QMP7.1 D/F

Channabasaveshwara Institute of Technology

(Affiliated to VTU, Belgaum & Approved by AICTE, New Delhi)
(**NAAC Accredited &ISO 9001:2015 Certified Institution)**
NH 206 (B.H. Road), Gubbi, Tumkur – 572 216.Karnataka.

Department of Civil Engineering

GEO-TECHNICAL ENGINEERING LABORATORY

BCV502

B.E - V Semester

Lab Manual 2024-25

Name :____

USN :____

Batch : __________________ Section : _____________

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Department of Civil Engineering

GEO-TECHNICAL ENGINEERING LABORATORY

September 2024

Prepared by:

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SL NO.	Name of the Experiment	Date: Conduction	Date: Submission of Record	Observation (05)	Record Marks (Max. 10)	Signature Student	Signature Faculty
1.							
2.							
3.							
4.							
5.							
6.							
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9.							
10.							
11.							
12.							
13.							
14.							
Average							

DEPARTMENT OF CIVIL ENGG.

COURSE OBJECTIVE

This course will enable students to;

1. To carry out laboratory tests and to identify soil as per IS codal procedures
2. To perform laboratory tests to determine index properties of soil
3. To perform tests to determine shear strength and consolidation characteristics of soils

COURSE OUTCOME

CO 502.1 **Analyze Physical** and index properties of the soil

CO 502.2 **Evaluate** properties of in situ soil based on index properties

CO 502.3 **Evaluate** field compaction and determine OMC and MDD.

CO 502.4 **Estimate** the Shear strength, consolidation parameters, strength and deformation characteristics of soil

CO 502.5 **Demonstrate** In-situ shear strength characteristics of soil

'Instructions to the Candidates'

1. Students should come with thorough preparation for the experiment to be conducted.

2. Students without uniform will not be permitted to attend the laboratory classes

3. Students will not be permitted to attend the laboratory unless they bring the practical record fully completed in all respects pertaining to the experiment conducted in the previous class.

4. All the calculations should be made in the observation book. Specimen calculations for one set of readings have to be shown in the practical record.

5. Wherever graphs are to be drawn, A-4 size graphs only should be used and the same should be firmly attached to the practical record.

6. Practical record should be neatly maintained.

7. They should obtain the signature of the staff-in-charge in the observation book after completing each experiment.

8. Theory regarding each experiment should be written in the practical record before procedure in your own words.

DEPARTMENT OF CIVIL ENGG.

GEOTECHNICAL ENGINEERING LABORATORY

Subject Code: BCV502 (IPCC)
No. of Practical Hours/Week: 2
Total No. of Practical Hours: 8-10 lab slots

1. Water content determination by oven drying, Rapid moisture meter method
2. Grain size analysis (Sieve analysis of soil)
3. In-situ density tests i. Core-cutter method ii. Sand replacement method
4. Consistency limits i. Liquid limit test(by Casagrande's and cone penetration method) ii. Plastic limit test iii.
5. Co-efficient of permeability test i. Constant head test ii. Variable head test
6. Standard compaction test (light compaction only)
7. Direct shear test
8. Unconfined compression test & Laboratory vane shear test
9. Triaxial test (unconsolidated undrained test only)
10. Demonstration of Standard penetration test & Boring equipment
11. Demonstration of Proctors Needle
12. Demonstration of Vane shear test

TEXT BOOKS:

1. Gopal Ranjan and Rao A.S.R., Basic and Applied Soil Mechanics, New Age International (P) Ltd., New Delhi. 2016
2. Murthy V.N.S., Principles of Soil Mechanics and Foundation Engineering, UBS Publishers and Distributors, New Delhi. 2018
3. Braja, M. Das, Geotechnical Engineering; Thomson Business Information India (P) Ltd., India. 2015
4. Punmia B C, Soil Mechanics and Foundation Engineering, Laxmi Publications co., New Delhi. 2017
5. Soil Testing for Engineers by S. Mittal and J.P. Shukla 2020

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DEPARTMENT OF CIVIL ENGINEERING

CONTENTS

Signature **Marks Obtained**

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Observations

Sl No	Container No	Empty weight of container (W_1)	Weight of container + wet soil (W_2)	Weight of container + dry soil (W_3)	Water content (%)
1					
2					
3					
4					
5					

Calculations:

Water content: $W = [(W_2 - W_3)/(W_3 - W_1)] * 100$

Experiment No.:1 Date:…………………….

DETERMINATION OF MOISTURE CONTENT

Aim: To determine the water content of the given soil by Oven Drying method

IS Code: IS 2720 (Part 2)- 1973

Apparatus: Container and Oven

Procedure:

1. Take the empty weight of container
2. Put some soil into it and weigh it
3. Keep the container in oven for 24hrs
4. Take the weight of container with dry soil
5. Repeat the procedure for more trials

Results:

OBSERVATIONS AND CALCULATIONS:

Total mass of soil taken for analysis = M_0 = ______ gram.

IS Sieve	Practical Size D mm	Mass Retained M^1, (g)	Corrected mass retained M.(g).	Percentage retained [M/ M_0] X 100	Cumulative Percentage retained	Percentage Finer (N)

Specimen Calculations:

Corrected Mass Retained = $M = M^1 \times \frac{Mo}{\sum M^1}$

Experiment No.:2 Date:…………………….

GRAIN SIZE ANALYSIS

AIM: To determine the grain size distribution of the given soil by Sieving.

IS CODE: IS: 2720 (Part-4)-1985

THEORY: Particle size classification of soils:

*** IS System:** All soils in general can be classified into coarse grained soils and fine grained soils. If 50% or more than 50% of the soil particles are retained on 75 μ IS sieve (0.75mm), the soil is classified as coarse grained soil particles pass through 75 μ IS sieve then the soil is known as fine grained soil.

Further classification of coarse and fine grained soil is shown below.

0.002 mm 0.075 mm 4.75 mm 75 mm 300 mm

Clay Size	Silt size			Sand			Gravel		Cobble	Boulder
	Fine	Medium	Coarse	Fine	Medium	Coarse	Fine	Coarse		

0.005 mm 0.04 mm 0.425 mm 2 mm 20 mm

Fine Grained ←→ Coarse Grained

Apparatus:

1. Set of IS Sieves 4.75mm, 2mm, 1mm, 600micron, 425 micron, 300 micron, 212 micron, 150 micron, 106 micron, 75 micron, brushes to clean the sieves.
2. Mechanical sieve shaker.
3. Balance, trays
4. Thermostatically controlled oven.

Procedure:

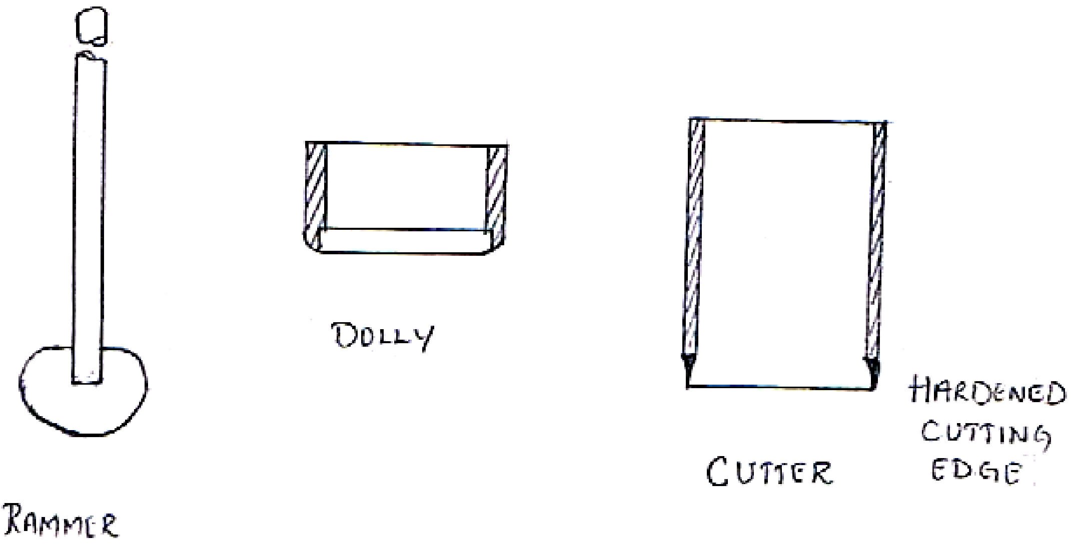
1. Weigh 1000g of soil retained on 4.75mm sieve and retained on 75 μ
2. Sieves should be arranged such that 4.75 is at the top and 75 μ is at the bottom
3. Fix the set of sieves to the mechanical sieve shaker; operate the sieve shaker for a minimum of 10 minutes.
4. Carefully collect and record the mass of the soil fraction retained on each sieve and in the receiver.
5. Calculate the cumulative mass of soil fraction retained on each sieve, calculate the percentage finer.
6. Plot a graph of percentage finer (along Y - axis) Vs equivalent particle diameter in mm (along x-axis in log scale) Draw a smooth curve encompassing the plotted points.

7. Record the values of percentage sand, percentage sill and percentage clay size fraction from the graph.
8. Record D_{10}, D_{20} and D_{30} from the graph.
9. Calculate co-efficient of curvature (Cc) and co-efficient of uniformity (Cu)
10. Classify the soil based on gradation.

From Graph:

- % of gravel =
- % of Sand =
- % of silt & clay =
- D_{10}=
- D_{30}=
- D_{60}=
- Coefficient of uniformity Cu = D_{60}/ D_{10}=
- Coefficient of curvature Cc = $D_{30}^2/(D_{10} \times D_{60})$ =

Result:



Observations and Calculations:

a) <u>Determination of In-Situ Bulk density of the Soil:</u>

- ∗ Inside diameter of the core-cutter = d cm =
- ∗ Inside height of the core-cutter = h cm =
- ∗ Volume of the core-cutter = V cm^3 =

  =
- ∗ Mass of the core-cutter =
- ∗ Mass of the [core cutter + wet soil] =
- ∗ Mass of the wet soil[M] =
- ∗ Bulk density of the soil ρ_b= M/V

b) <u>Determination of Field Water Content:</u>

- ∗ Container Number =
- ∗ Mass of the Container =
- ∗ Mass of the [Container + wet Soil] =
- ∗ Mass of the [Container + dry Soil] =
- ∗ Mass of the dry Soil [M_d] =
- ∗ Mass of water [M_w] =
- ∗ Water content Mw/Md =

Experiment No. 3 **Date:**

FIELD DENSITY

[a] AIM: To determine the dry density of the soil in-situ by core-cutter method.

THEORY:

Field Density and Field Moisture content

Practical Significance

Field density of soil and field moisture content of the soil are required from the point of view of determining the over burden pressure at any depth within a soil mass to help in quality control of a compacted earth fill.

Following methods are commonly adopted in practice to determine the in-situ density.

i. Core-cutter method.
ii. Sand replacement method.
iii. Water displacement method.
iv. Submerged mass density method.
v. Rubber balloon method.

Core-cutter method: In this method, a cylindrical steel core-cutter of known dimensions and hence volume is used to determine the field density. This method is suitable for cohesive or clayey soil, and cannot be used for cohesion less soils, hard soils.

Apparatus:

1. Cylindrical core-cutter of steel, 127.4 mm long and 100 mm internal diameter with a wall thickness of 3mm, beveled at one end.
2. Steel dolly, 25mm height and 100mm diameter with a wall thickness of 7.5mm, with a lip to enable it to be fitted on the top of the core-cutter.
3. Steel rammer, knife, grafting tool or picatoxe or spade.
4. Straight edge, balance accurate to 1g and containers for water content determination.

Procedure:

1. Measure the inner dimension of the core-cutter and calculate its volume. Determine the mass of the core-cutter [without dolly] accurate to 1g oil the inside surface of the core-cutter and the dolly.
2. Level the area where the in-situ density of the soil is required to be measure. Put the dolly on the top of the core-cutter and drive the assembly into the soil with the help of the rammer until the top of the dolly protrudes about 1½ cm above the surface.

c) Determination of In-Situ Dry Density of the Soil:

- Dry density = $P_d = \frac{P_d}{[1 + w]}$ g/cm^3 =
- Average dry density = $[P_d]_{av}$ g/cm^3 =

Specimen Calculations:

1) Volume of the core cutter = $V = \frac{\pi d^2 h}{4}$ =

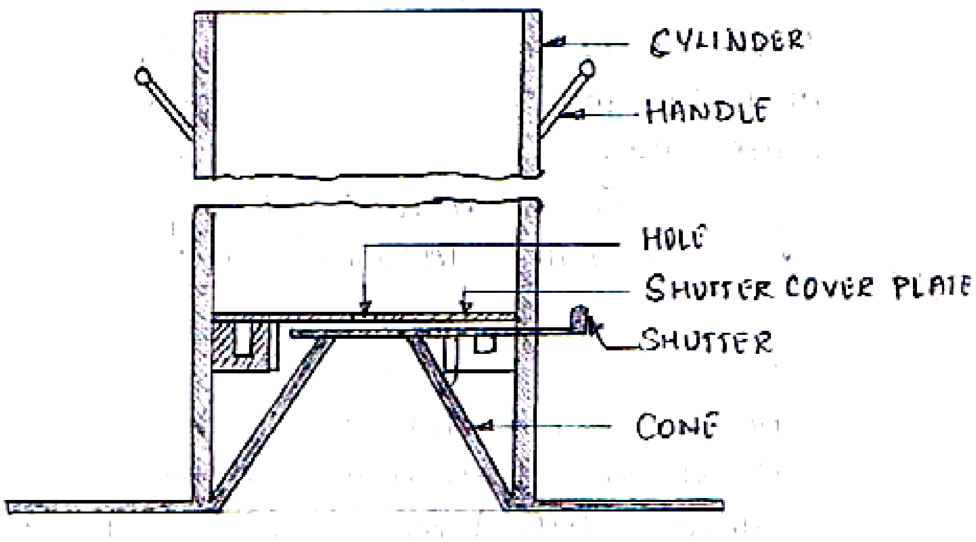
   =

2) In-situ bulk density of the soil $P_b = M/V$
3) In-situ water content of the soil $w = \frac{M_w}{M_d}$
4) In-situ dry density $P_d = \frac{P_d}{[1 + w]}$

3. Dig out the core-cutter along with the dolly from the surrounding soil such that some soil projects from the lower end of the core-cutter. Take out the dolly, and trim flat both the ends of the core-cutter.
4. Determine the mass of the core-cutter with the soil.
5. Keep some representative soil for water content determination.
6. Repeat the test at two or three locations nearby for the average result.

Result:

* Bulk density of soil by core-cutter method is __________
* The field water content of the given soil by core-cutter method is ______________
* In-situ dry density of the given soil by core-cutter method is ____



Sand Replacement Cylinder fig.

[a] Determination of the Bulk Density of Sand:

1. Inside diameter of the calibrating container = d =
2. Inside height of the calibrating container = h =
3. Volume of the calibrating container V_c =
4. Mass of [sand & cylinder] before pouring [M_1] =
5. Mass of the sand in the cone [M_2] =
6. Mass of the [sand + cylinder] after pouring into the calibrating container [M_3] =
7. Mass of the sand, filling the calibrating container,

$$M_{sand} = [M_1 – M_3 – M_2] =$$

8. Bulk density of the sand $\gamma_s = M_{sand}/V_c$

[b] Determination of the Bulk density of the Soil In-situ:

1. Mass of the wet soil excavated from the hole = M =
2. Mass of the [sand + cylinder] after pouring into the hole = M_4 =
3. Mass of sand in the hole $M_h = [M_1 – M_4 – M_2]$ =
4. Volume of the hole = M_h/ρ_s =
5. Bulk density of the soil in-situ = $\rho_b = (M/M_h) \times \rho_s$ =

[b] AIM: To determine the dry density of the soil in-situ by sand replacement method.

THEORY: Sand replacement Method of determining field dry density – practical significance. This method can be used under all circumstances. The method consists of making a hole into the ground where the field density is required to be determined. By knowing the weight of the soil excavated from the hole and the volume of the soil can be calculated. The volume of the hole is determined by sand replacement.

Apparatus:

1. Sand pouring cylinder with a pouring cone at its bottom separated from it by a shutter.
2. Cylindrical calibrating container. 100mm internal diameter and 150mm internal depth, with a flange.
3. Glass plate, about 45cm square and 1 cm thick.
4. Metal tray with a central circular hole of diameter equal to the diameter of the pouring cone.
5. Tools for excavating the hole.
6. Balance accurate to 1g.
7. Containers for water content determination.
8. Clean, uniformly graded natural sand passing the 600 micro IS sieve.

Procedure:

[a] Determination of the Bulk Density of the Sand:

1. Fill the sand in the sand pouring cylinder up to a height 1cm below the top. Determine the total initial mass of the cylinder with the sand [M_1], which is to be maintained constant throughout the test.
2. Keep the cylinder on a glass plate. Open the shutter and allow the sand to run out. Close the shutter when no movement of sand is observed. Remove the cylinder and record the mass of the sand collected on the glass plate (M_2). This represents the mass of the sand, filling the pouring cone. Put the sand back in to the cylinder to maintain the constant mass M_1.
3. Measure the inner diameter and height of the calibrating container and hence, determine the volume of the calibrating container.
4. Place the cylinder with sand concentrically on the top of the container. Open the shutter, and allow the sand to the run into the container. Close the shutter when no further movement of sand is observed. Remove the cylinder and find its mass along with the remaining sand [M_3]. Put the sand back into the container to maintain the constant mass M_1.
5. Calculate the density of sand in the cylinder.

[c] Determination of the field water content and in-situ dry density of the Soil:

1. Container number =
2. Mass of the container g =
3. Mass of the [container + wet soil] =
4. Mass of the [container + dry soil] =
5. Mass of dry soil M_d =
6. Mass of the water M_w =
7. Water content(w) =
8. Dry density of soil $\rho_d = \rho/(1+w)$ =

Specimen Calculations:

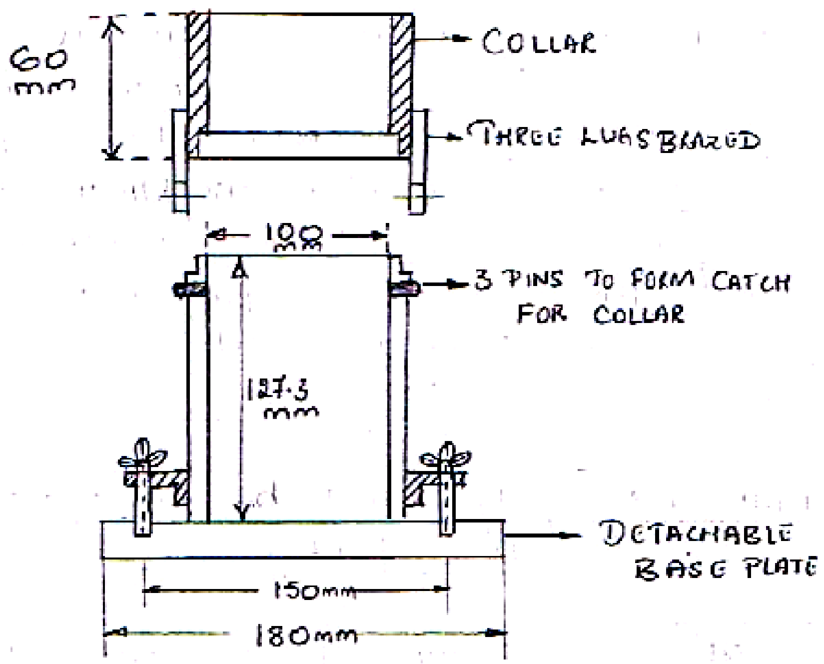
[b] Determination of the Dry Density of the Soil In-Situ:

1. Level the surface where the in-situ density of the soil is required to be measured. Keep the metal tray on the level surface and excavate a circular hole of about 15cm deep. Collect the excavated soil in the tray. Immediately record the mass of the excavated soil (M), and keep some soil for moisture content determination.
2. Remove the tray and place the cylinder with sand on the excavated hole. Open the shutter, and allow the sand to run into the hole. When the no further movement of the sand is seen, close the shutter. Determine the mass of the cylinder with the remaining sand in it [M_4].
3. Determine the bulk density, field water content and field dry density of the soil.

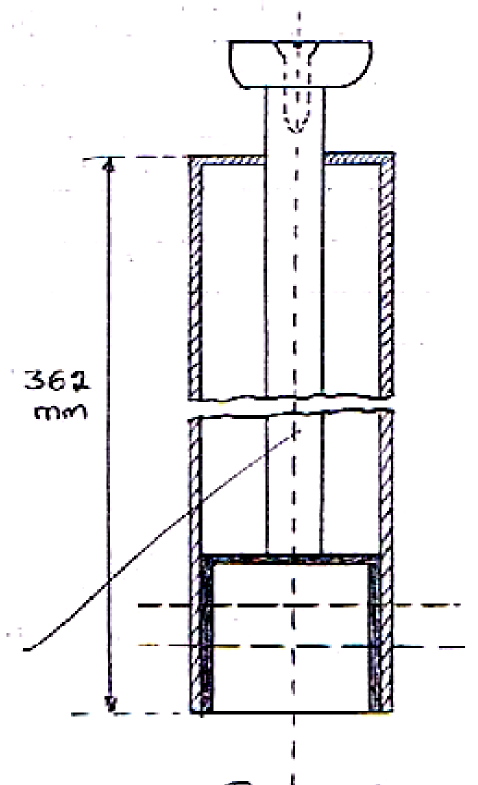
Results:

* Bulk density of sand by sand-replacement Method is ______
* In-situ dry density of the given soil by sand replacement method is __________
* The field moisture content of the given soil by sand replacement method is __________

*****



CYLINDRICAL METAL MOULD WITH COLLAR



RAMMER

Experiment No. 4 **Date:**

COMPACTION TESTS

Aim: To determine the water content dry density relationship for a given soil by **light compaction** test [IS version of standard proctor test] and hence to obtain optimum moisture content and maximum dry density for the given soil.

IS CODE:IS:2720 (Part 8)-1983

THEORY: Definition of Compaction: necessity of compacting the soil in the field.

Compaction is a process of packing the soil solids into a dense state by the application of external energy and thus achieving an increased dry density. **[or]**

Compaction refers to "a rapid reduction in the air voids of the soil mass under the application of a load for a short duration without any change in the water content of the soil mass." It can be achieved by different methods such as tamping, rolling or vibrating.

The effectiveness of the field compaction adopted during the construction of various geotechnical structures depends upon the knowledge of the compaction process, mechanism involved and the factors affecting the compaction process. Most of these information are obtained through laboratory compaction test. The results from these tests help during the quality control of field compaction works.

Standard proctor and modified proctor compaction tests:

[And their Indian Standard Versions]

Standard proctor and modified proctor compaction tests are belong to the dynamic compaction. The standard proctor [curve] test was developed by R.R. Proctor [1933] for the construction of earth fill dams in the state of California. In this test, the soil is compacted in the standard proctor mould in 3 layers each layer being given 25 blows of 2.6kg rammer dropped through a height of free fall of 310mm.

On the other hand, in order to achieve higher compaction for heavier transport and military aircraft the modified proctor test was developed to give a higher standard of compaction. This test was standardized by the American Association of state Highway Officials and is known as the modified AASHO test. In this test, the soil is compacted in the standard proctor mould, but in five layer being given 25 blows of 4.9kg rammer dropped through a height of free fall of 450mm.

Compaction Curves: Optimum Moisture Content:

A compaction curve is plotted between the water contents as abscissas and the corresponding dry densities a ordinates. The dry density goes on increasing as the water

Observations and Calculations:

1. Type of Soil:
2. Diameter of the mould = D =
3. Height of the mould = H =
4. Volume of the mould = V =
5. Mass of the rammer =
6. Free fall of the rammer =

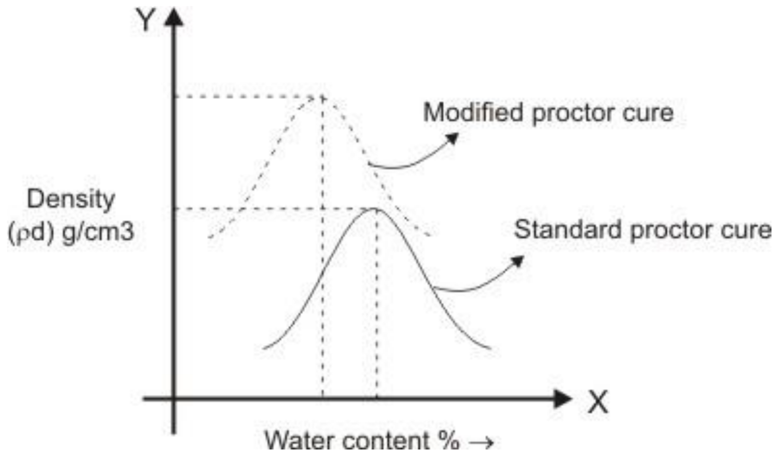
Standard Proctor Test:

[a] Determination of Bulk Density:										
Determination No.	**1**		**2**		**3**		**4**		**5**	
1. Mass of the [mould + compacted Soil] g										
2. Mass of mould g										
3. Mass of compacted soil [M] g										
4. Bulk density [ρ_b] g/cm^3										
[b] Determination of Water Content and Dry Density Of Soil:										
1. Container No.										
2. Mass of [Container + wet soil] g										
3. Mass of [container + dry soil] g										
4. Mass of water g										
5. Mass of container g										
6. Mass of the dry soil g										
7. Water content [w] ratio										
8. Dry density [ρ_d] g/cm^3										

Specimen Calculations:

1. Bulk density = ρ_b =Mass of wet soil/ volume of mould= $\frac{\mathbf{M}}{\mathbf{V}}$
2. Water content = W =Mass of water / Mass of dry soil
3. Dry Density = $\rho_d = \frac{\rho_b}{[1 + w]} =$

Content is increased, till maximum density reached. The water content corresponding to more density is called the optimum moisture content. The slope and shape of the compaction curve for the standard proctor and modified proctor test do not differ, but in the forms the maximum density achieves much slower compared to the later.



Maximum Dry Density: In the compaction test, the water content are increased gradually and the corresponding densities are calculated. The maximum density is then calculated from the graph or by just observation of the water content corresponding to it is the optimum water content.

The water content and the dry density (corresponding) are also calculated for all the trails. Then, a graph is plotted showing a line having the water content, dry density relation for the compacted soil containing a constant percentage air voids called air-voids line and this is established from the following relation

$$\rho_d = \frac{(1-\eta_a)G\rho_w}{1+wG}$$

Theoretically $(\eta_a = 0)$ maximum compaction for any given water content corresponds to zero air voids condition. The line showing the dry density as a function of water content for soil containing no air voids is called the zero air voids line or the saturation line.

$$\rho_d = \frac{G\rho_w}{1+wG}$$

Practically, maximum dry density corresponds to the minimum moisture content [∵ air void line]

To Plot ZAV Line:

$[W]_{ZAV}$ Ratio	2	4	6	8	10
$[\rho_d]_{ZAV}$ g/cm^3					

Specimen Calculation:

$$[\rho_d]_{ZAV} = \frac{G\rho_w}{\{1+(w)_{ZAV}G\}} =$$

OR

$[W]_{ZAV}$ Ratio						
$[\rho_d]_{ZAV}$ g/cm^3						

Line of Optimum:

When different graphs are drawn ie [dry density V/s moisture content] for different blows say 10, 15, 20, 25, ………….. etc., they will be having different shapes; however a line joining the maximum dry density of each graphs is called line of optimum.

Factors Affecting Compaction:

Water content, amount of compaction, methods of compaction, type of soil and the addition of admixtures.

Apparatus:

1. A cylindrical metal mould of capacity 1000cm^3, with an internal diameter of 100mm and an internal affective height of 127.3mm. The mould is fitted with a detachable base plate and a removable extension collar approximately 60mm high.
2. A metal rammer of 50mm diameter with a circular face and mass 206kg with a free fall of 310mm.
3. Steel straight edge about 30cm in length and with one beveled edge.
4. 4.75mm I.S. sieve.
5. Balance – (a) with a capacity of 10kg and accuracy of 1g.
   (b) With a capacity of 200g and accuracy of 1g.
6. Thermostatically controlled oven to maintain temperature b/n 105^{0}C to 110^{0}C.
7. Air tight and non-corrodible containers for water content determination.
8. Mixing tools like tray, trowel and spatula.

Procedure:

1. Measure the inner diameter and inner height of the cylindrical mould and hence, calculate the volume of the mould.
2. Take about 3kg of air dried soil passing through 4.75mm IS sieve and mix it with a suitable amount of water depending on the soil type [for sandy and gravelly soils, an initial moisture content of 4 to 6% and for cohesive soils, an initial moisture content of [wp – 10%] to [wp – 8%] would be suitable where wp is the plastic limit of the soil]. Keep the soil in a sealed container for saturation for a minimum period of about 16 hrs.
3. Clean the mould with the base plate and record its mass. Attach the collar to the mould. Place it on a solid base such as concrete floor.
4. Remix the soil thoroughly. Compact the moist soil in the mould, with the collar attached, in three equal layers, each layer being given 25 blows from a 2.6kg rammer

[a] Determination of Bulk Density:										
Determination No.	**1**		**2**		**3**		**4**		**5**	
1. Mass of the [mould + compacted Soil] g										
2. Mass of mould g										
3. Mass of compacted soil [M] g										
4. Bulk density [ρ_b] g/cm^3										
[b] Determination of Water Content and Dry Density Of Soil:										
1. Container No.										
2. Mass of [Container + wet soil] g										
3. Mass of [container + dry soil] g										
4. Mass of water g										
5. Mass of container g										
6. Mass of the dry soil g										
7. Water content [w] ratio										
8. Dry density [ρ_d] g/cm^3										

dropped from a height to 310mm above the soil surface. The surface of each layers of the compacted soil should be roughened with a spatula before laying the next layers. The final layer shall project not more than 6mm above the top of the mould after the collar is removed.

5. Remove the collar and level off the compacted soil surface to the top of the mould carefully. Then, record the mass of the mould with the base plate and compacted soil.
6. Remove the compacted soil specimen from the mould and place it on the mixing tray. Keep a representative soil sample of the specimen for water content determination.
7. Mix the remaining soil with the remainder of the original mixed soil in the tray. Add water at 2% increments to the soil sample and mix the soil thoroughly and repeat the above procedure.
8. Conduct a minimum of 5 determinations such that the optimum moisture content lies within this range.
9. Plot the light [standard proctor] compaction curve [w% along x-axis and ρ_d along y-axis] obtain OMC and ρ_{dmax} from the plotted curve. Plot also the ZAV line.

Results:

The optimum moisture content is _________

Maximum dry density is __________

AIM: To determine the water content dry density relationship for a given soil by **heavy compaction** test (IS version of modified proctor test) and hence, to obtain OMC and maximum dry density for the given soil.

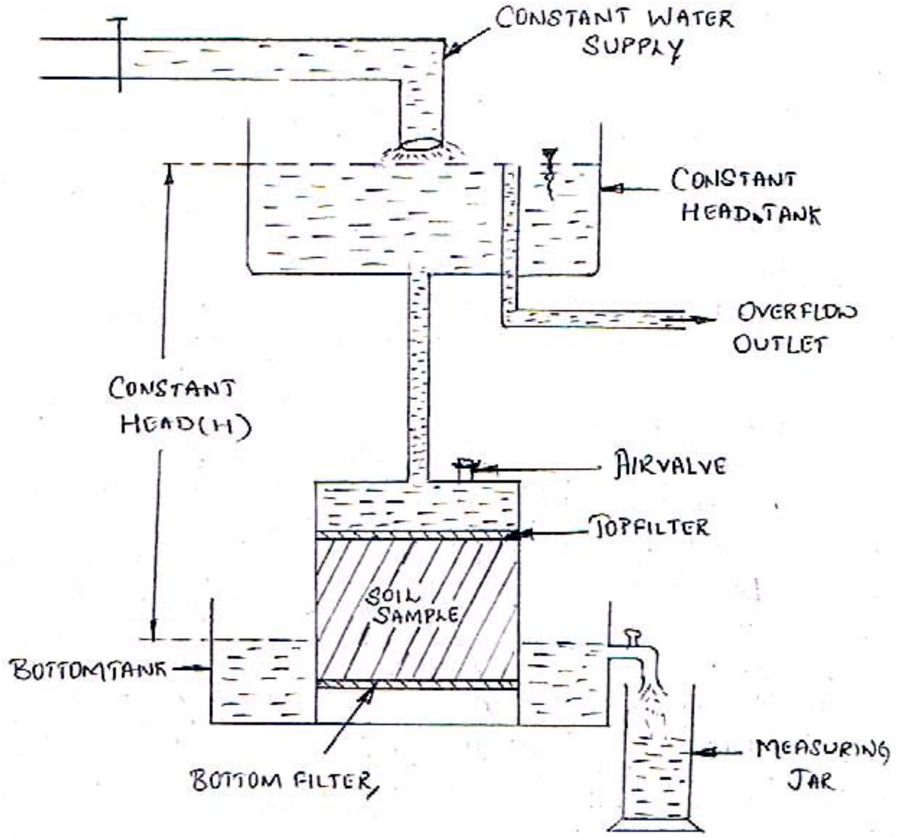
Apparatus: Same as standard proctor curve except (1) A metal rammer of 50mm diameter with a circular face and mass 4.9kg with a freefall of 450mm.

Procedure: Same as standard proctor test except

1. Remix the soil thoroughly. Compact the moist soil in the mould, with the collar attached, in five equal layers, each layer being given 25 blows form 4.9kg rammer dropped from a height to 450mm above the soil surface.
2. Plot the heavy [modified proctor] compaction curve [w% along x-axis and ρ_d along y-axis]. Obtain OMC and ρ_{dmax} from the plotted curve and also the ZAV line.

OBSERVATIONS AND CALCULATIONS:

[A] Constant Head Permeability Test:



Type of Soil: Red Soil

1. Constant hydraulic head H =
2. Length of the specimen L =
3. Hydraulic Gradient i= H/L =
4. Diameter of the specimen, D =
5. Cross sectional area of the specimen, A =
6. Time interval, t =
7. Quantity of flow, V :

   :

   :

   V_{avr} :
8. Test temperature, T =
9. Co-efficient of permeability, K =

Experiment No. 5 **Date:**

PERMEABILITY TESTS

[a] AIM: To determine the co-efficient of permeability of the given soil sample by constant head permeability test.

IS CODE:IS:2720 (Part 36)-1987

THEORY: Permeability:

Permeability of a soil is defined as the property of a soil which represents the ease with which a liquid flows through the interconnecting voids of the soil mass. The flow of liquid through the soil mass is also known as seepage.

Darcy's Law: Darcy, a French Engineer through a lot of experiments on flow through soil has proposed a law in the form,

q = KiA

Where, q = discharge through the soil mass.

I = hydraulic gradient

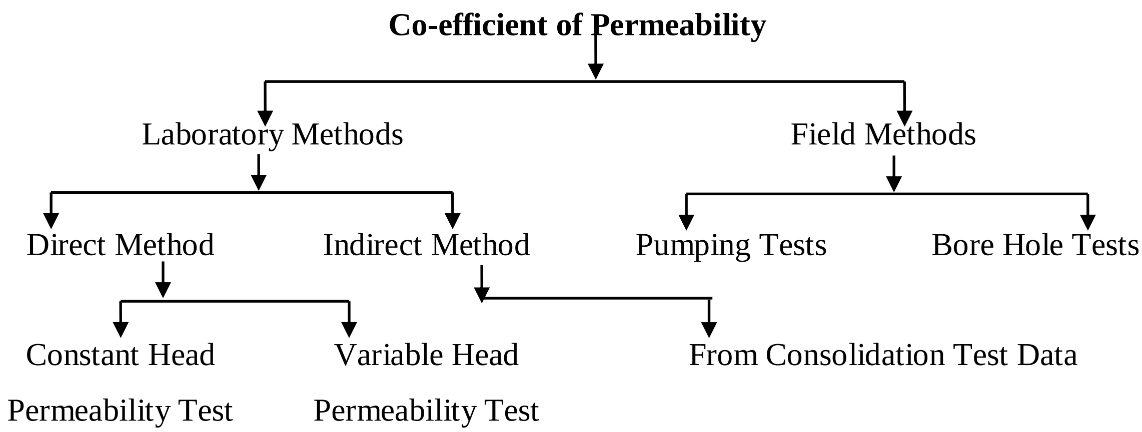
A = Total cross sectional area of soil mass perpendicular to the flow direction.

K = Co-efficient of permeability of the soil

[Dary's co-efficient of Permeability]

Darcy's law is valid only when the flow through the soil mass is laminar. Flow through the soil mass is considered laminar if Reynolds number of flow is less than or equal to one (1).

Co-efficient of Permeability: Following methods are available to determine the permeability of soil,



Specimen Calculations:

1. Co-efficient of permeability at test temperature,

2. Co-efficient of permeability at 27^0C, K_{27} =

Where, μ_T = Viscosity of water at test temperature =

μ_{27} = Viscosity of water at 27^0C =

Laboratory methods of determining co-efficient of Permeability:

In the laboratory, co-efficient of Permeability of soil can be determined with the help of Permeometers.

The test may be conducted on an undistributed soil sample or distributed soil sample. However even though the distributed remoulded soil sample in the laboratory can be seen to have same density and water content as in the field, they cannot reproduce all the condition, prevailing in the field and also the structures of the soil in the field. Hence, the value of 'K' obtained from laboratory testing don't represent the true field value. The value of 'K' can be obtained only by field testing and to some extent by conducting test in the lab on undisturbed sample. There are two methods, they are,

1. **Constant Head Permeability Test:**

   It consists of a mould in which the soil sample can be placed. There are filters at the top and bottom of the specimen. Water is supplied to the mould to pass through the soil sample from an overhead tank in which water level is maintained constant. After flowing through the soil sample water enters the bottom tank in which the mould is placed. The volume of water coming out of the mould can be measured with the help of a measuring jar. The difference in water levels in the overhead tank and the bottom tank is the head causing the flow through the soil sample of length 'L' and represents the constant head H. it can be calculated by the formula; $K = QL/HAt$

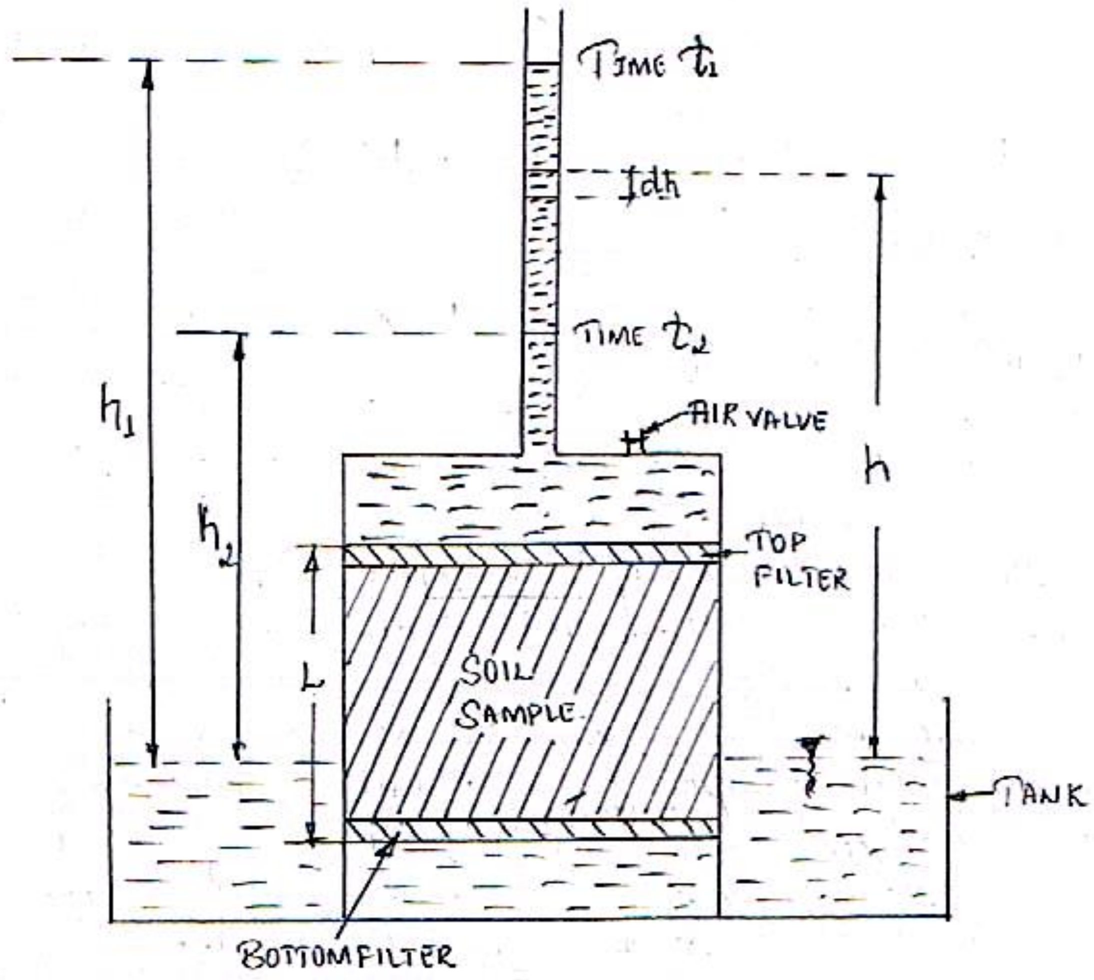
2. **Variable Head Permeability Test:**

   The variable or falling head permeability test is adopted for relatively less permeable soils like clays. This test is conducted in a falling head permeameter. This can be calculated through, $K = 2.303\ aL/At * Log_{10}(h_1/h_2)$

Apparatus:

1. Permemeter with all accessories.
2. De-aired water.
3. Balance, sensitive to 1g
4. Mixing pan
5. Stop watch.
6. Graduated measuring cylinder
7. Thermometer
8. Trimming knife
9. 4.75mm and 2mm IS sieves.

[b] Variable Head Permeability Test:IS:2720 (Part 17)-1986



Type of Soil : Red Soil

1. Diameter of the stand pipe = d =
2. Area of cross section of the stand pipe, a =
3. Diameter of the soil specimen = D =
4. Length of the soil specimen = L =
5. Area of c/s of the soil specimen = A =

Trial	h_1 ( )	h_2 ( )	Time t(s)
1.			
2.			
3.			

6. Average time interval = t_{av} =

Procedure:

1. Measure the inner diameter and inner height of permeameter, which are recorded as the diameter D and length L of the specimen.
2. Note down the temperature of water.
3. Place the permeameter assembly containing the soil specimen in the bottom tanks, and fill the tank with water up to its outlet.
4. Connect the outlet tube of constant head tank to the inlet nozzle of the permeameter. Remove the air-bubbles in the system, if any.
5. Maintain a constant water head in the constant head tank.
6. Once the discharge through the permeameter becomes steady. Collect the discharge of or the convenient time interval and measure the quantity of water collected.
7. Repeat the test thrice, with the same constant head and time interval.
8. Calculate the report value of co-efficient of permeability at T^0C and 27^0C.

Results: Constant Head Permeability

1. Co-efficient of permeability at test temperature,

   K_T =

2 Co-efficient of Permeability at 27^0 temperature,

   K_{27}=

Specimen Calculation:

1. Co-efficient of permeability at test temperature,

   K_T =

2. Co-efficient of permeability at 27^0C,

   $K_{27} = K_T \frac{\mu_T}{\mu_{27}}$ =

[b] AIM: To determine the co-efficient of permeability of the given soil sample by variable head permeability test.

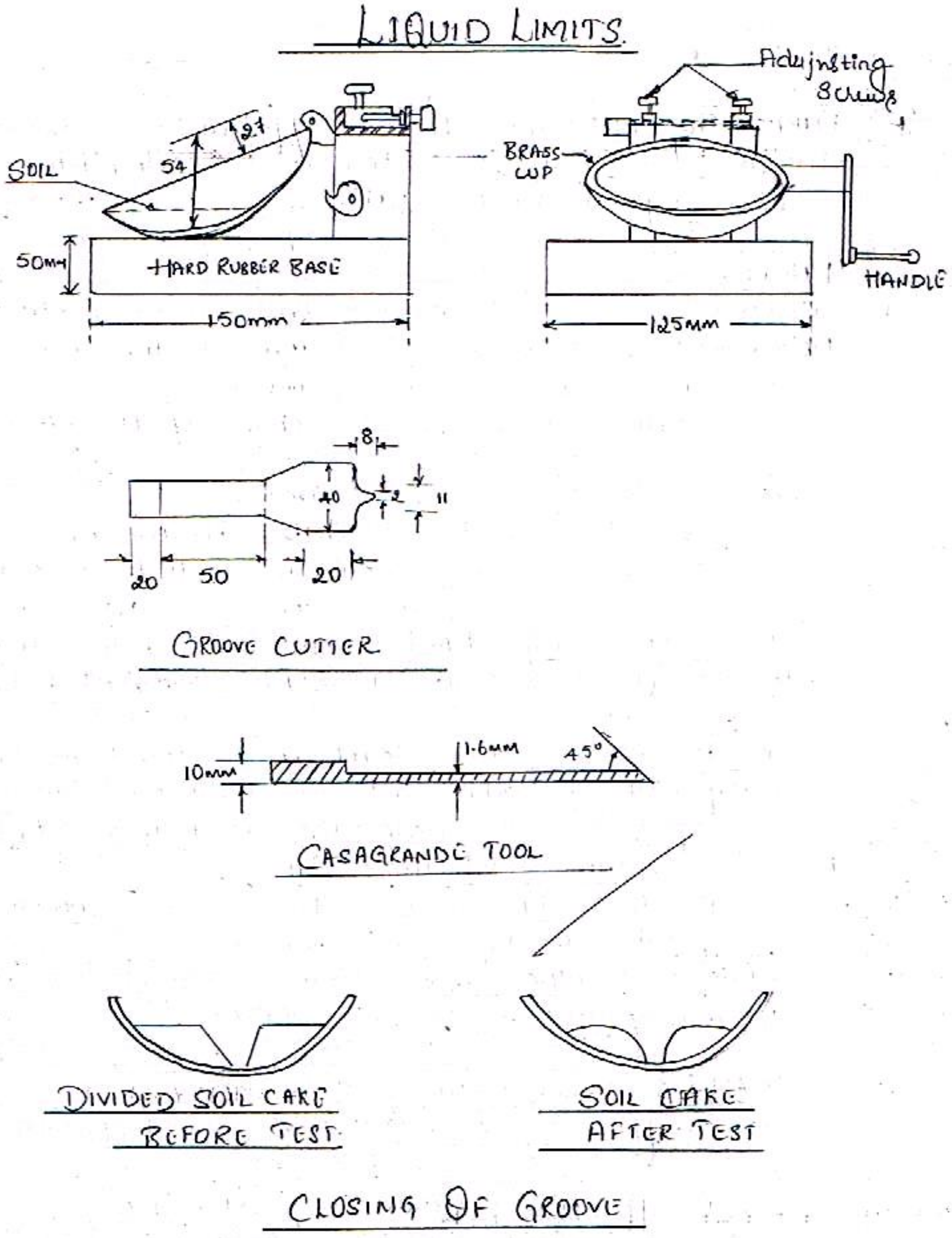
Procedure:

1. Measure the inner diameter and inner height of permeameter, which are recorded as the diameter D and length L of the specimen.
2. Measure the area of cross section of the stand pipe.
3. Note down the temperature of water.
4. Place the permeameter assembly in the bottom tank, and fill the tank with water up to its outlet.
5. Connect the water inlet nozzle of the mould to the stand pipe filled with water. Allow the water to flow for some time till steady state of flow is reached.
6. With the help of stop watch, none the time interval required for the water level in the stand pipe to fall from a convenient initial head (h_1) to the convenient final head (h_2).
7. Repeat the test thrice with the same initial and final heads.
8. Calculate and report the value of co-efficient of permeability at T^0C and 27^0C.

Results: Variable Head Permeability Test

1. Co-efficient of permeability at test temperature,
   K_T =
2. Co-efficient of Permeability at 27^0 temperature,
   K_{27} =

Liquid Limits



Experiment No. 6 **Date:**

ATTERBERG LIMITS OF FINE GRAINED SOIL

[a] AIM: To determine the liquid limit of the soil using casagrande liquid limit apparatus.
IS CODE: IS 2720(Part 5)-1985
THEORY:
Liquid Limit: It is the water content corresponding to the arbitrary limit between the liquid state and plastic state of the soil. It is the minimum water content at which the soil is still in the liquid state, but has a small shearing resistance against flowing which can be measured by standard means.
Plastic Limit [W_p]: Plastic limit is the water content corresponding to an arbitrary limit between the plastic state and semisolid state of consistency of a soil. It is defined as the minimum water content at which a soil will just begin to crumble when rolled into a thread approximately 3mm in diameter.
Shrinkage Limit [W_s]: Shrinkage limit is the maximum water content at which a reduction in water content will not cause a decrease in the volume of a soil mass. It is a lowest water content at which a soil can still be completely saturated.
Plasticity Index [I_p]: The range of consistency within which a soil exhibits plastic property is called plastic range and is indicated by plasticity index. It is the difference between the liquid limit and the plastic limit of a soil. i.e. $I_p = W_L – W_p$
Consistency Limit [I_c]: Consistency limit is defined as the ratio of the liquid limit minus the natural water content to the plasticity index of a soil. $I_c = W_L – W/I_p$.
Liquidity Index [IL]: it is expressed as a percentage of the natural water content of a soil [moisture] minus its plastic limit, to its plasticity index. ie $I_L = W – W_p/I_p$
Toughness Index [IT]: The toughness index is defined as the ratio of the plasticity index to the flow index. $I_T = I_p/I_f$.
Flow Index [If]: The flow index or the slope of the curve can be determined from the relation, $I_f = W_1\text{-}W_2/\log_{10}\left(\frac{n_2}{n_1}\right)$

The Atterberg limits are useful engineering purposes which are expressed in terms of water content.

Apparatus:

1. Casagrande liquid limit apparatus.
2. Casgrande grooving tool of standard dimensions (Type A).
3. Glass plate, 10mm thick and about 45cm square.
4. Spatula, balance, sensitive to 0.01g.
5. Thermostatically controlled oven.
6. Air tight and non-corrodible containers for moisture content determination.
7. Wash bottle containing distilled water.
8. 425 micron IS sieve.

Observation and Calculations:

Soil:

Determination number	**1**	**2**	**3**	**4**	**5**
Number of blows					
Container number					
Mass of container, g					
Mass of the [container + wet soil] g					
Mass of dry soil g					
Mass of water g					
Water content %					

From Flow Curve:

i. Liquid limit of the soil = W_L =

ii. Flow index = I_f =

$$\frac{(W_2 - W_1)}{\log_{10}\left(\frac{N_2}{N_1}\right)}$$

Procedure:

1. Using the gauge on the handle of the grooving tool or a separate gauge, adjust the height through which the cup of the casagrande apparatus is lifted and dropped so that the point on the cup which comes in contact with the base falls through exactly one centimeter for one revolution of the handle. Then, tighten the adjustment screws.
2. Take about 120g of soil sample, passing through 425μ IS sieve and mix it thoroughly with distilled water on the glass plate to form uniform paste. Allow sufficient time to ensure uniform moisture distribution throughout the soil mass.
3. Remix the soil thoroughly take a portion of the paste of soil with the spatula and place it in the center of the cup and spread it into position with the spatula so that the soil surface is parallel to the rubber base with the maximum depth of the soil as 1cm at the center.
4. With the help of the grooving tool, divide the paste in the cup along the diameter of the cup to get a clean, sharp groove of proper dimensions.
5. Turn the handle of the apparatus at a rate of 2 revolutions per second until the two parts of the soil paste come in contact at the bottom of the groove for a distance of about 12mm and record the number of revolutions to achieve this.
6. Collect a representative slice of the soil by moving the spatula normal to the groove, width wise from the portion of the groove in which the soil flowed together and put it in a container and keep that for moisture content determination.
7. Transfer the remaining soil in the cup back on to the glass place. Dried by kneading the wet soil using spatula.
8. Repeat the steps 3 to 6 to get a minimum of 5 trails. The trails are conducted such that the member of blows is in the range of 25$\pm$ 10.
9. Plot a flow curve on a semi-log shut with content on y-axis [arithmetic scale] and number of flows on x-axis [log scale]. Draw a well defined straight line through the points. Record the moisture content corresponding to 25 blows and round off to the nearest whole number and report it as the liquid limit of the soil. Measure the slope of the line which represents the flow index [I_f]

Results:

Liquid limit of the soil = W_L =

Flow index I_f =

Plastic Limit

Observations and calculations:

Determination Number	1	2
Container Number		
Mass of the [container + water]		
Mass of the [container + dry soil] g		
Mass of water g		
Mass of container g		
Mass of dry soil g		
Water content %		
Plastic limits = Wp %		

Calculations:

Plasticity Index $IP = W_L - W_P$

=

Toughness Index [IT] = $\frac{I_P}{I_f}$

[b] AIM: To determine the plastic limit of the soil sample and to calculate plasticity index, toughness index of the soil.

Apparatus:

1. Flat glass plate, 10mm thick and about 45cm square, spatula.
2. Balance, sensitive to 0.01g.
3. Thermostatically controlled oven.
4. Air tight and non-corrodible containers for moisture content determination.
5. Wash bottle containing distilled water.
6. 425 micron IS sieve.
7. 3mm diameter rod of about 10cm length.

Procedure:

1. Take about 20g of soil sample, passing 425 micron IS sieve. Mix it on the glass plate with sufficient water to make it plastic enough to be shaped into ball.
2. With about 8g of soil so prepared, make a ball and roll it on the glass plate with hand with pressure just sufficient to roll the mass into a thread of uniform diameter throughout its length. When the diameter of the thread reaches 3mm, kneed the soil together to a uniform mass and once again roll it. Continue the process until the soil thread just crumbles at 3mm diameter.
3. Collect the crumbled soil thread in a container and keep it for moisture content determination.
4. Repeat the test to have three trails.
5. Report the average water content rounded off to the nearest whole number as the plastic limit of the soil.

Result:

Plastic limit of the soil = W_p

Plastic Index = I_p

Toughness Index = I_T

Observations and Calculations:

1. Type of soil: ______________________
2. Initial dia of the specimen = D_o =
3. Initial length of the specimen = L_0 =
4. Initial area of the cross section of the specimen = A_0 = $\frac{\pi}{4}d^2$
5. After the test:

Specimen before failure.	Failure pattern	Sketch of the failed specimen

6. Plot the graph of axial stress Vs Axial strain

   From Graph:

   Unconfined compressive strength = qu =

Specimen Calculations:

Experiment No: 7 **Date:**

UNCONFINED COMPRESSION TEST

AIM: To determine the unconfined compressive strength of clayey soil.

IS Code: IS 2720 (Part 10)-1973

THEORY: Unconfined Compressive Strength:

The unconfined compressive strength is determined by the unconfined compressive test. It is generally applicable to saturated clays for which the apparent angle of shearing resistance ϕ is zero. It gives the value of σ .

The unconfined compression test is a special case of triaxial compression test in which σ_2 & σ_3 are zero. The cell pressure in the triaxial cell is also called the confining pressure. Due to the absence of such a confining pressure, the uniaxial test is called the unconfined compression test. Here the cylindrical specimen of soil is subjected to major principal stress [σ] till the specimen fails due to shearing along a critical plane of failure.

Its limitation is that it will give only one parameter value ie Cu or σ_1 [where $\frac{\sigma_1}{2} = Cu$] but not ϕ_u .

Apparatus:

1. Compression device of suitable type.
2. Sample ejector.
3. Deformation measuring dial gauge.
4. Remolding apparatus for specimen preparation.
5. Thermostatically controlled oven.
6. Balance with weights.
7. Vernier calipers.
8. Air tight, non-corrodible containers for water content determination.

Preparation of the Specimen:

The specimen for the test shall have a minimum diameter of 38mm and height to diameter ratio should be 2. The largest particle contained within the test specimen [preparation] should be smaller than 1/8 th the specimen diameter.The remoulded specimen may be prepared by compacting the soil at the considered water content and dry density in a bigger mould and then extracted using sampling tube.

OR

The remoulded specimen may be prepared directly using a split mould.

Specimen No: 1

Compression dial reading	Axial Compression of the specimen [Δ L]	Proving ring reading	Axial load (p) ratio	Axial strain (ε)	Corrected area (A)	Axial Stress (σ)	Remarks
Div	Cm	div	Kg	Ratio	Cm^2	Kg/cm^2	

Procedure:

1. Measure the initial length, diameter and mass of the specimen.
2. Place the specimen on the bottom plate of the loading device. Adjust the upper plate to make contact with the specimen. Set the load dial gauge [ie proving ring dial] and the compression dial gauge to zero.
3. Apply axial compressive load so as to produce axial strain at a rate of 0.5 to 2 percent per minute. Take the proving ring dial readings corresponding to compression dial readings at suitable intervals.
4. Compress the specimen until failure surfaces have definitely developed or the stress-strain curve is well past its peak or until an axial strain of 20% is reached, whichever occurs first.
5. Stock loading remove the failed specimen sketch the failure pattern, keep the soil sample taken from the failure zone for moisture content determination.

Results:

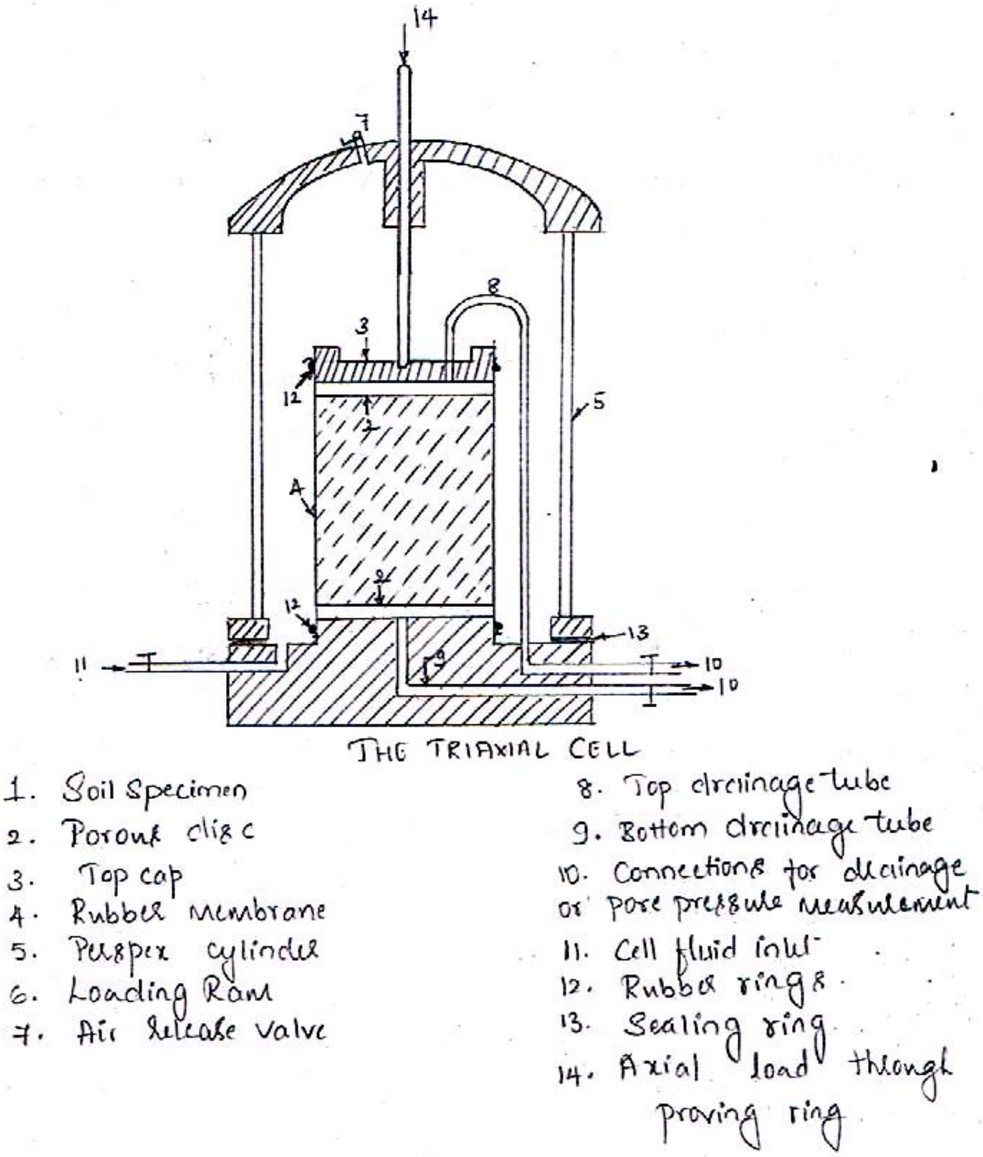
The Unconfined Compressive Strength [UCC Strength] = q_u

Results:

Specimen 1: qu =

Cu =

Unconsolidated, undrined triaxial compression test



Observations and Calculations:

1. Type of soil
2. Initial length of the specimen = Lo =
3. Initial diameter of the specimen = Do =
4. Area of cross section Ao =
5. Volume of specimen Vo =
6. Proving ring constant =
7. Rate of strain =

Experiment No: 8 **Date:**

Unconsolidated, undrained triaxial compression test

AIM: To determine the shear strength parameters of soil specimen by unconsolidated undrained triaxial compression test without the measurement of pore pressure.

IS Code: IS 2720 (part-11)-1978

THEORY: Shear Strength of Soil: (Components of Shear Strength)

When soil is loaded shearing stress are induced in it. The shear strength of soil is the resistance to deformation by continuous shear displacement of soil particles or on masses upon the action of a shear stress. The failure conditions for a soil may be expressed in terms of limiting shear stress called shear strength.

Components of shear strengths:

1. Structure resistance to displacement of the soil because of the interlocking of the particles.
2. The frictional resistance to translocation between the individual soil particles at their contact points and
3. Cohesion or adhesion between the surfaces of the soil particles.

Shear strength is defined as the maximum shear resistance developed by a given soil mass just before failure.

Pore Water Pressure: When the soil is loaded the water present in the pores exurt some pressure. This is termed as pore water pressure.

Total Stress: Total stress is the one which does not include pore water pressure whereas effective pressure takes into account of pore water pressure.

Where, c is cohesion, ϕ is angle of repose σ is normal stress, u is pore water pressure.

Shear strength parameters determined on the basis of effective stress is referred to as effective shear strength parameters and that determined on the basis of total stress is turned as total or apparent shear strength parameter.

Types of Shear Tests: Depending on drainage conditions during test, various shear tests are,

i. Drained test or slow test (c-test): In this the drainage is allowed from the specimen and hence consolidation.
ii. Undrained test or quick test(q – test): In this drainage from specimen is not allowed during test and hence consolidation does not take place.
iii. Consolidated quick test [c – test]: During this test consolidated in allowed to take place when the specimen carries only normal load.

Failure envelop is tangential to the Mohr’s circle at the instant of failure it is given by,

Where, c shear strength σ is normal stress at the instant of failure c and ϕ shear parameters of soil.

Specimen before failure	Failure Pattern	Sketch of the failed specimen

1. Cell pressure:

Compression dial reading DIV	Axial Compression of the Specimen cm	Proving Ring Reading DIV x 5	Axial Load [P] x	Axial Strain ε	Corrected Area (A) cm^2	Deviator stress (σd) kg/cm^2

Significance of shear strength of soils:

- To determine the safe bearing capacity of a foundation soil.
- To determine the stability of earth slope.
- To determine lateral earth pressure acting on a retaining wall.

Apparatus:

1. Triaxial cell with transparent chamber, capable of withstanding internal fluid pressure up to 10kg/cm^2, with all accessories.
2. Apparatus for applying and maintaining the desired fluid pressure within the cell, to an accuracy of 0.1kg/cm^2.
3. Compression machine capable of applying axial compression on the specimen at convenient speeds.
4. Dial gauge to measure axial compression.
5. Proving ring to measure the additional axial load.
6. Seamless rubber membranes.
7. Membrane stretches, rubber rings.
8. Air tight, non-corrodible containers for moisture content determination.
9. Balance with weights.
10. Apparatus for sample preparation such as split mould, trimming knife, wire saw, metal straight edge metal scale.
11. Thermostatically controlled oven.

Procedure:

1. Measure the length, diameter and the mass of the specimen accurately.
2. Cover the pedestal of the triaxial cell with a solid end cap or keep the drainage valve closed. Place the specimen on the soild end cap, on the pedestal of the triaxial cell and place the other end cap on the top of the specimen. Place a rubber membrane around the specimen using membrane stretches and seal the membrane to the end caps by means of rubber rings.
3. Assemble the cell, with the loading ram initially clear of the top of the specimen and place it in the loading machine.
4. Admit the operating fluid into the cell and bring its pressure to the desired value.
5. Adjust the loading machine such that the loading ram comes just in contact with the seat on the top of the specimen. Note the initial reading on the dial measuring axial compression [or adjust it to read zero]. Also adjust the proving ring dial reading to zero.
6. Apply a compressive force at a constant rate such that the failure occurs within a period of approximately 5 to 15 minutes. Note down the proving readings corresponding to known compression gauge readings. Continue the loading until the maximum value of the stress has passed [ie until the failure of the specimen is observed] or an axial strain of 20% has been reached, whichever occurs first.
7. Unload the specimen and drain off the cell fluid. Dismantle the cell and take out the specimen. Remove the rubber membrane and not down the mode of failure. Weigh the specimen and keep it for moisture content determination.
8. Repeat the test on three or more identical specimens under different cell pressures.

2. Cell pressure:

Compression dial reading DIV	Axial Compression of the Specimen cm	Proving Ring Reading DIV x __	Axial Load [P] x	Axial Strain ε	Corrected Area (A) cm^2	Deviator stress (σd) kg/cm^2

Specimen Preparation:

The specimens shall be in the form of right cylinders of cylinders of nominal diameter 38mm with a height to diameter ratio two.

a. Undistributed Specimens: The undistributed sample in a thin walled tube having the same internal diameter as that of the specimen required for testing is extruded out of the tube with the help of a sample extruder and pushed into a split mould. The ends of the specimen are trimmed flat and normal to its axis. Then the specimen is taken out of the split mould.

b. Remoulded Specimens: The remoulded specimens may be obtained by compacting the soil at required dry density and water content in a big size mould and then, may be extracted with the help of sampling tubes.

Results and Conclusions:

Results:

The shear strength parameters of the soil are

1) Cohesion intercept, C =
2) Angle of internal friction ϕ =

1. Cell Pressure:

Compression dial reading DIV	Axial Compression of the Specimen cm	Proving Ring Reading DIV x__	Axial Load [P] x 0.978/kg	Axial Strain ε	Corrected Area (A) cm^2	Deviator stress (σd) kg/cm^2

Plot a graph of deviator stress Vs axial strain to get deviator stress at failure.

Specimen Calculations:

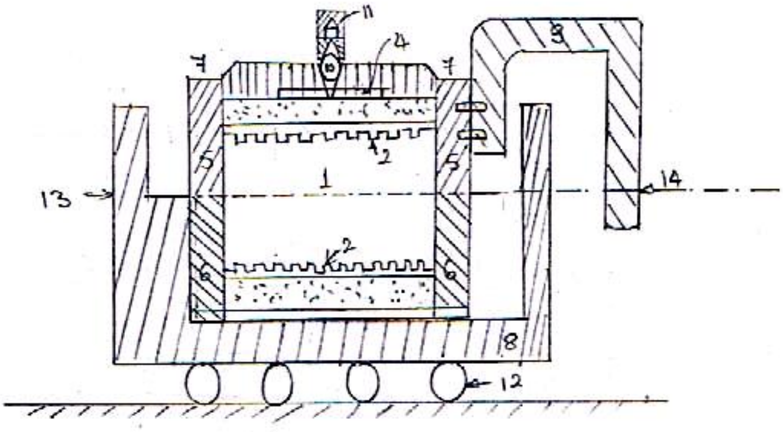
Axial load = P = proving Ring constant x proving ring reading

Axial strain = $\varepsilon = \frac{\Delta_L}{L_0}$ =

Axial stress = $\sigma = \frac{P}{A}$

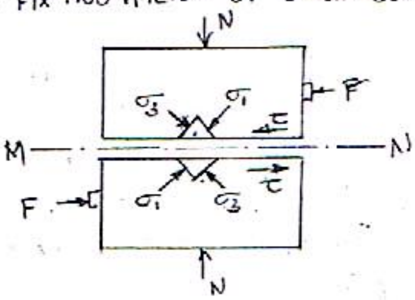
Test No.	Cell Pressure (σ_3) Kg/cm^2	Deviator stress at Failure (σ_d)f = ($\sigma_1 - \sigma_3$) kg/cm^2	σ_1 Kg/cm^2

DIRECT SHEAR TEST



PARTS OF DIRECT SHEAR BOX

1 SOIL SPECIMEN
2 METAL GRIDS
3 POROUS STONES
4 LOADING PAD
5 UPPER PART
6 LOWER PART
7 SCREWS TO FIX TWO HALVES OF SHEAR BOX
8. CONTAINER FOR SHEAR BOX
9. U- ARM
10. STEEL BALL
11. LOADING YOKE
12 ROLLERS
13. SHEAR FORCE APPLIED BY JACK
14. SHEAR RESISTANCE MEASURED BY PROVING RING



PRINCIPLE OF DIRECT SHEAR BOX

Observations and Calculations:

1. Type of Soil: Sand [Dry]
2. Area of the specimen: Ao =
3. Volume of the specimen: V =
4. Bulk density, ρ_b =
5. Proving Ring Constant =
6. Weight of Sand =
7. Moisture content = W =

Experiment No:9 **Date:**

DIRECT SHEAR TEST

AIM: To determine the shear strength parameters of a soil [ie, cohesion, intercept and angle of friction] by shear box test.

IS Code: IS 2720 (Part 39/Sec 1)-1971

THEORY: Direct Shear Test: Description: -

The apparatus consists of a two piece shear box of square or circular cross section of lower half of the box is rigidly held in a position. The upper half of the box bolts against a proving ring and thus the test is conducted.

Merits: The direct shear test is a simple test the relatively thin thickness of sample permits quick drainage and quick dissipation of pore pressure developed during the test.

Demerits:

1. The stress conditions across the soil sample are very complex. The distribution of normal stresses and shearing stress over the potential surface of sliding is not uniform. The stress is more at the center. Due to this there is progressive failure of the specimen.
2. As the test progresses, the area under shear gradually decreases.
3. Compared to the triaxial test, there is little control on the drainage of soil.
4. The plane of shear failure is predetermined which may not be the weakest one.
5. There is effect of lateral resist rained by the side walls.

Apparatus:

Shear box assembly consisting of

- Upper and lower parts of shear box coupled together with two pains or clamping screws.
- Container for shear box.
- Grid plates two pairs.
- Base place with cross grooves on its top which distribute the load over the specimen normal to shear plane.
- Loading frame & calibrated weights. Proving ring with dial gauge to measure shear force balance with weights. Spatula, straight edge, sample trimmer.

Preparation of the Specimen:

Remoulded Specimens: Cohesive soil may be compacted to the required density and moisture content in a separate mould. The sample is extracted and trimmed to the required size. **OR**

The soil may be compacted to the required density and moisture content directly into the shear box after fixing the two halves of the shear box together by means of fixing screws.

Non cohesive soil may be tamped in the shear box for required density with the base plate and the grid plate at the bottom of the box.

Procedure: [Untrained Test]

1. Measure the internal dimension of the shear box
2. Fix the upper part of the box to lower part using the locking screws. Attach the base plate to the lower part

Normal stress kg/cm^2	Displacement dial reading DIV	Displacement cm(δ)	Proving ring reading DIV	Shear force[p] kg	Corrected area [A]	Shear stress kg/cm^2

3. Place the grid plate in the shear box keeping the serrations of the grid at right angles to the direction of shear.
4. Place the soil specimen in the shear box and fix the loading pad on the box. Mount the box container on the loading frame
5. Bring the upper half of the box in contact with the proving ring.
6. Mount one dial gauge on the loading yoke to record the horizontal displacement
7. Place the weights on the loading yoke to apply a normal stress
8. Adjust the proving ring and the dial gauge to read zero
9. Apply the horizontal shear load and record the reading in the proving ring at a constant interval till the soil fails and the needle in the proving ring kicks back.

Normal stress kg/cm^2	Displacement dial reading DIV	Displacement cm (δ)	Proving ring reading DIV	Shear force[p] kg	Corrected area [A]	Shear stress kg/cm^2

Specimen Calculation:

1) Corrected area: A = Ao x (1 - δ /3)
2) Shear load = P = Proving ring constant x proving ring reading
3) Shear stress = C = $\frac{P}{A}$

Trial No	1	2	3	4	5
Normal stress Kg/cm^2					
Shear stress a + failure kg/cm^2					

At the end of the test remove the specimen from the box and determine its final water content [for cohesive soil only].

Repeat the test on identical specimens under different normal stresses [0.25 kg/cm^2, 0.5 kg/cm^2, 1, 1.5, 2, 2.5 kg/cm^2 etc].

Results:

1) Cohesion interrupt, C =
2) Angle of internal friction, ϕ =

Experiment No: 10 **Date:**

Liquid Limit of Soil

AIM: To determine the liquid limit of the soil using cone penetrometer.

Apparatus:

1) Cone penetrometer.
2) Marble plate or glass plate.
3) Spatula, balance & oven.
4) Containers for moisture content determination.
5) Wash bottle containing distilled water.
6) 425 micron IS service.

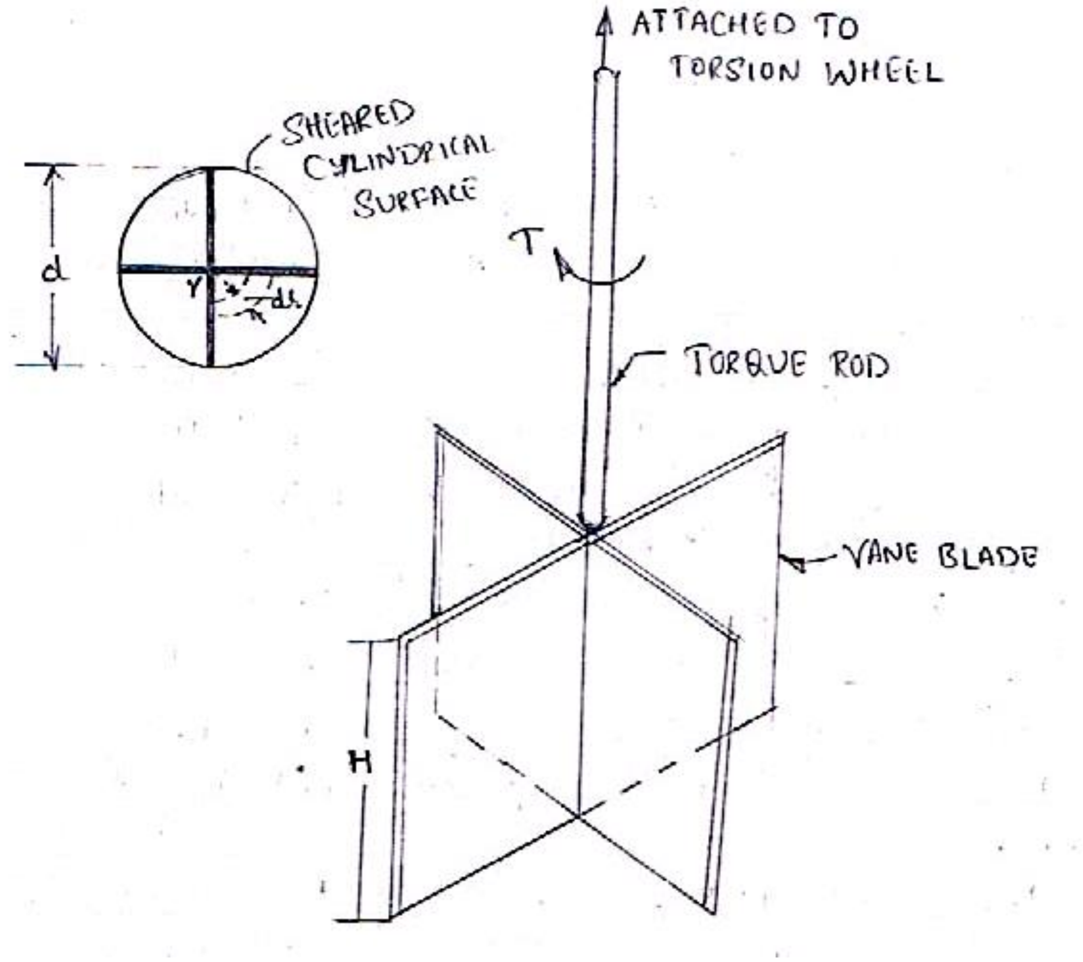
Procedure:

1. Take about 250g of soil sample, passing through 425 micron IS sieve and mix it thoroughly with distilled water on the glass plate to form uniform paste. Allow sufficient time for soaking of the soil so as to ensure uniform distribution of moisture throughout the soil mass.
2. Remix the soil thoroughly. Transfer the wet soil into the cylindrical cup of the cone penetrometer apparatus, ensuring that no air is entrapped within the soil mass during this process. The top surface of the wet soil mass is leveled off corresponding to the top of the cup.
3. Place the cup filled with soil on the base of the cone penetrometer apparatus. Adjust the penetrometer such that the cone point just touches the top surface of the soil in the cup. The initial reading of the meter jis adjusted to zero.
4. Release the cone allowing it to penetrate into the soil past under its own weight. The penetrometer reading shall be noted to nearest mm after five seconds.
5. Collect the representative sample of the soil from the cup for the moisture content determination and put it in a container and keep that for moisture content determination.
6. The test shall be done to have at least 4 to 5 sets of penetrometer values in the range 14mm – 28mm.
7. Plot a graph of water content on y-axis and cone penetration on x-axis. Draw the best fit straight line through the points plotted. The moisture content corresponding to a cone penetration of 20mm shall be taken as the liquid limit water content. Report the value to nearest first decimal place.

Result: The liquid limit of the given Red clay soil is (obtained from cone penetration method).

Reference: IS: 2720 (past 5) – 1985.

Laboratory Vane Shear Test



Vane Shear Tests

Observations and Calculations:

1. Diameter of the Vane = d =
2. Height of the Vane = H =
3. Spring constant = K =
4. Type of soil = Red Clayee soil.
5. Moisture content of the soil =
6. Initial reading of torque indicator = R_1 =
7. Final reading of torque indicator = R_2 =
8. Torque = T = $\left[\frac{(R_1 - R_2)K}{180}\right]$ =
9. Undrained shear strength = $\frac{T}{\pi d^2 \left[\frac{H}{2} + \frac{d}{6}\right]}$ =

Experiment No:11 **Date:**

Laboratory Vane Shear Test

AIM: To determine the undrained shear strength of a given cohesive soil using laboratory vane shear apparatus.

IS Code: IS 2720(Part 11)-1971

Apparatus:

1. Laboratory vane shears apparatus.
2. Marble plate or glass plate.
3. Spatula, balance, oven.
4. Containers for moisture content determination.
5. Wash bottle containing distilled water.
6. 425 micron IS sieve.

Procedure:

1. Mix the soil at known water content and transfer it into the test mould.
2. Mount the mould containing the soil specimen on the base of the vane shear apparatus and fix it securely to the base.
3. Lower the vanes into the specimen to their full length gradually with minimum disturbance to the specimen so that the top of the vane is at least 10mm below the top of the specimen and note down the initial reading of the torque indicator.
4. Rotate the vane at a uniform rate till the specimen fails. Note down the final reading of torque indicator.
5. Calculate the undrained shear strength of the given soil and report it.

Results:

Undrained shear strength of the given red clayey soil is

ADDITIONAL EXPERIMENTS

Following are the additional experiments included in the manual. These experiments are framed out of the prescribed VTU syllabus. The idea is to impart an essence of practicality into their learning.

Experiment 1: Determination of water content by pycnometer method

Objective of the above experiment is to make the students know, that there are more than one approach to determine the water content of a soil. The same experiment is done earlier in lab by oven drying method. By knowing the specific gravity of a soil, its water content is obtained by pycnometer method.

Experiment 2: Determination of void ratio

Objective: Now since students have learnt theoretical concept of void ratio, a question always raises about how to figure out the void ratio of soil? This experiment would stand as one of the answers for the question. Here student will learn to determine the void ratio practically.

Experiment 2: Determination of free swell index

Objective: Free swell or differential free swell, also termed as "free swell index", is the increase in volume of soil without any external constraint when subjected to submergence in water.

Observations

Sl No	Container No	Empty weight of container (W_1)	Weight of container + wet soil (W_2)	Weight of container + dry soil (W_3)	Water content (%)
1					
2					
3					
4					
5					

Calculations:

Water content: W= [{(W_2-W_1)/(W_3-W_4)*((G-1)/G)]}-1] * 100

Experiment No.:1 Date:…………………….

DETERMINATION OF WATER CONTENT BY PYCNOMETER

Aim: To determine the water content of the given soil by Pycnometer

IS Code: IS 2720 (Part 2) - 1973

Apparatus: Pycnometer

Procedure:

1. Clean the pycnometer and dry it. Find the mass (W1) of the pycnometer,
2. Put 200g to 400 g of wet soil sample in the pycnometer and find its mass (W2)
3. Fill the pycometer to half of its height and mix it thoroughly. Add water and stir it. Then fill the pycnometer to flush with the hole, find its mass (W3).
4. Empty the pycnometer, clean it thourougly and fill it with clean water, find its mass (W4)
5. Repeat the procedure for more trials

Results:

Sl No	Sample number	1	2	3
1.	Weight of container with lid (W_1) g			
2.	Weight of the container with lid + soil (W_2) g			
3.	Weight of the container with lid + soil + water (W_3) g			
4.	Void ratio $e = (W_3 - W_2)/(W_2 - W_1)$			

Result: Void ratio of the sample is __________

Experiment No: 2 Date:…………………….

DETERMINATION OF VOID RATIO

Aim: Determine the void ratio of the given soil sample.

Apparatus:

1. Air tight container
2. Weighing balance

Procedure:

1. Clean the container with dry cotton and make sure that there is no water present in it. Then take the weight of the container (W_1).
2. Collect some quantity of soil from the site and put it in a container, close it with the lid. Then take the total weight of the soil filled container (W_2).
3. Again take the container and remove the lid, take some pure distilled water and pour it to the soil filled container.
4. Then keep the container for some time so that the entire voids present in the soil get filled with water.
5. Close the lid of the container and again take the weight of the container (W_3).


Free Swell Index
Of Soil Test
IS - 2720 - 40

Experiment No.:3 Date:…………………….

DETERMINATION OF FREE SWELL INDEX OF SOIL

Aim: Determine the swell index of the given soil sample.

Apparatus:

1. 425 micron IS sieve.
2. Graduated glass cylinders 100 ml capacity 2Nos (IS: 878 -1956).
3. Glass rod for stirring.
4. Weighing balance

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 100ml capacity.
3. Fill one cylinder with kerosene and the other with the distilled water up to the100ml mark.
4. Remove the entrapped air in the cylinder by gentle shaking and stirring with a glass rod.
5. Allow the samples to settle in both the cylinders.
6. 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.
7. Record the final volume of the soils in each of the cylinders.

Specimen calculation:

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

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

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

REPORT:

1. Read the level of the soil in the kerosene graduated cylinder as the original volume of the soil samples, kerosene being non polar liquid does not cause swelling of the soil.
2. Read the level of the soil in the distilled water cylinders as free swell level.
3. Record the individual and the mean results to the nearest second decimal.

VIVA VOCE QUESTIONS

1. Define specific gravity
2. What should be the specific gravity of organic and inorganic soils
3. Differentiate cohesion and cohesion-less soil
4. What are the different methods to determine the water content of a soil
5. Define consistency limits, plasticity index , toughness index and flow index
6. Define coefficient of curvature and coefficient of uniformity and how is it obtained
7. How is the soil classified based on its gradations
8. Define different methods of grain size analysis
9. Why is the soil subjected to 105˚C to 110˚C
10. Define in-situ density of a soil and how is it obtained
11. Define permeability. What are the factors affecting permeability
12. What are the indirect method of determining permeability
13. Define compaction. Differentiate heavy and light compaction
14. What are the factors affecting compaction
15. What is the effect of compaction on soil
16. Differentiate compaction and consolidation
17. Define coefficient of consolidation
18. What is SBC
19. Define shear strength of a soil
20. Define shear parameters
21. How is UCS different from Triaxial test
22. Based on the drainage how is the shear strength tests are classified
23. Define pore water pressure
24. What is the energy applied in case of vane shear test
25. Define sensitivity of a soil
26. Differentiate disturbed and undisturbed samples
27. Define quick sand condition
28. What is thixotropy ?
29. Define porosity, voids ratio and relative density of a soil
30. Define CBR. What are its applications