial gauge for measuring the penetration values of the plunger is fitted in position.
6. The dial gauge of the proving ring (for load readings) and the penetration dial gauge are set to zero.

7. The load is applied through the penetration plunger at a uniform rate of 1.25 mm/min. The load readings are recorded at penetration readings of 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 7.5, 10.0 and 12.5 mm. In case the load readings start decreasing before 12.5 mm penetration, the maximum load value and the corresponding penetration value are recorded. After the final reading the load is released and the mould is removed from the loading machine. The proving ring calibration factor is noted so that the load dial values can be converted into load in kg. About 5 kg of soil is collected from the top three cm depth of soil sample for the determination of moisture content.

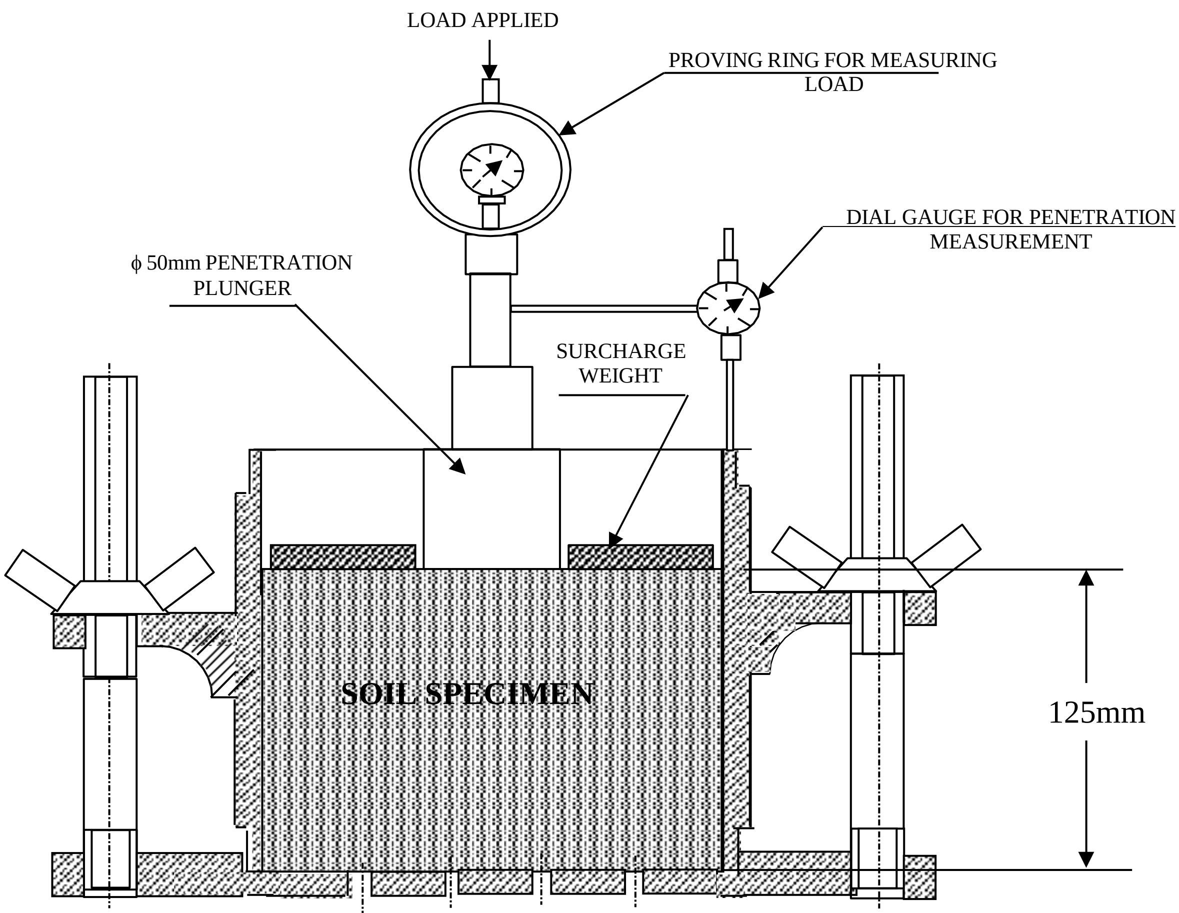


Fig. SET-UP FOR CBR TEST

OBSERVATIONS:

Compacting moisture content =

Dry density =

Condition of test specimen: - soaked / unsoaked

Proving ring calibration factor =

Surcharge weight =

Penetration mm (1)	Proving ring dial reading (2)	Load on Plunger, kg (3)
0.0		
0.5		
1.0		
1.5		
2.0		
2.5		
3.0		
4.0		
5.0		
7.0		
10.0		
12.0		

CALCULATION:

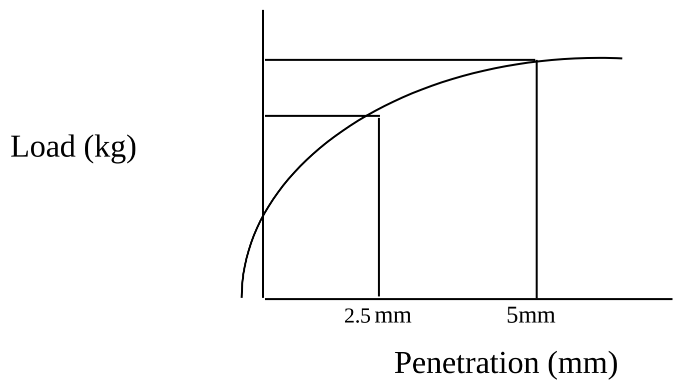
The load-penetration curve is then plotted in natural scale for each specimen. If the curve is uniformly convex upwards no correction is needed. Incase there is a reverse curve or the initial portion of the curve is concave upwards necessity of a correction is indicated. A tangent is drawn from the steepest position on the curve to intersect the base at point y which is the corrected origin corresponding to zero penetration. The load values corresponding to2.5 and 5.0 mm penetration values (either from the original origin for curve without correction or from the corrected origin for the curve with correction, as the case may be) are found from the graph. The CBR value is calculated from the formula.

$$CBR\% = \frac{\text{Load carried by soil sample at defined penetration level}}{\text{load carried by standard crushed stones at the above penetration level}} x100$$

Load values on standard stones are given in Table.

Penetration, mm	Standard load, kg
2.5	1370
5.0	2055

The CBR values at 2.5 mm and 5.0 mm penetrations are calculated for each specimen from the graph. Generally the CBR value at 2.5 mm is higher and this value is adopted. However, if higher CBR value is obtained at 5.0 mm penetration, the test is to be repeated to verify the results. If the value at 5.0 mm is again higher, this is adopted as CBR value of the soil sample.



RESULTS:

$CBR_{2.5}$ =

$CBR_{5.0}$ =

Design value of CBR =

Expt. No: **Date:**

DETERMINATION OF FREE SWELL INDEX (FSI)

As per IS 2720 (Part 40)-1977

AIM:

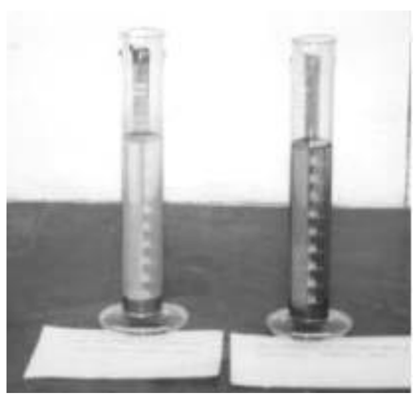
To determine Free Swell Index of Given Soil

APPARATUS:

1. 425 micron IS sieve.
2. Graduated glass cylinders 100 ml capacity 2Nos (IS: 878 -1956).
3. Glass rod for stirring.
4. Balance of capacity 500grams and sensitivity 0.01 gram.

PROCEDURE:

1. Take two representative oven dried soil samples each of 10 grams passing through 425 micron sieve.
2. Pour each soil sample in to each of the two glass graduated cylinders of 100 ml capacity.
3. Fill one cylinder with kerosene and the other with the distilled water up to the100 ml mark.
4. Remove the entrapped air in the cylinder by gentle shaking and stirring with a glass rod.



Sample kept for free swell index Allow the samples to settle in both the cylinders.

5. Sufficient time, not less than 24 hours shall be allowed for soil sample to attain equilibrium state of volume without any further change in the volume of the soils.
6. Record the final volume of the soils in each of the cylinders.

OBSERVATIONS AND CALCULATION:

$$\text{Free Swell Index, (\%)} = \frac{V_d - V_k}{V_k} \times 100$$

V_d = Volume of the soil specimen read from the graduated cylinder containing distilled water.

V_k = Volume of the soil specimen read from the graduated cylinder containing kerosene.

Determination No.	Measuring cylinder No.		Reading After 24 hours		Free Swell Index %
	Kerosene	Distilled water	Kerosene	Distilled water	

RESULT:

Free Swell Index of Soil =

Expt. No: **Date:**

DETERMINATION OF UNDRAINED SHEAR STRENGTH OF SOIL BY UNCONFINED COMPRESSION (UCC) TEST

As per IS 2720 (Part X)-1985

AIM:

To determine undrained cohesive strength of given cohesive soil sample.

THEORY:

The unconfined compressive strength is defined as the ratio of failure load to cross sectional area of the soil sample when it is not subjected to any lateral pressure.

$$q_u = \frac{P}{A_c}$$

Where q_u = unconfined compressive strength

P = failure load

A_c = corrected area at failure = $\frac{A_o}{1-\in}$

Where A_o = initial area

$$\in = strain = \frac{\Delta L}{L_o}$$

Where L_o = initial length of the sample

This test is undrained, since the rates of loading do not allow dissipation of pore water pressure.

Plastic equilibrium equation:

$$\sigma_1 = \sigma_3 \tan^2\alpha_f + 2c \tan\alpha_f$$

where σ_1 = major principal stress at fature

σ_3 = minor principal stress at failure

α_f = failure angle with major principal plane =$(45+\phi/2)$

ϕ = Angle of internal friction

In unconfined compression test: $\sigma_3 = 0$; $\sigma_1 = q_u$

If the soil is pure clay: $c=c_u$ and $\phi=0$

$\therefore q_u = 2c_u$.

$$\therefore c_u = \frac{q_u}{2}$$

APPARATUS:

1. Unconfined compression apparatus
2. Sampling tube
3. Split mould
4. Sample extractor
5. Oven
6. Balance
7. Vernier calipers.

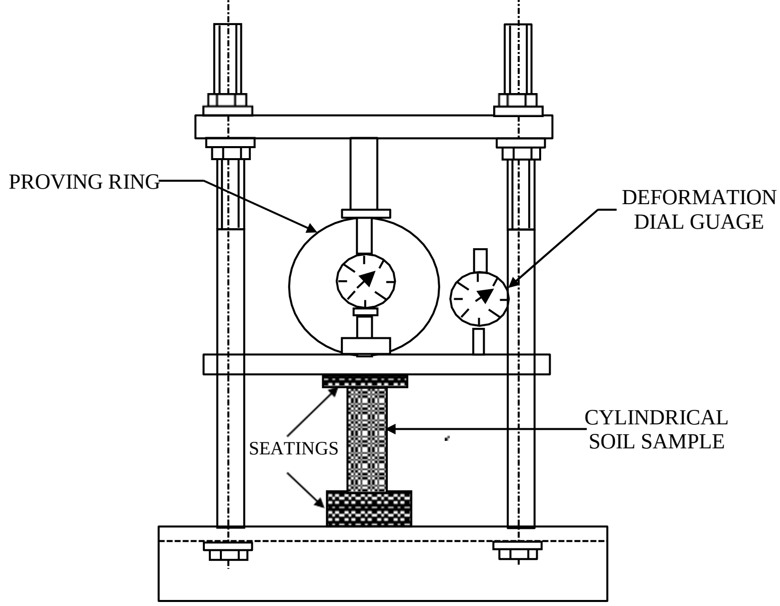
PREPARATION OF TEST SPECIMEN

1. Undisturbed cylindrical specimen may be cut from bigger sample obtained from the field.
2. Remoulded sample may be prepared by compacting the soil at the desired water content and dry density.

PROCEDURE:

1) The initial length, diameter and weight of the specimen shall be measured and the specimen placed on the bottom plate of loading device. The upper plate shall be adjusted to make the contact with the specimen.
2) The deformation dial gauge shall be adjusted to a suitable reading, preferably in multiples of 100. Force shall be applied so as to produce axial strain at a rate of 0.5 to 2% per minute causing failure with 5 to 10. The force reading shall be taken at suitable intervals of the deformation dial reading.
3) The specimen shall be compressed until the failure surfaces have definitely developed, or the stress-strain curve is reached its peak, or until an axial strain of 20% is reached.
4) The failure pattern shall be sketched carefully and shown on the data sheet or on the sheet presenting the stress-strain plot. The angle between the failure surface and the horizontal may be measured, if possible, and reported.
5) Determine the moisture content of the soil samples taken from the failure zone of the specimen.

FIG.UNCONFINED COMPRESSION (UCC) TEST APPARATUS



PRECAUTIONS:

1) Two ends of the specimen should be perpendicular to the long axis of the specimen.
2) The loading of the sample should be at constant rate.
3) Remoulded specimen should be prepared at the same moisture content and density as of undisturbed sample.

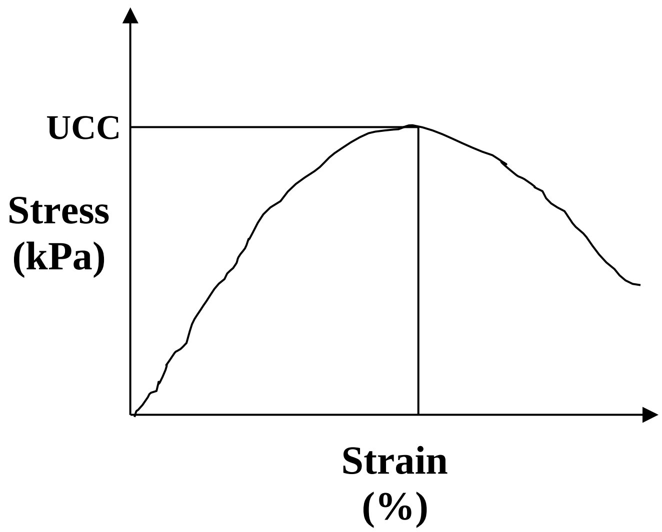
OBSERVATIONS AND CALCULATION:

Initial diameter of soil specimen, D_0 =
Initial length of soil specimen, L_0 =
Initial area of soil specimen = A_0 =
Initial volume of soil specimen = V_0 =
Initial mass of soil specimen = M_0 =
Initial density of soil specimen = M_0 / V_0 =

INITIAL WATER CONTENT OF SOIL SPECIMEN:
Can No. :
Wt. of Can =
Wt. of can + wet soil =
Wt. of Can = Dry soil =
Ware content =
Rate of strain:

Deformation dial reading	**Proving ring dial reading**	**Axial deformation ΔL (mm)**	**strain $\in = \frac{\Delta L}{L_0}$ (%)**	**Corrected area at failure (cm²) $A_c = \frac{A_o}{1-\in}$**	**Axial force (P) (kg)**	**Stress $\frac{P}{A_c}$**

- Plot the Stress – Strain diagram to find UCC strength and to know about the type of failure.



- Water content of the soil specimen after the test (determined from soil samples taken from the failure zone of the specimen)

Final mass of soil specimen (after completion of UCC test) = M_f=

<u>FINAL WATER CONTENT OF SOIL SAMPLE:</u>

Find the final water content of soil sample after end of the test

Can No =
Weight of can =
Weight of can + wet soil =
Weight of can + Dry soil =
Water Content =

RESULT:

Unconfined compressive strength of the given soil specimen = q_u=

Undrained Cohesion = C_u=

Expt. No: 9 **Date:**

DETERMINATION OF SHEAR STRENGTH PARAMETERS OF A SOIL SPECIMEN BY TRI-AXIAL COMPRESSION TEST

PART-A: UNCONSOLIDATED UNDRAINED(UU) TRI-AXIAL COMPRESSION TEST

As per IS 2720 (Part XI)

1. AIM:

To determine the shear strength parameters of a given soil specimen in tri-axial compression test apparatus by UU test without measurement of pore water pressure.

2. THEORY:

Shear strength of the soil is the resistance to deformation by continuous shear displacement of soil particles upon the action of shear stress. Shear strength of the soil is expressed as function of principal stresses (coulomb's) as

$$\tau = f(\sigma_1, \sigma_2, \sigma_3)$$

$$\tau = c + \sigma \tan\phi$$

Where, c= Cohesion

ϕ = angle of internal friction

τ = Shear strength

σ = Normal stress

Shear resistance can be determined in the laboratory using tri-axial test under three types of drainage conditions:

a) Unconsolidated Undrained (UU) test or quick test (Q-test)
b) Consolidated Undrained (CU) test (R-test)
c) Consolidated Drained (CD) test or slow test (S-test)

3. APPARATUS:

3.1 Triaxial cell,
3.2 Loading frame,
3.3 Apparatus for applying and maintaining cell pressure (or confining pressure),
3.4 Split mould, Sample tubes and other accessories,
3.5 Dial gauges,
3.6 Seamless Rubber Membrane,
3.7 Rubber 'O' rings.

4. SAMPLE PREPARATION:

(i) Undisturbed specimen: If the undisturbed sample collected from the field in the *thin-walled tube* has the equal diameter as that of specimen then the sample is pushed into the split mould with sample extruder and ends are trimmed flat and normal to its axis. If sample is of large diameter it should be cut by thin wall tube (or) hand trimming.

(ii) Remoulded Sample: These remoulded specimens are prepared by compacting the soil to required water content and density in a big size mould by static (or) dynamic method and then preparing cylindrical specimen of required dimensions.

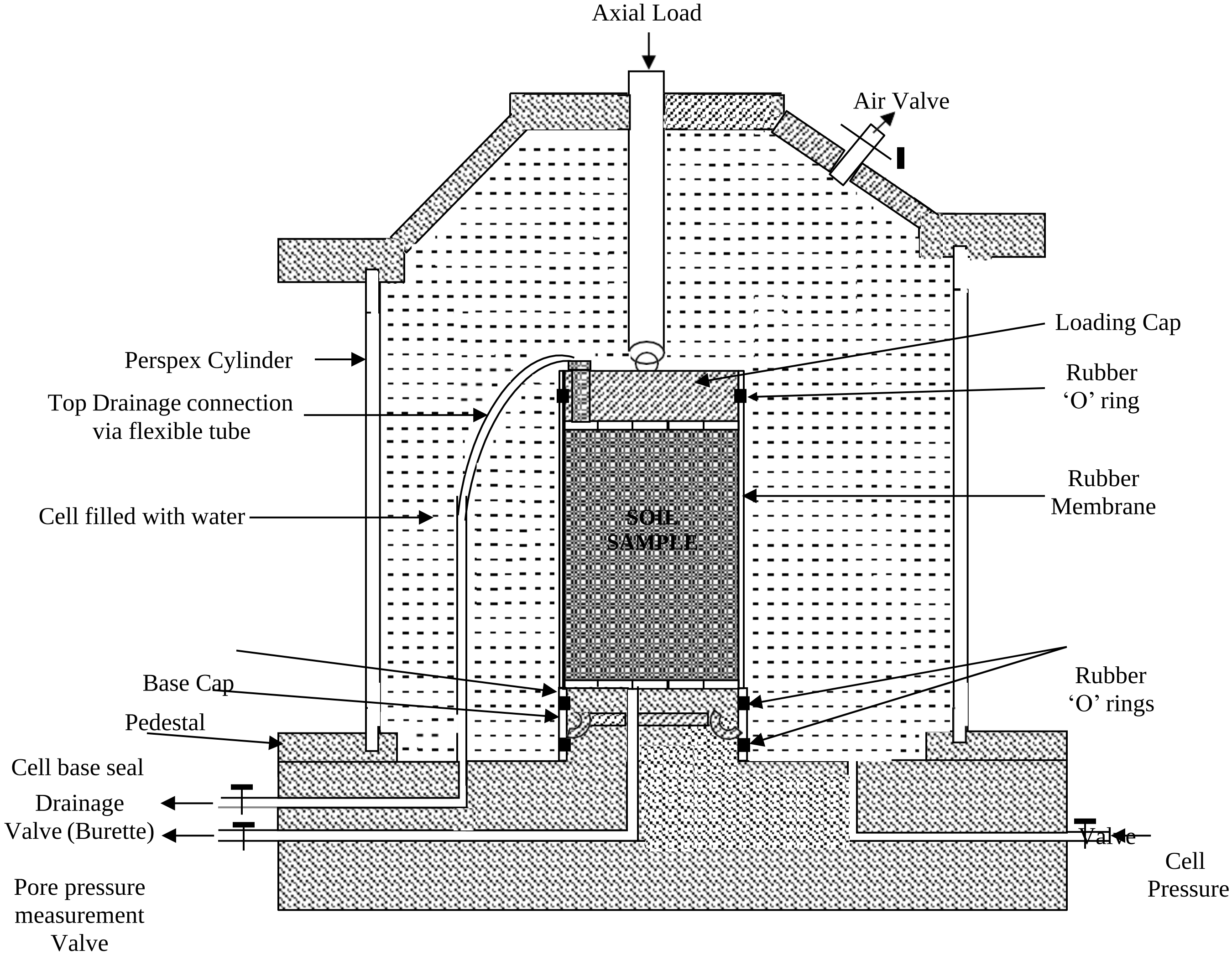


FIG. TRI-AXIAL CELL

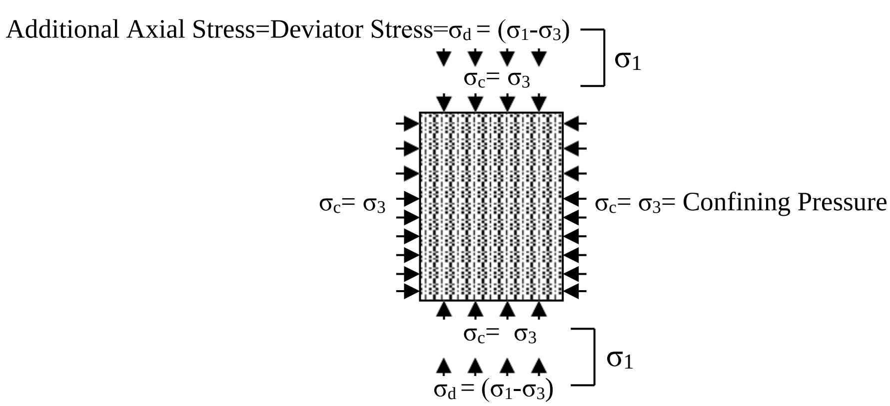


Fig. Stress condition on the tri-axial specimen

5. PROCEDURE FOR UU TRI-AXIAL TEST:

(i) At the first pedestal in the tri-axial cell was covered with soil specimen end cap and specimen is kept centrally on pedestal. The cell with loading ram initially covered of top of specimen and placed on the loading machine.

(ii) The fluid entered the cell and its pressure raised to desired value. The initial reading is taken from load measuring gauge. Ensure that loading ram comes just at the top of the specimen and the initial reading is taken from the dial gauge which measuring axial compression.

(iii) When the compressive force applied at a constant rate of axial compression, a failure is produced at time 5 to 15 minutes. Simultaneously readings are taken from load and deformation dial gauges. Test conducted till maximum stress has been passed or axial strain of 20 % has been passed.

(iv) The specimen is unleaded and fluid is drained off and cell is dismantled and specimen is taken out, the rubber membrane is removed and mode of failure was noted.

(v) Specimen was weighted and sample is to take for determination of water content.

(vi) Test is repeated on three or more samples which are identical under the different cell pressure.

6. OBSERVATIONS AND CALCULATIONS:

Water content of soil specimen before testing:

Wt. of moisture container = ----g
Wt. of moisture container+ wet soil = ----g
Wt. of moisture container+ dry soil = ---- g
Wt. of wet soil = ---- g
Wt. of dry soil = ---- g
Water content at failure =-----%

Initial Length/ Height of the Soil Sample(L) = 7.62 cm
Initial Diameter of the Soil Sample (D) = 3.81 cm
Initial c/s Area of the Sample (A_0) = ∏/4xD^2 = ------- cm^2
Initial Volume of the Sample (V_0) = A_0 x L =------ cc
Initial Weight of the sample (W) = ------ g
Initial Density of the Sample ($\rho=W/V_o$) = ------- g/cc

Strain rate = ------ mm/min
Least count of strain dial gauge =--------
ΔL= (Strain dial gauge reading x Least count of strain dial gauge) = -------
Axial Strain (%) = Є = (ΔL/Lx100) % =------%
Corrected area of the sample= A_c = A_0/ (1- Є) = --------- cm^2

Proving ring constant = -------

Additional Axial Load applied = (Proving ring reading x Proving ring Constant) =

$$\text{Deviator stress (or) Additional axial stress} = \sigma_d = \frac{\text{Additional Axial Load applied}}{\text{Corrected area of the sample}}$$

$\therefore$ Major Principal Stress= $\sigma_1 = (\sigma_d + \sigma_3)$

Water content of soil specimen at failure:

Wt. of moisture container =-----g

Wt. of moisture container+ wet soil =-----g

Wt. of moisture container+ dry soil =----- g

Wt. of wet soil =----- g

Wt. of dry soil =----- g

Water content at failure =-----%

7.

8.

Table:

Table:

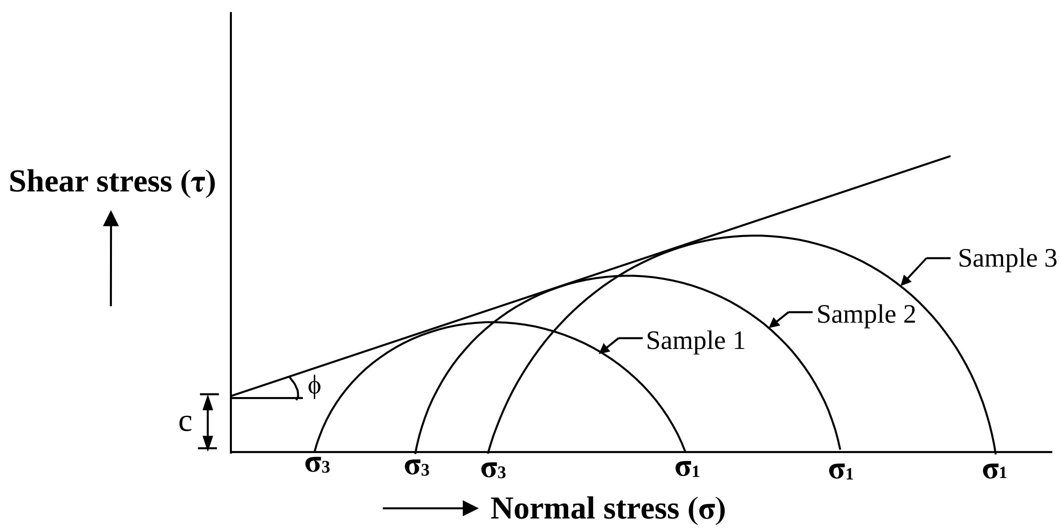
Strain Dial Gauge Readings	**Axial strain $\in$= (ΔL/L x 100) %**	**Additional axial load readings (proving ring readings)**			**Deviator stress (σ_d) (in kg/cm^2) (Additional Axial Stress)**		
		Cell Pressures (in kg / cm^2)			**Cell Pressures (in kg / cm^2)**		
		0.5	**1.0**	**1.5**	**0.5**	**1.0**	**1.5**
15							
30							
45							
60							
75							
90							
120							
150							
180							
210							
240							
270							
300							
330							
360							
390							
420							
450							
480							
510							
540							
570							
600							

Table: Stress at Failure

Test No.	Cell Pressure (Minor Principal Stress) σ_3 (in kg/cm^2)	Deviator stress at failure $\sigma_d = (\sigma_1 - \sigma_3)$ (in kg/cm^2)	Major Principal Stress $\sigma_1 = (\sigma_3 + \sigma_d)$ (in kg/cm^2)
1			
2			
3			

7. GRAPH:

Draw the graph between normal stress (σ) on X- axis and shear stress (τ) on Y- axis using natural scale. On the X- axis locate major and minor normal stresses (**σ_1 and σ_3**) at failure obtained from tests on soil sample. Construct Mohr's Circles. Draw a common tangent to Mohr's Circles to determine shear strength parameters (c &ϕ). The intercept at y-axis will give cohesion (c) and inclination of the tangent to the horizontal is the angle of internal friction (ϕ).



8. RESULT:

From the graph betweenτ &σ , the shear strength parameters of the given soil sample at water content-------% are:

Cohesion = c_{UU} =
Angle of internal friction =ϕ_{UU} =

Expt. No: **Date:**

DETERMINATION OF SHEAR STRENGTH PARAMETERS OF THE SOIL BY DIRECT SHEAR TEST (BOX SHEAR TEST)

As per IS 2720 (Part XIII)-1986

AIM:

To determine the shear strength parameters of the soil with the shear box.

THEORY:

The shear strength of the soil is the resistance to deformation by continuous shear displacement of soil particles upon the action of shear stress.

$$S = c + \sigma \tan\phi$$

Where c, ϕ are called Shear Strength Parameters

S = Shear strength (KN/m^2 or Kg/cm^2)

σ = Normal stress (KN/m^2 or Kg/cm^2)

c = Cohesion (KN/m^2 or Kg/cm^2)

ϕ = Angle of internal friction/ angle of shearing resistance (degrees)

The shear strength of a soil is constituted basically of three components. Namely i) Structural resistance ii) Frictional resistance iii) Cohesion

Shear resistance can be determined in the laboratory under three types of drainage conditions

a) Undrained test or Quick test – (Q-test)

b) Consolidated – Undrained test – (R – test)

c) Drained test or slow test – (S – test)

Direct shear test is a simple and most commonly used test. This test can be conducted under all the three drainage conditions. The failure plane is predetermined and is horizontal. This test is strain-controlled test as the shear strain is made to increase at constant rate.

APPARATUS:

1. Shear box equipment
2. Two gripper plates with grooves
3. Loading frame
4. Set of weights for applying normal stress
5. Proving ring with dial gauge

PREPARATION OF SOIL SAMPLE:

1. The undisturbed specimen is prepared by pushing a cutting ring of size 10cm diameter and 2cm high in the undisturbed soil sample obtained from the field. Then the square specimen of size 6cm x 6cm is cut from this circular specimen.
2. Non-cohesive soils will be tamped in the shear box with base plate and gripper plate at the bottom of the box.
3. Cohesive remoulded soil samples can be obtained by compacting the soil at required density and water content in a bigger mould and then trimming to the required size.

DECRIPTION OF DIRECT SHEAR TEST APPARATUS:

The apparatus consists of shear box 6 cm x 6 cm in size, which is separated horizontally into two halves. One half is fixed with the other half can move horizontally. A normal load is applied to the soil in the sear box through a rigid loading cap.

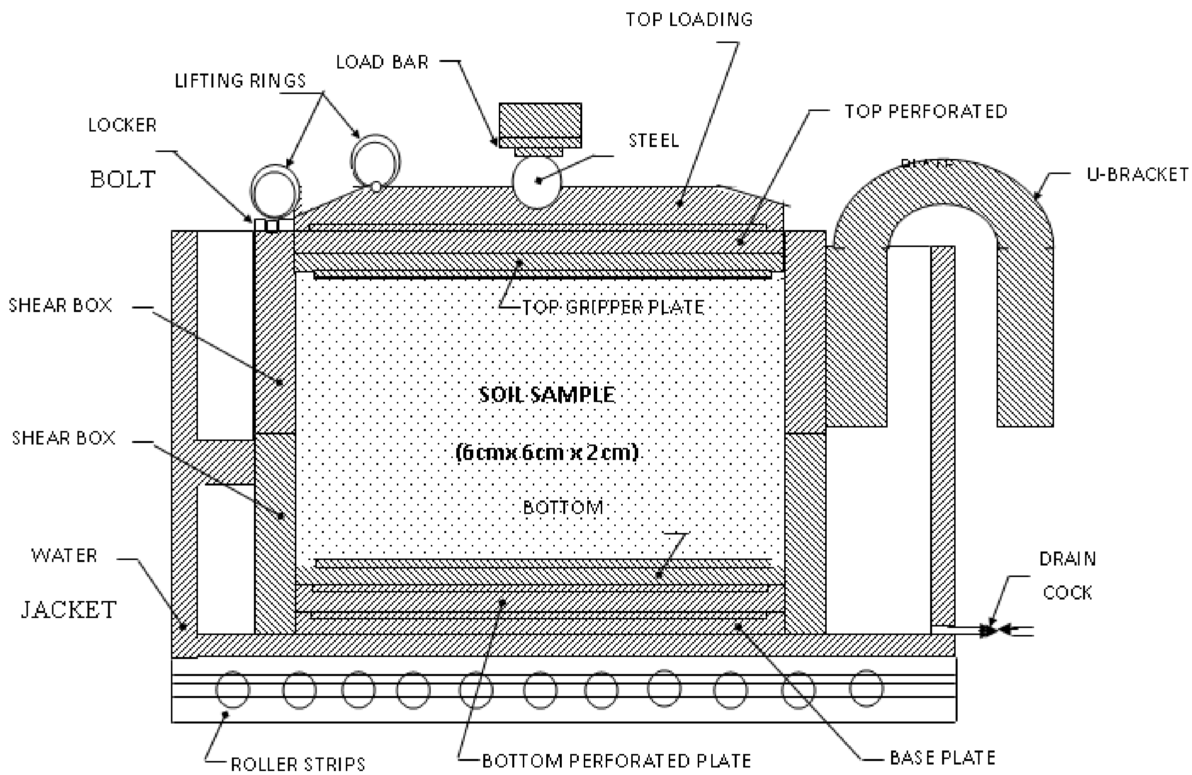


Fig. SHEAR BOX ASSEMBLY

TEST PROCEDURE FOR UNDRAINED TEST

1. Place the gripper plate at the bottom of the box with the grooves on the specimen side and perpendicular to the direction of the movement of the movable half of the shear box. Place the pins in the shear box so that the halves in the box do not move while filling the box and compacting the soil in it.
2. Place the sample in the shear box. For this take some amount of granular soil and weigh it. Divide it into three parts and fill the shear box with the soil in three layers, tamping each layer with a tamper. The final thickness of the compacted specimen should be 2 cm.
3. Place the other plate with grooves facing the soil specimen and in a direction perpendicular to the direction of movement. Place the loading plate on the top of the gripper plate. Adjust the normal loading yoke and place it centrally on the specimen. Apply the normal loads to the lever pan attached to the hanger (the loads are calibrated loads, based on the lever arm ratio).
4. Place the horizontal deformation measuring dial gauge with its spindle touching the moving half of the shear box.
5. Adjust the proving ring dial gauge to measure the shearing load. Note the initial readings of the proving ring dial gauge and the deformation dial gauge.
6. Shear the soil specimen after removing the pins from the shear box. Note the readings of the proving ring, dial gauge and the deformation dial gauge corresponding to different percentage strains until failure of the specimen has occurred. Shearing in the soilspecimen can be induced either manually or with the help of an electric motor.
7. Repeat the test with three or four more normal loads every time with a different soil specimen, compacted to the same initial dry density i.e. dry weight and volume of the soil being kept constant.
8. Draw a plot between the normal stress and the shear stress as the abscissa and the ordinate respectively. This will yield a straight line. If the soil has cohesion there will be an intercept on the shear stress axis. This gives the magnitude of cohesion. If the soil is cohesionless the straight line passes through the origin. The slope of the line gives the angle of internal friction of the soil.

OBSERVATIONS:

Weight of soil sample= W=

Area of Box shear=6cm x 6cm = 36 cm^2

Thickness of soil specimen=H=

Volume of soil specimen= V= 6x6xH=

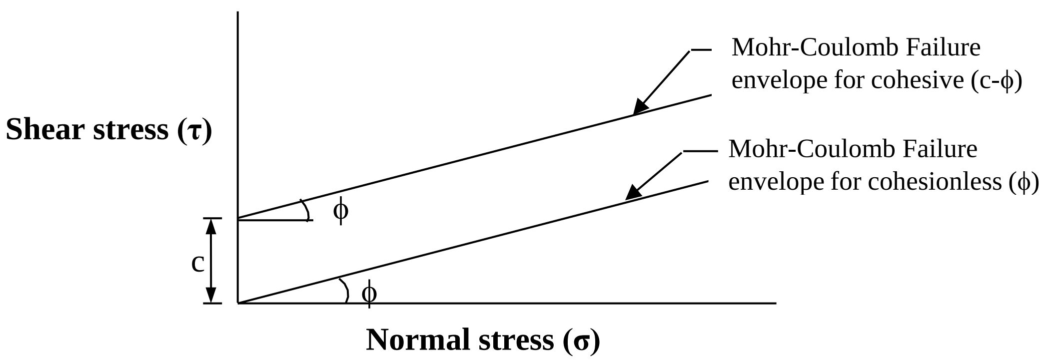
Dry density of soil sample= ρ_d= W/V=

Table 1:

Normal stress applied (σ)	**Maximum shear load measured**	**Shear stress (τ) = Shear load / Area of Box shear**

GRAPH:

Plot the graph between normal stresses applied and corresponding shear stresses at failure. The Y-intercept when σ = 0 is the cohesion (c) and angle made with horizontal is the angle of internal friction (ϕ).



RESULTS:

From graph:

Cohesion (c) =

Angle of internal friction (ϕ) =

Expt. No: **Date:**

DETERMINATION OF UNDRAINED SHEAR STRENGTH OF SOIL BY LABORATORY VANE SHEAR TEST

As per IS 2720 (Part 30)-1980

AIM:

To determine the undrained cohesive strength or cohesion of soil

THEORY:

The ability of a soil mass to support an imposed loading or for a soil mass to support itself is governed by the shear strength of the soil. As a result, the shearing strength of the soil becomes of primary importance in foundation design, highway and airfield design, slope stability problems, and lateral earth pressure problems that deal with forces exerted on underground walls, retaining walls, bulkheads and excavation bracing. The shearing strength and related deformations (or stress-strain relationship) of a foundation or construction soil is conventionally studied in the laboratory by testing soil samples obtained from the construction site.

In soils, shear strength is contributed by the two properties (i) cohesion and (ii) angle of internal friction. In pure clays the shear resistance due to internal friction is negligible, Hence, the complete shear strength, in clays, is due to cohesion (c).

Vane Shear Test is cheaper and quicker test. The test is used for determination of the undrained cohesion of clay, particularly very soft to medium stiff clay. Vane shear test is most valuable in sensitive clays wherein it is difficult to obtain truly undisturbed samples without disturbing their in-situ strength. The vane shear test is also useful in finding out sensitivity of subsoil by determining strength in undisturbed and remoulded state. The ratio of strength in undisturbed to remoulded state is known as sensitivity.

The undrained shear strength is obtained from the following equation:

$$C_u = \frac{T}{\Pi D^2 \, (H/2+D/6)}$$

Where C_u = Undrained cohesion, T= Applied Torque,

D = Diameter of Vane, H= Height of Vane = 2D

APPARATUS:

1. Vane shear apparatus: The vane shear test apparatus consists of a *torque head* mounted on a *bracket*. The *four steel shear vanes* are fixed on a *shaft* and the shaft is fixed in the lower end of a *circular plate* graduated in degrees. A *torsion spring* is fixed between *torque head* and the *circular plate (disc)*. A *maximum pointer* is provided to facilitate reading the angle of torque. As the *strain indicating pointer* rotates when the torque is applied, it moves the maximum pointer, leaving it in position when the torque gets released at failure and the vane returns to its initial position. Rotation of the vane is effected by turning the torque applicator handle,
2. Sampling mould,
3. Containers for moisture content determination,
4. Weighing balance sensitive to weigh 0.01 g.

PROCEDURE:

1. Clean the Vane shear apparatus thoroughly. Apply grease to the lead screw.
2. Fill up the sampling mould with remoulded soil at required density and moisture content or the undisturbed soil sample level the surface of the sample with the mould.
3. Mount the sampling tube with sample under the base of the unit and clamp it in position.
4. Bring the maximum pointer into contact with the strain indicating pointer. Note down the initial reading of these pointers on the Circular graduated scale.
5. Lower the bracket until the shear vanes go into soil sample to their full length.
6. Operate the torque applicator handle until the specimen fails which is indicated by the return of the strain indicating pointer.
7. Note down the reading of the maximum pointer.
8. The difference between the two readings (Initial and final) gives the angle of torque.
9. Repeat steps (3) to (8) with different moisture contents.

OBSERVATIONS AND CALCULATION:

Height of vane = H =

Diameter of vane = D =

Spring constant =

S. No	**Initial Reading, θ_1 (degrees)**	**Final Reading, θ_2 (degrees)**	**Angle of Torque = Difference Angle, $\theta = \theta_2 \sim \theta_1$**	**Torque, T = θ x k/180** (kg-cm)	**Undrained Shear Strength, C_u (kg/cm^2)**	**Water Content**
1						
2						
3						
4						
5						

RESULT: The undrained cohesive strength or cohesion of soil =

Expt. No: **Date:**

DETERMINATION OF DENSITY INDEX (RELATIVE DENSITY-) OF COHESIONLESS SOILS

As per IS 2720 (Part 14)-1983

Aim: To determine the relative density of given soil sample.

Reference: IS 2720 (Part - 14) – 1983

Apparatus:

1. Empty mould
2. Pouring device
3. Vibrating Machine

Type and amount of oven-dried pulverised soil

Formulae:

Relative Density $$I_D = \frac{e_{max}-e}{e_{max}-e_{min}} x100$$

$$I_D = \frac{\gamma_{dmax}}{\gamma_d}\left[\frac{\gamma_d - \gamma_{dmin}}{\gamma_{dmax} - \gamma_{dmin}}\right] x100$$

$\gamma_{d\ max} = Max\ Dry\ density\ when\ soil\ is\ in\ dense\ state,$

$\gamma_{d\ min} = Min\ Dry\ density\ when\ soil\ is\ in\ loose\ state,$

$\gamma_d = Natural\ dry\ density$

Procedure:

1. Volume of cylindrical mould (V_1) was calculated by measuring the diameter & height.
2. Empty weight of the mould was taken (W_1).
3. Dry weight of the soil was poured into mould throughout funnel in a steady stream. The spout was adjusted so that the free fall of the soil particles is always 25mm, it was taken leveled and weight (W_2) was recorded.
4. Minimum dry density $\gamma_{d\ min}$ was obtained.

$$\gamma_{dmin} = \frac{W_2 - W_1}{V_1}$$

5. The mould was placed on the vibrating table and placed on it.
6. The vibrator was placed and allowed to run for 8 minutes. The mould with soil was taken and weighed as W3.
7. The reduction in height of sand were measured at five different places and average reduction in height was taken, then height was obtained from h2 = original height average reduction.
8. Volume V2 was obtained from V2=πd2h2/4

9. Maximum dry density $\gamma_{d\,max}$ was obtained

$$\boldsymbol{\gamma_{dmax} = \frac{W_3 - W_1}{V_2}}$$

10. Relative density I_D was calculated

Observations:

Height of the mould =

Dia of the mould d_1 =

Volume of the mould V_1 =

Weight of the mould W_1=

Weight of the mould + Sand after pouring into the mould W_2=

Weight of the mould + sand after vibration W_3=

Height compacted soil after vibration h_2= h_1 – average reduction in height

Volume of the compacted soil, V_2 =

Assumed in-situ density of soil $\gamma_d =$

Calculations:

Minimum dry density $\gamma_{d\,max} =$

Maximum dry density $\gamma_{d\,max} =$

Relative density I_D =

Inference:

Denseness	**Density Index (%)**
Very loose	< 15
Loose	15 – 35
Medium	35 – 65
Dense	65 – 85
Very Dense	85 – 100

Result:

Relative density of the given soil sample =

The given soil is

Expt. No: **Date:**

VARIABLE (FALLING) HEAD PERMEAMETER METHOD

AIM:

To determine the coefficient of permeability of the given fine-grained soil.

APPARATUS:

Variable Head Permeameter,

Filter paper,

Scale,

Vernier calipers,

Metal tray,

Measuring jar,

Stand-pipe

Stop watch, and

Thermometer

PROCEDURE:

1. Remove the cover of the mould and apply a little grease on the sides of the mould.
2. Measure the internal diameter and effective height of the mould and then attach the collar and the base plate.
3. Take the required weight of the dry cohesionless soil to fill the soil to the desired dry density (void ratio). Compact the soil into the mould after fixing the base plate to the mould and placing the porous discs.
4. Remove the collar, trim off the excess soil and level with the top of the mould.
5. Put the porous plate and a filter paper both at top and bottom of the soil sample.
6. Secure both the base plate and the top plate to mould with suitable clamps and rubber gaskets to make the entire assembly watertight.
7. Place this assembly in a shallow metal tray with an outlet.
8. Fill the metal tray with water to submerge the base plate completely.
9. Connect the standpipe to the inlet at the top plate

10. Fill the standpipe with water to convenient height and measure the hydraulic head (h_1) w.r.t the tail water level corresponding to the bottom of the outlet of the tray.

11. Commence the flow of water by opening the inlet valve and simultaneously start the stopwatch.

12. Record the time intervals for the head to fall from h_1 to h_2 for five times. Note the temperature of water.

OBSERVATIONS:

a = C/s area of stand pipe=

A=C/s area of soil sample=

L= Length of the soil sample=

S.No.	*Initial head (h_1) cm*	*Final head (h_2) cm*	*Time interval 't'*	$K = 2.3\frac{aL}{At}\log_{10}\frac{h_1}{h_2}$
1.				
2.				
3.				
4.				
5.				

Average coefficient of permeability of the given soil sample at test temperature $T^oc = k_T =$

Average coefficient of permeability of the given soil sample at $27^oc = k_{27} = k_T \times \mu_T / \mu_{27} =$

Where, μ_T = Viscosity of Water at test temperature T^oc

μ_{27} = Viscosity of Water at 27^oc

1 dyne-sec/cm^2 = 1 Poise; 1 g-sec/ cm^2 = 980.7 poise

RESULT: Average coefficient of permeability of the given soil sample at 27^oc=