ATRIA INSTITUTE OF TECHNOLOGY
Affiliated to VTU

LABORATORY MANUAL
18CVL57- GEOTECHNICAL ENGINEERING

20121-22

DEPARTMENT OF CIVIL ENGINEERING
ATRIA INSTITUTE OF TECHNOLOGY
Adjacent to Bangalore Baptist Hospital
Hebbal, Bengaluru-560024

TITLE OF THE COURSE: GEOTECHNICAL ENGINEERING LAB B.E., V Semester, Civil Engineering [As per Choice Based Credit System (CBCS) scheme]			
Course Code	**18CVL57**	**CIE Marks**	**40**
Number of Lecture Hours/Week	**03=(1 Hour Instruction + 2 Hours Laboratory)**	**SEE Marks**	**60**
Total Number of Hours	**40**	**Exam Hours**	**03**
RBT LEVEL L1,L2			
Credits – 02			

Course Objectives: 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

Modules

1. Visual soil classification. Water content determination by oven drying method and infrared moisture method. Specific gravity test (pycnometer and density bottle method).

2. Grain size analysis
   - i. Sieve analysis
   - ii. Hydrometer analysis

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. Shrinkage limit test

5. Standard compaction test (light and heavy compaction)

6. Co-efficient of permeability test
   - i. Constant head test
   - ii. Variable head test

7. Shear strength tests
   - i. Unconfined compression test
   - ii. Direct shear test
   - iii. Triaxial test (undrained unconsolidated)

8. Consolidation test : Determination of compression index and co- efficient of Consolidation

9. Laboratory vane shear test

10. Demonstration of Swell pressure test, Standard penetration test and boring Equipment

Course outcomes: Students will be able to conduct appropriate laboratory/field experiments and interpret the results to determine 1. Physical and index properties of the soil 2. Classify based on index properties and field identification 3. To determine OMC and MDD, plan and assess field compaction program 4. Shear strength and consolidation parameters to assess strength and deformation characteristics 5. In-situ shear strength characteristics (SPT- Demonstration)
Question paper pattern:

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EXPERIMENT 1

DETERMINATION OF SPECIFIC GRAVITY OF SOIL

AIM

To determine the specific gravity of soil fraction passing 4.75 mm I.S sieve by Pycnometer method.

NEED AND SCOPE

The knowledge of specific gravity is needed in calculation of soil properties like void ratio, degree of saturation etc.

DEFINITION

Specific gravity G is defined as the ratio of the weight of an equal volume of distilled water at that temperature both weights taken in air.

APPARATUS

1. Pycnometer
2. Balance to weigh the materials (accuracy 10gm).
3. Wash bottle with distilled water.
4. Alcohol and ether.

PROCEDURE

1. Clean and dry the pycnometer
    a. Wash the pycnometer with water and allow it to drain.
    b. Wash it with alcohol and drain it to remove water.
    c. Wash it with ether, to remove alcohol and drain ether.
2. Weigh the pycnometer (W1)
3. Take about 200 gm of oven-dried soil sample which is cooled in a desiccator. Transfer it to the pycnometer. Find the weight of the pycnometer and soil (W2).
4. Put 10ml of distilled water in the pycnometer to allow the soil to soak completely. Leave it for about 2 hours.
5. Again fill the pycnometer completely with distilled water put the stopper and keep the pycnometer under constant temperature water baths (Tx^0).
6. Take the pycnometer outside and wipe it clean and dry it. Now determine the weight of the pycnometer and the contents (W3).
7. Now empty the pycnometer and thoroughly clean it. Fill the pycnometer with only distilled water and weigh it. Let it be W4 at temperature (Tx^0 C).
8. Repeat the same process for 2 to 3 times, to take the average reading of it.

OBSERVATIONS

S. No.	Observation Number	1	2	3
1	Weight of pycnometer (W_1 g)			
2	Weight of pycnometer + dry soil (W_2 g)			
3	Weight of pycnometer + dry soil + water at temperature T_x ^{0}C (W_3 g)			
4	Weight of pycnometer + water at temperature T_x ^{0}C (W_4 g)			
5	Specific gravity G at T_x ^{0}C			

Average specific gravity at T_x ^{0}C

CALCULATIONS

$$\textit{Specific gravity of soil} = \frac{\text{Density of water at 27 C}}{\text{Weight of water of equal volume}}$$

$$= \frac{(W_2 - W_1)}{(W_4 - W_1) - (W_3 - W_2)}$$

$$= \frac{(W_2 - W_1)}{(W_2 - W_1) - (W_3 - W_4)}$$

RESULT

Specific Gravity of given soil =

INFERENCE

QUESTIONS

1. If entrapped air is not removed completely, how will it affect the value of specific gravity of solids?
2. Specify the range over which the average specific gravity of soil solids will lie.
3. How is specific gravity of solids for fine grained soil (Clay) found in laboratory?
4. Mention the practical application of specific gravity of soil solids.

EXPERIMENT 2

GRAIN SIZE DISTRIBUTION OF SOIL BY

I. SIEVE ANALYSIS

AIM

To determine the percentage of various size particles in a soil sample, and to classify the soil.

APPARATUS

i. 1st set of sieves of size 300 mm, 80 mm, 40 mm, 20 mm, 10 mm, and 4.75mm.

ii. 2nd set of sieves of sizes 2mm, 850 micron, 425 micron, 150 micron, and 75micron.

iii. Balances of 0.1 g sensitivity, along with weights and weight box.

iv. Brush.

THEORY

Soils having particle larger than 0.075mm size are termed as coarse grained soils. In these soils more than 50% of the total material by mass is larger 75 micron. Coarse grained soil may have boulder, cobble, gravel and sand.

The following particle classification names are given depending on the size of the particle:

i. BOULDER: particle size is more than 300mm.

ii. COBBLE: particle size in range 80mm to 300mm.

iii. GRAVEL (G): particle size in range 4.75mm to 80mm.

a. Coarse Gravel: 20 to 80mm.

b. Fine Gravel: 4.75mm to 20mm.

iv. SAND (S): particle size in range 0.075mm to 4.75mm.

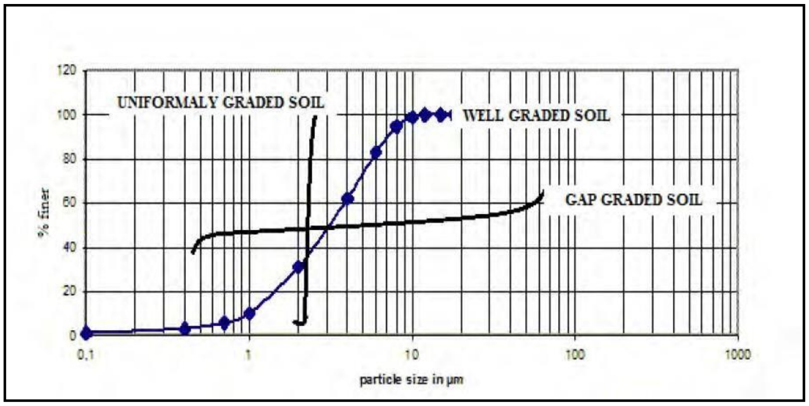
a. Coarse sand: 2.0mm to 4.75mm.

b. Medium Sand: 0.425mm to 2.0mm.

c. Fine Sand: 0.075mm to o.425mm.

Dry sieve is performed for cohesion less soils if fines are less than 5%. Wet sieve analysis is carried out if fines are more than 5% and of cohesive nature.

In simpler way the particle size distribution curve for coarse grain soil as follows,



Gravels and sands may be either poorly graded (Uniformly graded) or well graded depending on the value of coefficient of curvature and uniformity coefficient.

Coefficient of curvature (Cc) may be estimated as:

$$C_c = \frac{{D_{30}}^2}{D_{10} \times D_{60}}$$

Coefficient of curvature (Cc) should lie between 1 and 3 for well grade gravel and sand.

Uniformity coefficient (Cu) is given by:

$$C_u = \frac{D_{60}}{D_{10}}$$

Its value should be more than 4 for well graded gravel and more than 6 for well graded sand.

Were, D60 = particle size at 60% finer.

D30 = particle size at 30% finer.

D10 = particle size at 10% finer.

PROCEDURE:

i. Weight accurately about 200gms of oven dried soil sample. If the soil has a large fraction greater than 4.75mm size, then greater quantity of soil, that is, about 5.0 Kg should be taken. For soil containing some particle greater than 4.75 mm size, the weight of the soil sample for grain size analysis should be taken as 0.5 Kg to 1.0 Kg.

ii. Clean the sieves and pan with brush and weigh them upto 0.1 gm accuracy. Arrange the sieves in the increasing order of size from top to bottom. The first set shall consist of sieves of sizeWWW 300 mm, 80mm, 40mm, 20mm, 10mm, and 4.75 mm. While the second set shall consist of sieves of sizes 2mm, 850 micron, 425 micron, 150 micron, and 75 micron.

OBSERVATION AND CALCULATION TABLE:

Mass of soil Sample taken for Analysis =

Sieve size (mm)	Mass of soil Retained (gms)	% of soil retained (%)	Cumulative % of soil retained (%)	% of soil passing (%)

Coefficient of curvature (Cc) may be estimated as:

Uniformity coefficient (Cu) is given by:

iii. Keep the required quantity of soil sample on the top sieve and shake it with mechanical sieve shaker for about 5 to 10 minutes. Care should be taken to tightly fit the lid cover on the top sieve.

iv. After shaking the soil on the sieve shaker, weigh the soil retained on each sieve. The sum of the retained soil must tally with the original weight of soil taken.

PRECAUTIONS:

i. During shaking the lid on the topmost sieve should be kept tight to prevent escape of soils.

ii. While drying the soil, the temperature of the oven should not be more than 105^0C because higher temperature may cause some permanent change in the 75µ fraction.

RESULT:

1. The given soil is................................
2. Coefficient of curvature (Cc) =
3. Uniformity coefficient (Cu) =

Questions:

i. What do you understand by well graded, poorly graded and uniformly graded soils?

ii. What do you understand by dry sieve and wet sieve analysis? Which once did you perform and why?

iii. What is the grain size distribution curve? Why do you use a semi-long graph paper for plotting it?

iv. What do you understand by GW,GP,GM,GC,SW,SP,SM,SC,SW-SM,GP-SC?

II. HYDROMETER ANALYSIS

Aim: To determine percentage silt size and clay size fractions of the given soil by hydrometer analysis.

Theory: Sedimentation analysis: Principle and assumptions made; Hydrometer analysis; Calibration of hydrometer, corrections to hydrometer readings.

Apparatus

1. Three 1000 ml capacity measuring jars
2. Hydrometer
3. Mechanical stirrer
4. Balance
5. Dispersion agents- Sodium hexa meta phosphate and sodium carbonate
6. Thermostatically controlled hot air oven
7. Stop watch

Procedure

1. Calibrate the hydrometer to be used in the test.
2. Determine the meniscus correction.
3. Take about 50 g of oven dried soil sample passing 75 µ IS sieve.
4. Subject the soil to pre-treatment to remove soluble salts or organic matter or calcium compounds, if necessary.
5. Dissolve 3.3 g of sodium hexa meta phosphate and 0.7 g of sodium carbonate in 100 ml distilled water. Transfer the solution to 1000 ml capacity jar and add distilled water to make the volume of the solution to 1000 ml (This dispersion agent solution is required for getting the composite correction).
6. Take the measured quantity of soil in a beaker. Add 100 ml of solution prepared by dissolving 3.3 g of sodium hexa meta phosphate and 0.7 g of sodium carbonate in distilled water to the beaker.
7. Warm the soil suspension gently for about 10 minutes.
8. Transfer the soil suspension to the cup of a mechanical stirrer using about 100 ml of distilled water. Stir the suspension for about 15 minutes.
9. Transfer the stirred soil suspension to another 1000 ml capacity measuring jar. Add distilled water to the suspension to make its volume to 1000 ml.
10. Place suitable covers on the top of the two 1000 ml measuring jars – one containing the dispersion agent solution and the other containing the soil suspension. Shake the contents in the two jars vigorously and place them slowly on a level platform. Start a stop watch immediately.
11. Insert the hydrometer in to the jar containing the soil suspension slowly and allow it to float freely.

12. Note down the hydrometer readings corresponding to upper meniscus after suitable time intervals or note down the time intervals corresponding to well defined hydrometer readings.
13. After 4 minutes reading, take out the hydrometer from the jar, rinse it with distilled water and allow it to stand in another 1000 ml jar containing distilled water.
14. Insert the hydrometer in to the jar containing soil suspension from time to time and note down the hydrometer readings and corresponding time intervals. After removing the hydrometer from the jar each time, rinse it with distilled water and store it in the jar containing distilled water.
15. Record the temperature of the soil suspension and the composite correction in the beginning of the test and also after each time the hydrometer reading is taken beyond 15 minutes period

Note: Recording of composite correction: Insert the hydrometer in to the 1000 ml jar containing the dispersion agent solution; allow it to float freely; note down the hydrometer reading corresponding to upper meniscus. Record the negative of this reading as the composite correction.

16. Calculate the equivalent diameter of the soil particles corresponding to the noted time intervals (D) and also the corresponding values of percentage finer based on the dry mass of the soil sample taken for the test (N') and based on the total mass of the dry soil sample taken for the grain size analysis(N).
17. Carry out the test till the equivalent diameter of the particles is less than 2 µm.
18. Using the values of equivalent diameter of the particles (D) and the values of corresponding percentage finer (N), plot the grain size distribution curve. From the plotted curve, note down the percentage of silt size and clay size fractions present in the soil.

Results and Discussions:

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Specimen Calculations

1. $D = 17.487\sqrt{\frac{\mu}{(G\text{-}1)}}\sqrt{\frac{H_e}{t}}$ = --------------------------- mm

   Note: In the above equation, substitute H_e in cm, t in minutes and µ in kPa -s.

2. $N' = \frac{100\,G}{M_d(G-1)}R$ = %

3. $N = N' \times \frac{M'}{M}$ = --------------------------- %

Relevant BIS Code:

IS 2720-Part 4, 1985

Contd.....

Observations and Tabulation

1. Soil:
2. Mass of total dry soil taken for the analysis (M) g
3. Mass of the dry soil fraction passing 75 µ sieve (M') g
4. Mass of the dry soil sample taken for the test (M_d) g
5. Specific gravity of soil solids passing 75 µ sieve (G)
6. Hydrometer No.:
7. Meniscus correction (C_m)
8.

Date	Time	Elapsed time (t)	Hydrometer reading (R_h')	Temperature	Composite correction (C)	$R_h = R_h' + C_m$	Effective depth (H_R)	D	$R = R_h' + C$	% finer based on M'	% finer based on M
		Minutes		°C			cm	Mm			

EXPERIMENT 3

DETERMINATION OF FIELD DENSITY OF SOILS BY

I. CORE CUTTER METHOD

AIM

To determine the field or in-situ density or unit weight of soil by core cutter method

APPARATUS

a) Special:

i. Cylindrical core cutter

ii. Steel rammer

iii. Steel dolly

b) General:

i. Balance of capacity5 Kg and sensitivity 1 gm.

ii. Balance of capacity 200gms and sensitivity 0.01 gms.

iii. Scale

iv. Spade or pickaxe or crowbar

v. Trimming Knife

vi. Oven

vii. Water content containers

viii. Desiccator.

THEORY:

Field density is defined as weight of unit volume of soil present in site. That is

$$y = \frac{W}{V}$$

Where, γ= Density of soil, W = Total weight of soil, V = Total volume of soil

The soil weight consists of three phase system that is solids, water and air. The voids may be filled up with both water and air, or only with air, or only with water. Consequently the soil may be dry, saturated or partially saturated. In soils, mass of air is considered to be negligible, and therefore the saturated density is maximum, dry density is minimum and wet density is in between the two.Dry density of the soil is calculated by using equation,

$$y_d = \frac{y_b}{1 + w}$$

Where, γ_d=dry density of soil, γ_b=Wet density of soil,w = moisture content of soil.

PROCEDURE:

i. Measure the height and internal diameter of the core cutter.

ii. Weight the clean core cutter.

iii. Clean and level the ground where the density is to be determined.

iv. Press the cylindrical cutter into the soil to its full depth with the help of steel rammer.

v. Remove the soil around the cutter by spade.

vi. Lift up the cutter.

vii. Trim the top and bottom surfaces of the sample carefully.

viii. Clean the outside surface of the cutter.

ix. Weight the core cutter with the soil.

x. Remove the soil core from the cutter and take the representative sample in the water content containers to determine the moisture content

PRECAUTIONS:

i. Steel dolly should be placed on the top of the cutter before ramming it down into the ground.

ii. Core cutter should not be used for gravels, boulders or any hard ground.

iii. Before removing the cutter, soil should be removed around the cutter to minimize the disturbances.

iv. While lifting the cutter, no soil should drop down

RESULT:

a. Bulk Density of soil:

By Sand Replacement method =...................................

By Core Cutter Method =..

b. Dry Density of soil:

By Sand Replacement method =...................................

By Core Cutter Method =..

QUESTIONS

i. Out of wet density, dry density, and saturated density, which one of them is maximum and minimum? Explain.

ii. What are the main factors which affect in-situ density of soil? Explain.

iii. Beside the density what other properties do you need to calculate the void ratio and degree of saturation of soils?

iv. What are the other methods to calculate the field density of soil?

II. SAND REPLACEMENT METHOD

OBJECTIVE

Determine the in situ density of natural or compacted soils using sand pouring cylinders.

NEED AND SCOPE

The in situ density of natural soil is needed for the determination of bearing capacity of soils, for the purpose of stability analysis of slopes, for the determination of pressures on underlying strata for the calculation of settlement and the design of underground structures.

It is very quality control test, where compaction is required, in the cases like embankment and pavement construction.

APPARATUS REQUIRED

1. Sand pouring cylinder of 3 litre/16.5 litre capacity mounted above a pouring come and separated by a shutter cover plate.

2. Tools for excavating holes; suitable tools such as scraper tool to make a level surface.

3. Cylindrical calibrating container with an internal diameter of 100 mm/200 mm and an internal depth of 150 mm/250 mm fitted with a flange 50 mm/75 mm wide and about 5 mm surrounding the open end.

4. Balance to weigh unto an accuracy of 1g.

5. Metal containers to collect excavated soil.

6. Metal tray with 300 mm/450 mm square and 40 mm/50 mm deep with a 100 mm/200 mm diameter hole in the centre.

7. Glass plate about 450 mm/600 mm square and 10mm thick.

8. Clean, uniformly graded natural sand passing through 1.00 mm I.S. sieve and retained on the 600micron I.S. sieve. It shall be free from organic matter and shall have been oven dried and exposed to atmospheric humidity.

9. Suitable non-corrodible airtight containers.

10. Thermostatically controlled oven with interior on non-corroding material to maintain the temperature between 105^0C to 110^0C.

11. A dessicator with any desiccating agent other than sulphuric acid.

12. Metal containers

13. Sand pouring cylinder of 3 litre/16.5 litre capacity mounted above a pouring come and separated by a shutter cover plate.

14. Tools for excavating holes; suitable tools such as scraper tool to make a level surface.

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21. Suitable non-corrodible airtight containers.

22. Thermostatically controlled oven with interior on non-corroding material to maintain the temperature between 105^0C to 110^0C.

23. A dessicator with any desiccating agent other than sulphuric acid

OBSERVATIONS AND CALCULATIONS

S. No.	Sample Details Calibration	1	2	3
1	Weight of sand in cone (of pouring cylinder) W_2 gm			
2	Volume of calibrating container (V) in cc			
3	Weight of sand + cylinder before pouring W_3 gm			
4	Weight of sand + cylinder after pouring W_3 gm			
5	Weight of sand to fill calibrating containers $W_a = (W_1 - W_3 - W_2)$ gm			
6	Bulk density of sand $\gamma_s = W_a / V$ gm/cc			

S. No	Measurement of Soil Density	1	2	3
1	Weight of wet soil from hole W_w gm			
2	Weight of sand + cylinder before pouring W_1 gm			
3	Weight of sand + cylinder after pouring W_4 gm			
4	Weight of sand in hole $W_b = (W_1 - W_2 - W_4)$ gm			
5	Bulk density $\gamma b = (W_w / W_b) x\ \gamma_s$ gm/cc			
	Water content determination			
1	Container number			
2	Weight of wet soil			
3	Weight of dry soil			
4	Moisture content (%)			
5	Dry density $\gamma_d = \gamma_b / (1+w)$ gm/cc			

THEORY

By conducting this test it is possible to determine the field density of the soil. The moisture content is likely to vary from time and hence the field density also. So it is required to report the test result in terms of dry density. The relationship that can be established between the dry density with known moisture content is as follows:

PROCEDURE

Calibration of the Cylinder

1. Fill the sand pouring cylinder with clean sand so that the level of the sand in the cylinder is within about 10 mm from the top. Find out the initial weight of the cylinder plus sand (W_1) and this weight should be maintained constant throughout the test for which the calibration is used.

2. Allow the sand of volume equal to that of the calibrating container to run out of the cylinder by opening the shutter, close the shutter and place the cylinder on the glass sand takes place in the cylinder close the shutter and remove the cylinder carefully. Weigh the sand collected on the glass plate. Its weight (W_2) gives the weight of sand filling the cone portion of the sand pouring cylinder. Repeat this step at least three times and take the mean weight (W_2) Put the sand back into the sand pouring cylinder to have the same initial constant weight (W_1)

Determination of Bulk Density of Soil

3. Determine the volume (V) of the container be filling it with water to the brim. Check this volume by calculating from the measured internal dimensions of the container.

4. Place the sand poring cylinder centrally on the top of the calibrating container making sure that constant weight (W_1) is maintained. Open the shutter and permit the sand to run into the container. When no further movement of sand is seen close the shutter, remove the pouring cylinder and find its weight (W_3).

Determination of Dry Density of Soil in Place

5. Approximately 60 sq.cm of area of soil to be tested should be trimmed down to a level surface, approximately of the size of the container. Keep the metal tray on the level surface and excavate a circular hole of volume equal to that of the calibrating container. Collect all the excavated soil in the tray and find out the weight of the excavated soil (W_w). Remove the tray, and place the sand pouring cylinder filled to constant weight so that the base of the cylinder covers the hole concentrically. Open the shutter and permit the sand to run into the hole. Close the shutter when no further movement of the sand is seen. Remove the cylinder and determine its weight (W_3).

6. Keep a representative sample of the excavated sample of the soil for water content determination.

OBSERVATION AND CALCULATION TABLE:

Internal diameter of cutter (cm): _ _ _ _ _ _ _ _

Height of the cutter (cm): _ _ _ _ _ _ _ _

Cross sectional area of the cutter (cm^2): _ _ _ _ _ _ _ _

Volume of the cutter, V (cm^3): _ _ _ _ _ _ _ _ _

Calculation Table:

	sample 1	sample 2	sample 3
Mass of core cutter, W_1 (gm)			
Mass of cutter + soil from field, W_2 (gm)			
Wet density, (gm/cm3) $\gamma_t = \frac{W_2 - W_1}{V}$			
Dry density , (gm/cm3) $\gamma_d = \frac{\gamma_t}{1+w}$			

Water/Moisture content determination:

	sample 1	sample 2	sample 3
Weight of can, W_1 (g)			
Weight of can + wet soil W_2 (g)			
Weight of can + dry soil W_3 (g)			
Water/Moisture content $w\ (\%) = \frac{(W_2 - W_3)}{(W_3 - W_1)}\ x\ 100$			

EXPERIMENT 4

ATTERBERG LIMITS TEST

AIM:

To determine the liquid limit, plastic limit, shrinkage limit of the given soil sample.

THEORY:

The definitions of the consistency limits proposed by Atterberg are not, by themselves, adequate for the determination of their numerical values in the laboratory, especially in view of the arbitrary nature of these definitions. In view of this, Arthur Casagrande and others suggested more practical definitions with special reference to the laboratory devices and methods developed for the purpose of the determination of the consistency limits. In this sub-section, the laboratory methods for determination of the liquid limit, plastic limit, shrinkage limit, and other related concepts and indices will be studied, as standardized and accepted by the Indian Standard Institution and incorporated in the codes or practice.

APPARATUS:

1. Casagrande's liquid limit device and grooving tool
2. Spatula
3. Balance
4. Glass plate
5. Hot air oven maintained at 105 ± 1^{0}C
6. Moisture Containers

STANDARD REFERENCE:

FOR LIQUID LIMIT:

IS: 2720(Part V)–1985.

FOR PLASTIC LIMIT:

IS: 2720, Part V–1985.

TERMS:

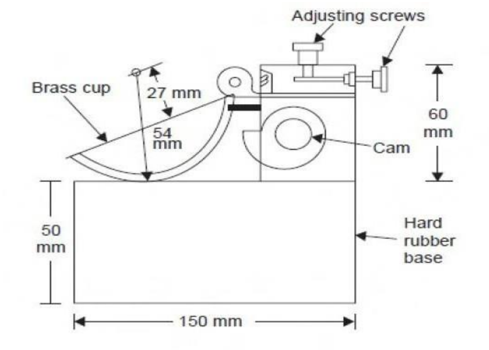
Shrinkage limit:

The shrinkage limit (SL) is the water content where further loss of moisture will not result in any more volume reduction. The shrinkage limit is much less commonly used than the liquid limit and the plastic limit.

Plastic limit:

The plastic limit (PL or w_P) is the water content where soil starts to exhibit plastic behaviour. A thread of soil is at its plastic limit when it is rolled to a diameter of 3 mm or begins to crumble.

To improve consistency, a 3 mm diameter rod is often used to gauge the thickness of the thread when conducting the test. (AKA Soil Snake Test).



Liquid limit device

Liquid limit:

Liquid limit (LL or w_L) is defined as the arbitrary limit of water content at which the soil is just about to pass from the plastic state into the liquid state. At this limit, the soil possesses a small value of shear strength, losing its ability to flow as a liquid. In other words, the liquid limit is the minimum moisture content at which the soil tends to flow as a liquid.

PLATICITY INDEX:

Plasticity index (PI or I_p) is the range of water content within which the soil exhibits plastic properties; that is, it is the difference between liquid and plastic limits.

PI (or I_p) = (LL - PL) = ($w_L - w_P$)

When the plastic limit cannot be determined, the material is said to be non-plastic (NP).

Plasticity index for sands is zero.

For proper evaluation of the plasticity properties of a soil, it has been found desirable to use both the liquid limit and the plasticity index values.

SHRINKAGE INDEX:

Shrinkage index (SI OR I_s) is defined as the difference between the plastic and shrinkage limits of a soil; in other words, it is the range of water content within which a soil is in a semisolid state of consistency.

$$\text{SI (or } I_S \text{) = (SL OR } I_S\text{) = } (W_p - W_S)$$

CONSISTENCY INDEX:

Consistency index or Relative consistency (CI OR I_C) is defined as the ratio of the difference between liquid limit and the natural water content to the plasticity index of a soil:

$$\text{CI OR } I_C = \text{(LL - w) / PI} = (w_L - w) / I_P$$

Where w = natural water content of the soil (water content of a soil in the undisturbed condition in the ground).

If I_C= 0, w = LL

I_C = 1, w = PL

I_C > 1, the soil is in semi-solid state and is stiff.

I_C < 0, the natural water content is greater than LL, and the soil behaves like a liquid.

LIQUIDITY INDEX:

Liquidity index (LI OR I_L) or Water-plasticity ratio is the ratio of the difference between the natural water content and the plastic limit to the plasticity index:

LI or (I_L) = (w - PL) / PI or (I_P) = (w - w_P) / I_p

If I_L = 0, w = PL

I_L= 1, w = LL

I_L> 1, the soil is in liquid state.

I_L< 0, the soil is in semi-solid state and is stiff.

Obviously, CI + LI = 1

PROCEDURE:

1. FOR DETERMINATION OF LIQUID LIMIT:

1. About 120 gm of air-dried soil from thoroughly mixed portion of material passing 425 micron I.S sieve is to be obtained.
2. Distilled water is mixed to the soil thus obtained in a mixing disc to form uniform paste. The paste shall have a consistency that would require 30 to 35 drops of cup to cause closer of standard groove for sufficient length.
3. A portion of the paste is placed in the cup of Casagrande apparatus and spread into portion with few strokes of spatula.
4. Trim it to a depth of 1cm at the point of maximum thickness and return excess of soil to the dish.
5. The soil in the cup shall be divided by the firm strokes of the grooving tool along the diameter through the centre line of the follower so that clean sharp groove of proper dimension is formed.
6. Lift and drop the cup by turning crank at the rate of two revolutions per second until the two halves of soil cake come in contact with each other for a length of about 1 cm by flow only.
7. The number of blows required to cause the groove close for about 1 cm shall be recorded.

8. A representative portion of soil is taken from the cup for water content determination.

9. Repeat the test with different moisture contents at least three more times for blows between 10 and 40.

Atterberg Limits Determination

Natural water content of given soil =

LIQUID LIMIT DETERMINATION

Can No.					
Mass of can (g)					
Mass of wet soil + can (g)					
Mass of dry soil + can (g)					
Mass of dry soil (g)					
Mass of water (g)					
Water content, (%)					
No. of drops					

Plastic Limit Determination

Can No.					
Mass of can (g)					
Mass of wet soil + can (g)					
Mass of dry soil + can (g)					
Mass of dry soil (g)					
Mass of water (g)					
Water content, (%)					

CALCULATIONS:

1. Plasticity index =

2. Shrinkage index =

3. Consistency index =

4. Liquidity index=

2. FOR DETERMINATION OF PLASTIC LIMIT:

1. Take about 20gm of thoroughly mixed portion of the material passing through 425 micron I.S. sieve obtained in accordance with I.S. 2720 (part 1).

2. Mix it thoroughly with distilled water in the evaporating dish till the soil mass becomes plastic enough to be easily moulded with fingers.

3. Allow it to season for sufficient time (for 24 hrs) to allow water to permeate throughout the soil mass

4. Take about 10gms of this plastic soil mass and roll it between fingers and glass plate with just sufficient pressure to roll the mass into a threaded of uniform diameter throughout its length. The rate of rolling shall be between 60 and 90 strokes per minute.

5. Continue rolling till you get a threaded of 3 mm diameter.

6. Kneed the soil together to a uniform mass and re-roll.

7. Continue the process until the thread crumbles when the diameter is 3 mm.

8. Collect the pieces of the crumbled thread in air tight container for moisture content determination.

9. Repeat the test to atleast 3 times and take the average of the results calculated to the nearest whole number.

3. **FOR DETERMINATION OF SHRINKAGE LIMIT**

Preparation of soil paste

1. Take about 100 gm of soil sample from a thoroughly mixed portion of the material passing through 425-micron I.S. sieve.

2. Place about 30 gm of the above soil sample in the evaporating dish and thoroughly mix it with distilled water and make a creamy paste. Use water content somewhere around the liquid limit.

Filling the shrinkage dish

3. Coat the inside of the shrinkage dish with a thin layer of Vaseline to prevent the soil sticking to the dish.

4. Fill the dish in three layers by placing approximately 1/3 rd of the amount of wet soil with the help of spatula. Tap the dish gently on a firm base until the soil flows over the edges and no apparent air bubbles exist. Repeat this process for 2nd and 3rd layers also till the dish is completely filled with the wet soil. Strike off the excess soil and make the top of the dish smooth. Wipe off all the soil adhering to the outside of the dish.

5. Weigh immediately, the dish with wet soil and record the weight.

Shrinkage Limit Determination

S.No	Determination No.	1	2	3
1	Wt. of container in gm,W_1			
2	Wt. of container + wet soil pat in gm,W_2			
3	Wt. of container + dry soil pat in gm,W_3			
4	Wt. of oven dry soil pat, W_0 in gm			
5	Wt. of water in gm			
6	Moisture content (%), W			
7	Volume of wet soil pat (V), in cm			
8	Volume of dry soil pat (V_0) in cm3			
9	By mercury displacement method a. Weight of displaced mercury b. Specific gravity of the mercury			
10	Shrinkage limit (WS)			
11	Shrinkage ratio (R)			

CALCULATION

First determine the moisture content

$$\text{Shrinkage limit (WS)} = \left(W - (V - V_0) \times \gamma_W / W_0\right) \times 100$$

Where, W = Moisture content of wet soil pat (%)

V = Volume of wet soil pat in cm3

V0 = Volume of dry soil pat in cm3

W0 = Weight of oven dry soil pat in gm.

6. Air-dry the wet soil cake for 6 to 8hrs, until the colour of the pat turns from dark to light. Then oven-dry the soil to constant weight at 105^0C to 110^0C say about 12 to 16 hrs.

7. Remove the dried disk of the soil from oven. Cool it in a desiccator. Then obtain the weight of the dish with dry sample.

8. Determine the weight of the empty dish and record.

9. Determine the volume of shrinkage dish which is evidently equal to volume of the wet soil as follows. Place the shrinkage dish in an evaporating dish and fill the dish with mercury till it overflows slightly. Press it with plain glass plate firmly on its top to remove excess mercury. Pour the mercury from the shrinkage dish into a measuring jar and find the volume of the shrinkage dish directly. Record this volume as the volume of the wet soil pat.

Volume of the Dry Soil Pat

10. Determine the volume of dry soil pat by removing the pat from the shrinkage dish and immersing it in the glass cup full of mercury in the following manner.

11. Place the glass cup in a larger one and fill the glass cup to overflowing with mercury. Remove the excess mercury by covering the cup with glass plate with prongs and pressing it. See that no air bubbles are entrapped. Wipe out the outside of the glass cup to remove the adhering mercury. Then, place it in another larger dish, which is, clean and empty carefully.

12. Place the dry soil pat on the mercury. It floats submerge it with the pronged glass plate which is again made flush with top of the cup. The mercury spills over into the larger plate. Pour the mercury that is displayed by the soil pat into the measuring jar and find the volume of the soil pat directly.

RESULT:

For given soil:

1. Liquid limit =
2. Plastic limit =
3. Plasticity index =
4. Shrinkage index =
5. Consistency index =
6. Liquidity index=
7. Shrinkage limit =

Questions:

1. What is liquid limit?
2. What is plastic limit?
3. What apparatus is used to measure the liquid limit of a given soil sample.
4. What number of blows is taken for consideration while determining the liquid limit of a given soil sample.
5. What is plasticity index?

EXPERIMENT 5

COMPACTION TESTS

A) Aim: To determine the water content – dry density relationship for a given soil by Indian Standard light compaction test and hence, to obtain optimum moisture content and maximum dry density for the given soil.

Theory: Definition of compaction; necessity of compacting the soil in the field; standard Proctor and modified Proctor compaction tests (and their Indian Standard versions); compaction curves; optimum moisture content and maximum dry density; zero air voids line; line of optimum; factors affecting compaction.

Apparatus

1. A cylindrical metal mould of capacity 1000 cm^3, with an internal diameter of 100 mm and an internal affective height of 127.3 mm. The mould is fitted with a detachable base plate and a removable extension collar approximately 60 mm high.
2. A metal rammer of 50 mm diameter with a circular face and mass 2.6 kg with a free fall of 310 mm.
3. A steel straight edge about 30 cm in length and with one beveled edge.
4. 4.75 mm I.S. sieve
5. Balance – (a) with a capacity of 10 kg and accuracy of 1 g
   (b) with a capacity of 200 g and accuracy of 0.01 g
6. Thermostatically controlled hot air oven.
7. Airtight 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. Compare them with standard values.
2. Take about 3 kg of air dried soil passing 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 (w_p-10)% to (w_p-8)% would be suitable, where w_p 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.

Contd......

4. Remix the soil thoroughly. Compact the moist soil in to the mould, with the collar attached, in three equal layers, each layer being given 25 blows from a 2.6 kg rammer dropped from a height to 310mm above the soil surface. The blows should be uniformly distributed over the surface of each layer. The surface of each layer of the compacted soil shall be roughened with a spatula before laying the next layers. The final layer shall project not more than 6 mm 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 reminder of the originally mixed soil in the tray. Add water in suitable 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 Indian Standard light compaction curve (w % along x-axis and ρ_d along y-axis). Obtain OMC and $\rho_{d\,max}$ from the plotted curve. Plot also the ZAV line.

Results and Discussions

--

Observations and Calculations

1. Type of soil:
2. Specific gravity of the soil:
3. Diameter of the mould (D) = -- cm
4. Height of the mould (H) = -- cm
5. Volume of the mould (V) = -- cm
6. Mass of the rammer = 2.6 kg
7. Free fall of the rammer = 310 mm

TABLE - I

Determination No.	1	2	3	4	5	6	7	8	9	10
(a) Determination of Bulk Density:										
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 the 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 $= \rho_b = \frac{\text{Mass of compacted wet soil}}{\text{Volume of the mould}} = \frac{M}{V} =$ ---------------------------- g/cm^3

2. Water content = w = $\frac{\text{Mass of water}}{\text{Mass of dry soil}}$ = ------------------------------- %

3. Dry density $= \rho_d = \frac{\rho_b}{(1+w)} =$ ---------------------------- ----- g/cm^3

To plot ZAV line

$(w)_{ZAV}$ Ratio						
$(\rho_d)_{ZAV}$ g/cm^3						

Specimen Calculation

$(\rho_d)_{ZAV} = \frac{G\rho_w}{\{1+(w)_{ZAV}G\}}$ = ------------------------------------ g/cm^3

Relevant BIS Code:

- IS: 2720, Part-7, 1980 (Reaffirmed 1987)
- IS: 9198, 1979 (Reaffirmed 1987)
- IS: 10074, 1982

Contd......

B) Aim: To determine the water content – dry density relationship for a given soil by Indian Standard heavy compaction test and hence, to obtain optimum moisture content and maximum dry density for the given soil.

Apparatus

1. A cylindrical metal mould of capacity 1000 cm^3, with an internal diameter of 100 mm and an internal affective height of 127.3 mm. The mould is fitted with a detachable base plate and a removable extension collar approximately 60 mm high.
2. A metal rammer of 50 mm diameter with a circular face and mass 4.9 kg with a free fall of 450 mm.
3. Steel straight edge about 30 cm in length and with one beveled edge.
4. 4.75 mm I.S. sieve
5. Balance – (a) with a capacity of 10 kg and accuracy of 1 g
   (b) with a capacity of 200 g and accuracy of 0.01 g
6. Thermostatically controlled hot air oven.
7. Airtight 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. Compare them with standard values.
2. Take about 3 kg of air dried soil passing 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 (w_p-10)% to (w_p-8)% would be suitable, where w_p 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 to the mould, with the collar attached, in five equal layers, each layer being given 25 blows from a 4.9 kg rammer dropped from a height to 450 mm above the soil surface. The blows should be uniformly distributed over the surface of each layer. The surface of each layer of the compacted soil shall be roughened with a spatula before laying the next layers. The final layer shall project not more than 6 mm 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 reminder of the originally mixed soil in the tray. Add water in suitable 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 Indian Standard heavy compaction curve (w % along x-axis and ρ_d along y-axis). Obtain OMC and $\rho_{d\,max}$ from the plotted curve. Plot also the ZAV line.

Results and Discussions

Observations and Calculations

1. Type of soil:
2. Specific gravity of the soil:
3. Diameter of the mould (D) = -- cm
4. Height of the mould (H) = -- cm
5. Volume of the mould (V) = -- cm
6. Mass of the rammer = 4.9 kg
7. Free fall of the rammer = 450 mm

TABLE - I

Determination No.	1	2	3	4	5	6	7	8	9	10
(a) Determination of Bulk Density:										
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 the 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 = $\rho_b = \frac{\text{Mass of compacted wet soil}}{\text{Volume of the mould}} = \frac{M}{V}$ = --------------------------- g/cm^3

2. Water content = w = $\frac{\text{Mass of water}}{\text{Mass of dry soil}}$ = --------------------------- %

3. Dry density = $= \rho_d = \frac{\rho_b}{(1+w)}$ = --------------------------- g/cm^3

To plot ZAV line

$(w)_{ZAV}$ Ratio						
$(\rho_d)_{ZAV}$ g/cm^3						

Specimen Calculation

$(\rho_d)_{ZAV} = \frac{G\rho}{\{1+(w)_{ZAV}{}^{w}\ G\}} =$ g/cm^3

Relevant BIS Code:

- IS: 2720, Part-8, 1983
- IS: 9198, 1979 (Reaffirmed 1987)
- IS: 10074, 1982

EXPERIMENT 6

PERMEABILITY TEST

AIM:

To determine the coefficient of permeability of a given soil sample by

i) Constant head method
ii) Variable head method

APPARATUS REQUIRED:

i) Permeameter with all accessories for constant head
ii) Compaction equipment
iii) Stop watch
iv) Balance
v) Measuring cylinder
vi) Scale

THEORY:-

Permeability is defined as the property of porous material which permits the passage or seepage of water through its interconnected voids. The coefficient of permeability is finding out following method.

a) Laboratory method:

i. Variable head test.

ii. Constant head test.

b) Field method:

i. Pumping out test.

ii. Pumping in test.

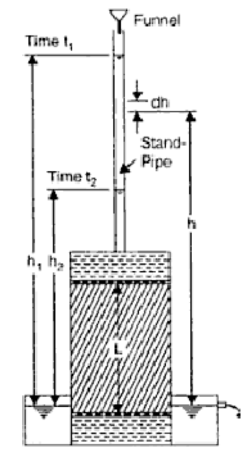
c) Indirect test:

i. Computation from grain size or specific surface.

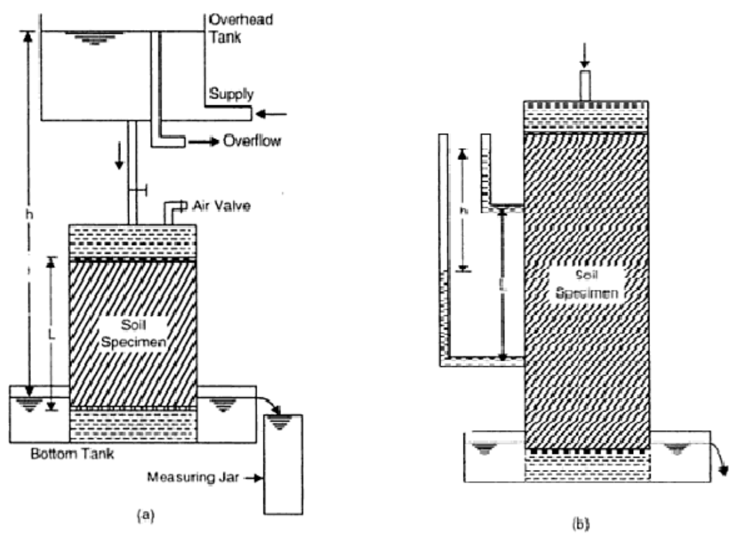
ii. Horizontal capillarity test.

iii. Consolidation test data.

The derivation of the coefficient of permeability is based on the assumption of the validity of the Darcy's law to the flow of water in soil. The term coefficient of permeability implies the velocity of flow of water through the soil under unit hydraulic gradient, and consequently has the same units as that of velocity.



FALLING HEAD TEST.



CONSTANT HEAD TEST.

A. Variable head test:

The variable head test is used for fine grained soils like silts and silty clays.

For the Variable head test the following formula is applicable:

$$k = 2.203 \frac{a * L}{A * t} log_{10} (\frac{h_1}{h_2})$$

Where, k = Coefficient of permeability at To C (cm/sec).

a = Cross Sectional area of stand pipe (cm^2).

L = Length of soil specimen (cm)

A = Cross-sectional area of soil sample inside the mould (cm^2)

t = ($t_1 – t_2$) = Time interval for the head to fall from h_1 to h_2.

h_1 = Initial head of water at time t_1 in the pipe, measured above the outlet.

h_2 = Final head of water at time t_2 in the pipe, measured above the outlet.

B. Constant head test:

The Constant head test is suitable for coarse grained soils like sands, sandy silts.

If Q is the total quantity of flow in a time interval t, we have from Darcy's law,

K = QL / (hAT)

Where, k = Coefficient of permeability at T^o C (cm/sec).

L = Length of soil specimen (cm)

A = Total cross-sectional area of soil sample (cm^2)

Q = Quantity of water collected in measuring jar.

t = total time required for collecting 'Q' quantity of water.

h = Difference in the water levels of the overhead and bottom tank.

APPLICATION:

Water flowing through soil exerts considerable seepage force which has direct effect on the safety of hydraulic structures.

The rate of settlement of compressible clay layer under load depends on its permeability. The quantity of water escaping through and beneath the earthen dam depends on the permeability of the embankments and its foundations respectively. The rate of discharge through wells and excavated foundation pits depends on the coefficient of permeability of the soils. Shear strength of soils also depends indirectly on its permeability, because dissipation of pore pressure is controlled by its permeability.

The table below gives rough values of the coefficient of permeability of various soils:

Type of soil	Value of permeability (cm/sec)
Gravel	10^3 to 1.0
Sand	1.0 to 10^{-3}
Silt	10^{-3} to 10^{-6}
Clay	less than 10^{-3}

According to U.S Bureau of Reclamations, soil are classified as follows:

Impervious	k less than 10^{-6} cm/sec
Semi-pervious	k between 10^{-6} to 10^{-4} cm/sec
Pervious	k greater than 10^{-4} cm/sec

PROCEDURE:

a) Preparation of remoulded soil specimen:

i. Weight the required quantity of oven dried soil sample. Evenly sprinkle the calculated quantity of water corresponding to the OMC. Mix the soil sample thoroughly.

ii. Clean the mould and apply a small portion of grease inside the mould and around the porous stones in the base plate. Weight the mould and attach the collar to it. Fix the mould on the compaction base plate. Keep the apparatus on solid base.

iii. The soil sample is placed inside the mould, and is compacted by the standard Proctor compaction tools, to achieve a dry density equal to the pre-determine3d MDD. Weight the mould along with the compacted soil.

iv. Saturate the porous stones. Place the filter papers on both ends of the soil specimen in the mould. Attach the mould with the drainage base and cap having saturated porous stones.

b) Saturation of soil specimen:

i. Connect the water reservoir to the outlet at the bottom of the mould and allow the water to flow in the soil. Wait till the water has been able to travel up and saturate the sample. Allow about 1 cm depth of free water to collect on the top of the sample.

ii. Fill the remaining portion of cylinder with de-aired water without disturbing the surface of soil.

iii. Fix the cover plate over the collar and tighten the nuts in the rods.

OBSERVATION AND CALCULATION TABLE FOR CONSTANT HEAD PERMIABILITY TEST:

S No	OBSERVATION	1	2	3
1	Diameter of stand pipe (cm) 'd'			
2	c/s area of stand pipe 'a = $\pi d^2/4$			
3	Diameter of cylindrical soil sample D			
4	c/s area of soil specimen 'A = $\pi D^2/4$			
5	Height of soil specimen, L			
6	Hydraulic head 'h' (cm)			
7	Time interval 't' (sec)			
8	Coefficient of permeability (cm/sec) $k = \frac{Q}{t} \frac{L}{h} \frac{1}{A}$			

Avg. Coefficient of permeability (cm/sec) = ____________

OBSERVATION AND CALCULATION TABLE FOR FALLING HEAD PERMIABILITY TEST:

Table 1:

Sr no.	Observation	1	2	3
1	Diameter of stand pipe (cm) 'd'	1.0	1.1	1.2
2	c/s area of stand pipe 'a = $\pi d^2/4$			
3	Diameter of cylindrical soil sample D			
4	c/s area of soil specimen 'A = $\pi D^2/4$			
5	Height of soil specimen, L			

Table 2:

Sr. No.	Initial Head (h_1) cm	Final Head (h_2) cm	Time required (t) sec	Permeability, $k = 2.203 \frac{a*L}{A*t} \log_{10}(\frac{h_1}{h_2})$
1				
2				
3				

c) Constant head test:

i. Place the mould assembly in the bottom tank and fill the bottom tank with water up to the outlet.

ii. Connect the outlet tube with constant head tank to the inlet nozzle of the permeameter, after removing the air in flexible rubber tubing connecting the tube.

iii. Adjust the hydraulic head by either adjusting the relative height of the permeameter mould and constant head tank or by raising or lowering the air intake tube with in the head tank.

iv. Start the stop watch and at the same time put a bucket under the outlet of the bottom tank, run the test for same convenient time interval and measure.

v. Repeat the test twice more, under the same head and for the same time interval.

d) Variable head permeability test method:

i. Disconnect the water reservoir from the outlet at the bottom and connect the stand pipe to the inlet at the top plate.

ii. Fill the stand pipe with water. Open the stop cock at the top and allow water to flow out so that all the air in the cylinder is removed.

iii. Fix the height h1 and h2 on the stand pipe from the centre of the outlet such that (h1 – h2) is about 30 cm to 40 cm.

iv. When all the air has escaped, close the stop clock and allow the water from the pipe to flow through the soil and establish a steady flow.

v. Record the time interval, t, for the head to drop from h1 to h2.

vi. Take about five such observations by changing the values of h1 and h2.

vii. Measure the temperature of water.

RESULTS

Coefficient of permeability of given soil

By Constant head method =................................
By Variable head method =.................................

QUESTIONS

i. What is Darcy's law of flow velocity through soils? What are its Limitations?
ii. What are the steady and unsteady flows of water? What type of flow is assumed to occur in soils?
iii. What are the laboratory methods of determination of coefficient of permeability of soil? State their suitability.
iv. What is the effect of entrapped air on the coefficient of permeability of soil?

EXPERIMENT 7

SHEAR STRENGTH TEST

I. DIRECT SHEAR TEST

Aim: To determine the shear strength parameters of a soil (i.e. Cohesion intercept and angle of internal friction) by direct shear test.

Theory: Direct shear test – description, merits and limitations.

Apparatus

1. Shear box assembly consisting of
   - Upper and lower parts of shear box coupled together with two pins or clamping screws.
   - Container for shear box
   - Grid plates – two pairs
   - Base plate with cross grooves on its top face to fit into the shear box.
   - Loading pad with a steel ball on its top which distributes the load over the specimen, normal to the shear plane.
2. Loading frame
3. Calibrated weights
4. Proving ring with dial gauge to measure shear force
5. Balance with weights.
6. Dial gauge
7. Spatula, straight edge, sample trimmer.

Preparation of the specimen

Remoulded specimens: Cohesive soils 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 soils 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: (Undrained Test)

1. Assemble the shear box with the base plate at the bottom and a grid plate over it, the two halves of the box being connected by the locking screws. The serrations of the grid plate should be at right angles to the direction of shear.
2. Place the specimen over the bottom grid plate. Place another grid plate at the top of the specimen such that the serrations of the plate or in contact with the specimen and at right angles to the direction of shear. Place the loading pad on the top of the grid plate.

Contd......

3. Place the shear box inside the container of the shear box. The container can move over roller supports at its bottom.
4. Set the lower part of the shear box to bear against the load jack, the upper part of the box against the proving ring. Set the gauge of the proving ring to read zero.
5. Apply the required normal stress on the specimen inside the shear box through a lever arrangement.
6. Remove the locking screws or pins so that both the parts of the shear box are free to move relative to each other.
7. Conduct the test by applying a horizontal shear load to failure or to 20% longitudinal displacement, whichever occurs first. Take the proving ring dial readings corresponding to known displacement dial readings.
8. At the end of the test, remove the specimen from the box and determine its final water content (for cohesive soil only).
9. Repeat the test on identical specimens, under different normal stresses (0.25 kgf/cm^2, kgf/cm^2, 1 kgf/cm^2, 1.5 kgf/cm^2, 2 kgf/cm^2, and 2.5 kgf/cm^2 etc.). A minimum of three (preferably four) tests shall be made on separate specimens of the same density.

Results and Discussions:

Observations and Calculations

1. Type of soil:
2. Are of the specimen (A_o) = ---------------------------------- cm^2
3. Volume of the specimen (V) = ---------------------------------- cm^3
4. Bulk density (ρ_b) = ---------------------------------- g/cm^3
5. Moisture content (w) = -------------------------------- %
6. Rate of strain = --------------------------------
7. Proving ring constant = ----------------------------------
8.

Trial No.	Normal stress (σ) kgf/cm^2	Displacement dial reading Div.	Displacement (δ) cm	Corrected Area (A)	Proving ring reading Div.	Shear force (P) kgf	Shear Stress (τ) kgf/cm^2
1.							

Corrected area = A = A_o x $(1 – \delta / 3)$ = -- cm^2

Shear load = P = Proving ring reading x Proving ring constant = -------------------- kgf

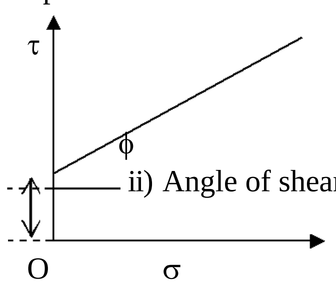
Shear stress = τ = P/A = ...

* Conduct the test for different normal stresses (at least four normal stresses). For each test, plot shear stress vs displacement curve to obtain maximum shear stress at failure.

9.

Trial No.				
Normal stress (σ) kg/cm^2				
Shear stress at failure (τ_f) kgf/cm^2				

Plot the graph of normal stress (x – axis) vs. maximum shear stress (y-axis). Adopt same scale to plot both normal stress and maximum shear stress.



i) Cohesion intercept = c =................ kgf/cm_2

ii) Angle of shearing resistance = ϕ = c

Relevant BIS Code:

IS: 2720, Part-13, 1986

II. UNCONFIED COMPRESSION TEST

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

Theory: Unconfined compressive strength; UCC test and its limitations.

Apparatus

1. Compression device of suitable type
2. Sample ejector
3. Deformation measuring dial gauge
4. Remoulding apparatus – for specimen preparation
5. Thermostatically controlled oven
6. Balance with weights
7. Vernier callipers.
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 38 mm and a height to diameter ratio of 2. The largest particle contained within the test specimen 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.

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 (i.e. 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. Stop loading; Remove the failed specimen; Sketch the failure pattern; Keep the soil sample taken from the failure zone for moisture content determination.

Results and Discussions:

--

Contd......

Observations and Calculations

1. Type of soil:
2. Specimen preparation procedure: Undisturbed / remoulded / compacted
3. Initial dia of the specimen (D_0) =.. cm.
4. Initial length of the specimen (L_0) =.. cm
5. Initial area of the cross section of the specimen

   (A_0) =.. cm^2
6. Rate of strain = ……………………………………
7. Water content determination (initial)

Container No.		**1**	**2**
Mass of (container + wet soil)	g		
Mass of (container + dry soil)	g		
Mass of dry soil	g		
Mass of container	g		
Mass of water	g		
Water content (w_i)	%		

8.

Specimen No.	**Initial mass (m), G**	**ρ_b, g/cm^3**	**(w_i), %**	**ρ_d, g/cm^3**
1.				
2.				
3.				

9.

Specimen No.:

Compression dial reading	**Axial compression of the specimen (ΔL)**	**Proving ring reading**	**Axial load (P)**	**Axial Strain (ε)**	**Corrected area (A)**	**Axial stress (σ)**	**Remarks**
div	Cm	div	kgf	Ratio	cm^2	kgf/cm^2	

Conduct tests on three identical specimens.

10. After the test:

Specimen No.	Failure Pattern	Sketch of the failed specimen
1.		
2.		
3.		

11. Water content determination (final)

Container No.		**1**	**2**	**3**
Mass of (container + wet soil)	g			
Mass of (container + dry soil)	g			
Mass of dry soil	g			
Mass of container	g			
Mass of water	g			
Water content	%			

12. Plot the graph of axial stress Vs. Axial strain.
From the graph:

Unconfined compressive strength = q_u =… .... kgf/cm^2

SPECIMEN CALCUALTIONS:

- Axial load (P)= Proving ring constant x proving ring reading = ... kgf
- Axial strain (ε) = $\Delta L/L_o$ = ……………………………………
- Corrected area (A) = $A_o/(1 - \varepsilon)$ = ... cm^2
- Axial stress (σ) = P/A =.. kgf/cm^2

Relevant BIS Code:
IS: 2720, Part-10, 1973

III. UNCONSOLIDATED, UNDRAINED TRIAXIAL COMPRESSION TEST

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

Theory: Shear strength of soil; Components of shear strength; Total stress, Pore water pressure and Effective stress; Types of shear tests; Total and effective stress shear strength parameters; Conventional failure envelope; Modified failure envelope; Significance of shear strength of soils.

Apparatus

1. Triaxial cell with transparent chamber, capable of with-standing internal fluid pressure up to 10 kgf/cm^2 (i.e., 100 kPa), with all accessories.
2. Apparatus for applying and maintaining the desired fluid pressure within the cell, to an accuracy of 0.1 kgf/cm^2 (i.e., 10 kPa).
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 stretcher
8. Rubber rings.
9. Air tight, non-corrodible containers for moisture content determination.
10. Balance with weights.
11. Apparatus for sample preparation such as split mould, trimming knife, wire saw, metal straight edge, metal scale etc.
12. Thermostatically controlled hot air oven.

Sample Preparation

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

(a) Undisturbed Specimens

The undisturbed sample in a thin walled tube having the same internal diameter as that of the specimen required for testing shall be extruded out of the tube with the help of a sample extruder and pushed into a split mould. The ends of the specimen shall be trimmed flat and normal to its axis. Then, the specimen shall be 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.

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 solid 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 stretcher 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 on 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 an axial compressive force at a constant rate such that the failure occurs within a period of approximately 5 to 15 minutes. Note down the proving ring readings corresponding to known compression gauge readings. Continue the loading until the maximum value of the stress has passed (i.e. 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 note 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.

Results and Discussions:

Observations and Calculations

1. Type of soil:
2. Specimen preparation procedure: Undisturbed / remoulded / compacted
3. Initial length of the specimen (L_0) = ... cm
4. Initial diameter of the specimen (D_0) = ………………………………
5. Area of cross section (A_0) = ... cm^2
6. Volume of specimen (V_0) = ... cm^3
7. Proving ring constant = …………………………………
8. Rate of strain = ……………………………………

Contd......

9. Water content determination (initial)

Container No.		1	2
Mass of (container + wet soil)	g		
Mass of (container + dry soil)	g		
Mass of dry soil	g		
Mass of container	g		
Mass of water	g		
Water content (w_i)	%		

10.

Specimen No.	**Initial mass (m), G**	**ρ_b, g/cm^3**	**(w_i), %**	**ρ_d, g/cm^3**
1.				
2.				
3.				

11. Cell pressure:

Compression dial reading	**Axial compression of the specimen (ΔL)**	**Proving ring reading**	**Axial Load (P)**	**Axial Strain (ε)**	**Corrected area (A)**	**Deviator stress (σ_d)**
div	Cm	div	Kgf	Ratio	cm^2	kgf/cm^2

* Conduct tests on three identical specimens with different cell pressures.

12. After the test:

Specimen No.	Failure Pattern	Sketch of the failed specimen
1.		
2.		
3.		

13. Water content determination (final)

Container No.		1	2	3
Mass of (container + wet soil)	g			
Mass of (container + dry soil)	g			
Mass of dry soil	g			
Mass of container	g			
Mass of water	g			
Water content	%			

Contd......

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

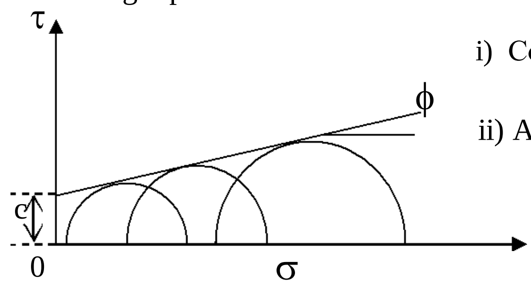
Specimen Calculations

- Axial load (P) = Proving ring constant x proving ring reading = ... kgf
- Axial strain (ε) = $\Delta L/L_o$= ………………………………………
- Corrected area (A) = $A_o/(1 - \varepsilon)$ = ... cm^2
- Axial stress (σ) = P/A=.. kgf/cm^2

15.15.

Test No.	Cell pressure (σ_3) kgf/cm^2	Deviator stress at failure $(\sigma_d)_f = (\sigma_1 - \sigma_3)$ kgf/cm^2	σ_1 kgf/cm^2
1.			
2.			
3.			

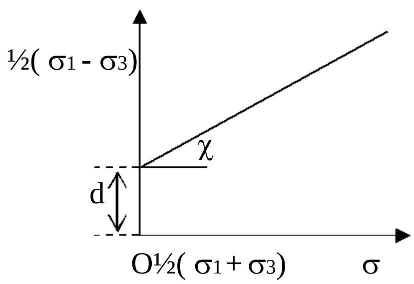
16. Plot (a) Conventional failure envelope (by drawing Mohr's circles) and obtain the shear strength parameters.



i) Cohesion intercept = c = …… kgf/cm^2

ii) Angle of shearing resistance = ϕ =

(b) Modified failure envelope and calculate shear strength parameters.



i) Sin ϕ = tan χ

$\therefore$ ϕ = ………………………………….

ii) c = $\frac{d}{\quad}$ =........................... kgf/cm^2

Relevant BIS Code:

IS: 2720, Part-11, 1971 (Reaffirmed 1978).

EXPERIMENT 8

CONSOLIDATION TEST

Aim: To determine the consolidation properties of given soil.

Theory: Definition of the terms consolidation, compression index, coefficient of volume change; pre-consolidated, normally consolidated and under-consolidated sediments; pre-consolidation pressure and its determination; over-consolidation ratio; fixed ring and floating ring type consolidometers; drainage path; listing of methods to determine the coefficient of consolidation.

Apparatus

1. Fixed ring type consolidometer cell assembly consisting of specimen ring of height not less than 20 mm with a height to diameter ratio of about 3, two porous stones, guide ring, outer ring, pressure pad, steel ball, rubber gasket.
2. Loading frame
3. Dial gauge with an accuracy of 0.002 mm.
4. Balance
5. Thermostatically controlled hot air oven
6. Containers for moisture content determination
7. Mixing basin
8. Soil trimming tools
9. Spatula
10. Ground glass plate/ plate made of Perspex material
11. Whatman No.54 filter papers
12. Stop watch
13. Water reservoir
14. Flexible rubber tube

Procedure

1. Saturate the porous stones either by boiling the porous stones in distilled water for 15 minutes or by submerging them in distilled water for about 5-6 hours. Wipe away the excess water.
2. Assemble the consolidometer cell with one porous stone at the base and one at the top of the specimen ring containing the specimen (undisturbed or remoulded). Provide the filter papers between the porous stones and the specimen.

Note: i) For testing the over consolidated soil or soils sensitive to moisture content, porous stones shall be placed dry. ii) For testing normally consolidated soils, porous stones shall be wet. iii) For testing stiffer soils and moisture sensitive soils, no filter papers shall be used.

3. Place the consolidometer cell assembly in position on the loading frame and suitably adjust its position.

4. Clamp the dial gauge in position to measure the vertical deformation of the specimen such that it has a sufficient margin to measure the swell, if any. Note down the initial reading of the dial gauge.
5. Apply a seating stress of 0.05 kgf / cm^2 on the specimen.
6. Fill the consolidation cell with distilled water and connect the cell to the water reservoir such that the level of water in the reservoir and that in the cell are the same.
7. Allow the specimen to reach equilibrium for 24 h.
8. Note down the final dial gauge reading under the seating stress.
9. Apply the next load of intensity such that the stress increment ratio is unity and start the stop watch simultaneously. Record the dial gauge reading at various time intervals.

Note: i) The recommended loading sequence is 0.05 kgf / cm^2, 0.1 kgf / cm^2, 0.2 kgf / cm^2, 0.4 kgf / cm^2, 0.8 kgf / cm^2, 1.6 kgf / cm^2, 3.2 kgf / cm^2 etc.,. However, a loading sequence of 0.05 kgf / cm^2, 0.1 kgf / cm^2, 0.2 kgf / cm^2, 0.5 kgf / cm^2, 1 kgf / cm^2, 2 kgf / cm^2, 4 kgf / cm^2 etc., may also be used. ii) The time sequence for taking the dial gauge readings is such as to facilitate the plotting of time – compression curve

10. After reaching a near equilibrium state (which can be judged by the changes in the dial gauge readings), note down the final dial gauge reading corresponding to the existing stress on the specimen, increment the stress on the specimen to its next

value. **Note:** Normal equilibrium loading period is 24 h. For some soils, it may be more than 24 h. However, same equilibrium loading period shall be used for all stress increments during the test.

11. On completion of the final loading stage, start unloading the sample by reducing the stress by following a stress decrement ratio of 0.25. Allow sufficient time between successive load decrements and reach the seating stress of 0.05 kgf / cm^2.
12. Maintain the stress for 24 h.
13. After recording the final dial gauge reading, siphon out the water from the cell. Quickly dismantle the specimen from the cell assembly. Remove the excess water on the specimen by using blotting paper.
14. Record the final mass and height of the specimen.
15. Determine the final water content of the specimen by oven drying method.
16. From the equilibrium dial gauge readings recorded under each effective consolidation stress on the specimen, calculate the equilibrium void ratios corresponding to each effective consolidation stress by either the height of solids method or change in void ratio method.
17. Draw void ratio (e) versus log σ' curve and calculate the values of pre-consolidation stress (σ') (if the tested soil is over consolidated) by either Casagrande's method or log-log method, coefficient of volume change (m_v) and compression index (C_c).
18. Calculate the value of coefficient of consolidation (c_v) for each stress range by any of the methods such as square root of time fitting method (Taylor's method), logarithm of time fitting method (Casagrande's method), rectangular hyperbola method and one point method.

Results and Discussions:

Observations and Calculations

1. Soil: ……………………………………………
2. Specific gravity of soil (G_s) = ………………………………………
3. Specimen preparation: Undisturbed / remoulded / compacted
4. Height of the consolidation ring =.. cm
5. Diameter of the consolidation ring =.. cm
6. Area of cross section of consolidation ring (A) =..cm^2
7. **Stress – void ratio data:**

Applied stress (σ'), kgf/cm^2								
Final dial reading, div.								

Calculation of equilibrium void ratio:

8. Height of solids method:

Applied stress (σ'),	Final dial reading,	Change in dial (ΔH)		Specimen height (H)	Void ratio €	Remarks
kgf/cm^2	div	div.	mm	Mm	ratio	
0.0						
0.05						
0.1						

OR

Change in void ratio method:

Applied stress (σ'),	Final dial reading,	Change in dial (ΔH)		Specimen height (H)	Change in void ratio (Δe)	Void ratio €	Remarks
kgf/cm^2	div	div.	mm	mm	ratio	ratio	
0.0							
0.05							
0.1							

EXPERIMENT 9

VANE SHEAR TEST

Aim: To determine Cohesion or Shear Strength of Soil. The structural strength of soil is basically a problem of shear strength. Vane shear test is a useful method of measuring the shear strength of clay. It is a cheaper and quicker method. The test can also be conducted in the laboratory. The laboratory vane shear test for the measurement of shear strength of cohesive soils, is useful for soils of low shear strength (less than 0.3 kg/cm2) for which triaxial or unconfined tests cannot be performed. The test gives the undrained strength of the soil. The undisturbed and remoulded strength obtained are useful for evaluating the sensitivity of soil.

Specifications: The test is conducted as per IS 4434 (1978). This test is useful when the soil is soft and its water content is nearer to liquid limit.

Equipment Required: i. Vane shear test apparatus with accessories
ii. The soil sample

Theory:

The vane shear test apparatus consists of four stainless steel blades fixed at right angle to each other and firmly attached to a high tensile steel rod. The length of the vane is usually kept equal to twice its overall width. The diameters and length of the stainless steel rod were limited to 2.5mm and 60mm respectively. At this time, the soil fails in shear on a cylindrical surface around the vane. The rotation is usually continued after shearing and the torque is measured to estimate the remoulded shear strength. Vane shear test can be used as a reliable in-situ test for determining the shear strength of soft-sensitive clays. The vane may be regarded as a method to be used under the following conditions**.** 1. Where the clay is deep, normally consolidated and sensitive. 2. Where only the undrained shear strength is required. It has been found that the vane gives results similar to that as obtained from unconfined compression tests on undisturbed samples.

Procedure:

1. A posthole borer is first employed to bore a hole up to a point just above the required depth
2. The rod is pushed or driven carefully until the vanes are embedded at the required depth.
3. At the other end of the rod just above the surface of the ground a torsion head is used to apply a horizontal torque and this is applied at a uniform speed of about 0.1 degree per second until the soil fails, thus generating a cylinder of soil
4. The area consists of the peripheral surface of the cylinder and the two round ends.
5. The first moment of these areas divided by the applied moment gives the unit shear value.

Observations:

Force observed P=-------kg

Eccentricity (lever arm) x= ------cm

Turning moment Px= ---------- kg-cm

Length of the vane L= ------cm

Radius of the vane blades r=-------cm Calculations:

Undrained Shear strength of Clay Cu= (Px) / (2*.Π*r2 (L+2/3*r))

Questions:

1. Draw the schematic diagram of the three phase system based on the result.
2. Is there a possibility of the soil getting burnt? In that case, what will be effect on the water content value?
3. How does air-dry soil differ from oven-dry soil?
4. Is this method the most direct method to compute the water content of soil?
5. To get accurate result, how much gram of soil have you taken to conduct the test?

EXPERIMENT 10

I. DEMONSTRATION OF SWELL PRESSURE TEST

AIM: to determine the swelling pressure of soil.

APPARATUS:

1. Consolidometer (specimen diameter = 60mm, height of specimen = 20mm,the ratio of diameter of the particles to the thickness of the specimen should be minimum 3)
2. brass rings, porous stones (minimum thickness = l5mm)
3. dial gauges (LC= 0.01 mm & range 20mm)
4. water reservoir
5. moisture room
6. soil trimming tools
7. oven
8. desiccators
9. balance (sensitive to 0.01 gm)
10. containers.

PROCEDURE:

The consolidation specimen ring with the specimen shall be kept between two porous stones saturated in boiling water providing a filter paper (Whatman No. 1 or equivalent) between the soil specimen and the porous stone. The loading block shall then be positioned centrally on the top of the porous stone. This assembly shall then be placed on the platen of the loading unit as shown in figure. The load measuring proving ring tip attached to the load frame shall be placed in contact with the consolidation cell without any eccentricity. A direct strain measuring dial gauge shall be fitted to the cell. The specimen shall be inundated with distilled water and allowed to swell.

The initial reading of the proving ring shall be noted. The swelling of the specimen with increasing volume shall be obtained in the strain measuring load gauge. To keep the specimen at constant volume, the platen shall be so adjusted that the dial gauge always shows the original reading. This adjustment shall be done at every 0.1 mm of swell or earlier. The dial gauge readings shall be taken till equilibrium is reached. This is ensured by making a plot of swelling dial reading versus time in hours, which plot becomes asymptotic with abscissa (time scale). The equilibrium swelling is normally reached over a period of 6 to 7 days in general for all expansive soils. The assembly shall then be dismantled and the soil specimen extracted from the consolidation ring to determine final moisture content.

Calculation: The difference between the final and initial dial readings of the proving ring gives total load in terms of division which when multiplied by the calibration factor gives the total load. This when divided by the cross-sectional area of the soil specimen gives the swell pressure expressed in kN/m2 (kgf/cm2).

OBSERVATION:

1. Undisturbed/Remoulded soil:

2. Liquid limit of soil:
3. Plasticity Index of soil:
4. Specific Gravity of soil:
5. Bulk/natural density of soil:
6. Field moisture content of soil:

SWELL PRESSURE DATA

Date	Time	Strain dial Rdg before Adjustment	Proving ring Reading	Difference	Load in Kg	Swell Pressure in Kg/cm^2	Remark

$$\text{Swelling Pressure in}(Kg/cm^2) = \frac{Final\ dial\ reading - Initial\ dial\ reading}{Area\ of\ specimen} \text{ X Calibration Factor of proving ring}$$

Conclusion:

II. STANDARD PENETRATION TEST

AIM: To determine the resistance of soil against penetration

APPARATUS:

1. Tripod
2. Manila rope
3. doughnut hammer of weight 63.5kg
4. anvil
5. split spoon sampler
6. driving rod.

PROCEDURE:

The standard penetration test is conducted in a bore hole using a standard split- spoon sampler. when the bore hole has been drilled to the desired depth, the drilling tools are removed and the sample is driven into the soil by a drop hammer of 63.5kg mass falling through a height of 750mm at the rate of30 blows per minute (IS: 2131-1963).the number of hammer blows required to drive 150mm of sample is counted. The sample is further driven by 150 mm and the number of blows recorded. Likewise, the sampler is once again further driven by 150 mm and number of blows recorded. The number of blows recorded for the first 150 mm is disregarded. The number of blows recorded for the last two 150 mm intervals are added to give standard penetration number (N).in other words, the standard penetration number is equal to the number of blows required for 300 mm penetration beyond a seating drive of 150 mm. If the number of blows for 150 mm drive exceeds 50, It is taken as refusal and test is discontinued. If the split spoon sampler is driven less than 45cm (total), then the penetration will be for the last 30cm of penetration (if less than 30cm is penetrated, the logs should state the number of blows and the depth of penetration.

THEORY:

The standard penetration test is most commonly used in in-situ test, especially for cohesion-less soils which cannot be easily sampled. The test is extremely useful for determining the relative density and the angle of shearing resistance of cohesion-less soils. It can also be used to determine the unconfined compressive strength of cohesive soils.

The standard penetration number is corrected for dilatancy correction and overburden correction and overburden correction as explained below.

(a) Dilatancy correction: Silty fine sand and fine sand below the water table develop pore pressure which is not easily dissipated. The pore pressure increases the resistance of the soil and hence the penetration number (N).Terzaghi and peak (1967) recommend the following correction in the case of silty fine sands when the observed value of N exceeds

The corrected penetration number, **Ne = 15 +** $\frac{\mathbf{(NR-15)}}{\mathbf{2}}$

Where N_R is recorded value and N_C is the corrected value $N_R \leq 15$, $N_C = N_R$

(b) Overburden pressure correction: In granular soils, the over burden pressure affects the penetration resistance. If the two soils having same relative density but different confining pressures are tested, the one with higher confining pressure gives a higher penetration number. As the confining pressure in cohesion-less soils increases with the depth, the penetration number for soils at shallow depths is underestimated and that at greater depth is overestimated. For uniformity, the N-values obtained from field test under different effective overburden pressures are corrected to a standard effective overburden pressure.

Gibbs and Holtz (1957) recommend the use of the following equation for dry or moist clean sand.

Ne = NR X $\frac{\mathbf{350}}{\boldsymbol{\sigma}\mathbf{+70}}$

Where N_R observed N value and σ = effective overbidding pressure.

The eq2.2 is only applicable for cr :::; 280 kN/m2.

The ratio (Ne / NR) should lie between 0.45 and 2.0.if (Ne / NR) ratio is greater than 2.0, Ne should be divided by 2.0 to obtain the design value used in finding the bearing capacity of the soil. The correction may be extended to saturated silty sand and fine sand after modifying the NR according to Eq.2.2, i.e. Nc obtained from Eq. 2.2 would be taken as NR In Eq. 2.1. Thus the overburden correction is applied first and then the dilatancy correction is applied. Peck, Hansen and Thornburn (1974) give the chart for correction of N- values to an effective overburden pressure of96 kN/m2, according to them.

$$N = 0.77\, N_R \log\left(\frac{1905}{\sigma}\right) \text{ for } \sigma \geq 24 \text{ kN/m}^2$$

Correction is given by Bazaara (1967), and also by Peck and Bazaara (1969), is one of the commonly used corrections. According to them,

$$N = 4\, N_R \left(\frac{1}{1+0.0418\sigma}\right) \text{ if } \sigma < 71.8 \text{ kN/m}^2$$

$$N = 4\, N_R \left(\frac{1}{3.25+0.0104\sigma}\right) \text{ if } \sigma > 71.8 \text{ kN/m}^2$$

Where $N = N_R$, if $\sigma = 71.8$ KN/m^2

The value of the standard penetration number N depends upon the relative density of the cohesion-less soil and the unconfined compressive strength of cohesive soil. If the soil is compact or stiff, the penetration number is high. The angle of shearing resistance ((j)) of the cohesion-less soil depends upon the number N. in general, greater the N-value, the greater shearing resistance table 2.1 gives the average values of a for different ranges of N

The consistency and the unconfined shear strength of the cohesive soils can be approximately determine from the SPT number N. as the correlation is not dependable, it is advisable to determine the shear strength of the cohesive soils by conducting shear test on undisturbed samples or by conducting in-situ vane shear test. Table 2.2 gives the approximate value of the unconfined shear strength for different ranges of N the unconfined compressive strength can also be determined from the following relation.

N(Penetration Resistance)	**Degree of Density**	**(jJ)**
0-4	Very loose	25u _32u
4-10	Loose	27u-35u
10-30	Medium	30u _40u
30-50	Dense	35u _45u
>50	Very Dense	>45u
N(Penetration Resistance)	**Degree of Density**	**{jl/ (kN/JI/)**
0-2	Very soft	<25
2-4	Soft	25-50
4-8	Medium	50-100
8-15	Stiff	100-200
15-30	Very stiff	200-400
>30	Hard	>400

A sub-soil investigation report should contain the data obtained from bore holes , site observations and laboratory results. It should also give recommendations about the suitable type of foundation, allowable soil pressure and expected settlements. It is essential to give a complete and accurate data collected. Each bore hole should be identified by code number. The Location of each bore hole should be fixed by measurement of its distance or angles from some permanent feature. All relevant data for the bore is recorded in a boring log. A boring hole gives description or classification of various strata encountered at different depth.

- Any additional information that is obtained in the field, such as soil consistency, unconfined compressive strength, standard penetration test, cone penetration test, is also indicated on boring log.
- It should also show water table. If the laboratory tests have been conducted, the information about index properties, compressibility, shear strength, permeability, etc should also be provided.

The data obtained from a series of bore holes is presented in the form of a sub-surface profile. Sub-surface profile is a section through the ground along the line of exploration. It indicates the boundaries of different strata, along with their classification. It is important to remember that conditions between bore holes are estimated by interpolation, which may not be correct. Obviously, the larger the number of holes, the more accurate is the sub-surface profile. The site investigation report should contain the discussion of the results. The discussion should be clear and concise. The recommendations about the type and depth of foundation, allowable soil pressure and expected settlements should be specific. The main findings of the report are given in conclusion.

(1) Introduction, which gives the scope of investigation.

(2) Description of proposed structure, the location and geological conditions at the site.

Details of the field exploration program, indicating the number of borings ,their location and depth.

(3) Details of the methods of explorations.

(4) General description of the sub-soil conditions as obtained from in-situ tests, such as standard penetration test, cone penetration test.

(5) Details of the laboratory test conducted on the soil samples obtained and the results obtained.

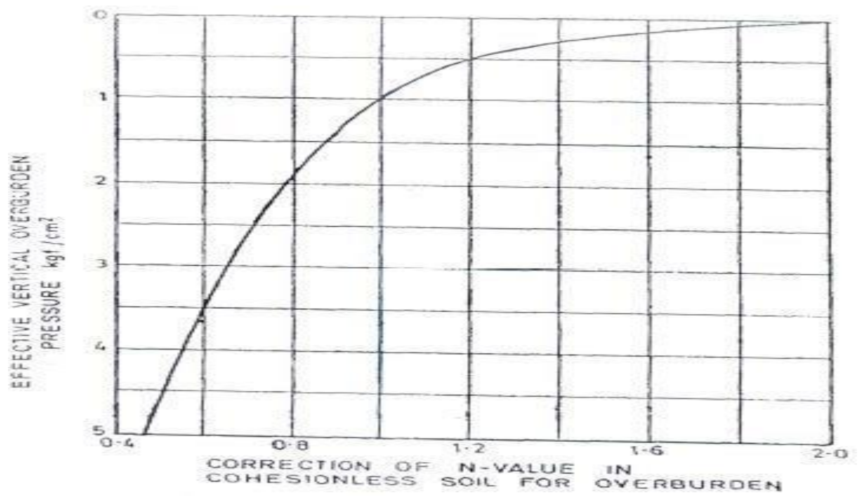
(6) Depth of ground water table and changes in water levels.

(7) Discussion of the results.

(8) Recommendations about the allowable bearing pressure, the type of foundation or

(9) Conclusion the main findings of the investigations should be clearly stated. It should be brief but should mention salient points.

(10)Limitations of the investigations should also briefly stated.



III. DEMONSTRATION ON BORING EQUIPMENTS (AUGUR BORING)

AIM: To collect soil sample using Auger Boring

APPARATUS:

1. Hand operated Auger (75 mm dia.)
2. drilling rods
3. guiding plates
4. Trowels.

PROCEDURE:

The hand augers used in boring are about 15 to 20 cm in diameter. These are suitable for advancing holes up to a depth of 3 to 6m in soft soils. The hand auger is attached to the lower end of a pipe of about l8mm diameter. The pipe is provided with a cross-arm at its top. The hole is advanced by turning the cross-arm manually and at the same time applying thrust in the downward direction. When the auger is filled with soil, it is taken out and for the required depth the disturbed samples are preserved in order to determine required physical properties. If the hole is already driven, another type of auger, known as post hole auger is used for taking soil samples.

THEORY:

An auger is a boring tool similar to one used by a carpenter for boring holes in wood. It consists of shank with a cross-wise handle for turning and having central tapered feed screw. The augers can be operated manually or mechanically. Mechanical augers are driven by power. These are used for making holes in hard strata to a great depth. However, for depths greater than 12m, even mechanical augers become inconvenient and other methods of boring are used. Continuous flight augers are special type of mechanical augers which are provided with a central hollow tube. When the hole is advanced, the central tube is kept plugged. As the auger is turned into the ground, the cuttings rise to the surface through the spiral. During sampling, the plug is removed and a sampler is inserted for taking the samples. The main disadvantage of using a continuous flight auger is that it becomes difficult to ascertain the depth from which the cutting coming on the ground have been removed. Auger boring is generally used in soils which can stay open without casing or drilling mud. Clays, silts and partially saturated sands can stand unsupported. For soils which cannot stand unsupported, especially for sandy soils below water table, a casing is normally required. For such soils, the method of auger boring becomes slow and expensive. Auger boring cannot be used when there are large cobbles, boulders or other obstructions which prevent drilling of the hole, Auger borings are particularly useful for subsurface investigations of highways, railways and air fields, where the depth of exploration is small. The investigations are done quite rapidly and economically by auger boring. The main disadvantage of the auger boring is that the soil samples are highly disturbed. Further, it becomes difficult to locate the changes in the soil strata.

BORE LOG

Date of Boring:
Boring No.:
Water Table:

Location of Boring :
Type of Boring:
Type of Sampler:

Soil Description	Soil Inden-tification	Depth of Strata	Sample Type	ω (%)	γ, kg/cm^2	ω_L (%)	ω_P (%)	ω_S (%)	G	Cu Kg/cm^2	Ǿ