Geotechnical Engineering

Laboratory Record

Name: ……………………………………………………………………………….

Subject: ………………………………………… Roll No.:……………………......

Branch: ……………………………. Sec: ..……………… Year:………………..

GOKARAJU RANGARAJU

INSTITUTE OF ENGINEERING & TECHNOLOGY

Nizampet Road, Bachupally, Hyderabad - 500 090

"Ragging is prohibited as per the decision of the Supreme Court of India in write petition No. (c) 656 / 1998"

GOKARAJU RANGARAJU

Institute of Engineering & Technology
Hyderabad.

CERTIFICATE

This is to certify that it is a bonafide record of practical work done in the …………………………………………………………………………….laboratory in ………………semester of ………………. year during the year ………………by

Name :..………………………………………..

Roll No :..………………………………………..

Branch :..……………………………………….

Section :……………………………….............

Signature of the Internal Examiner

Signature of the Head of Department

Signature of the External Examiner

CONTENTS

INDEX

S. No	Date	Name of the Experiment	Page No.	Marks Awarded	Signature

Experiment - 01 **Date:**

DETERMINATION OF MOISTURE CONTENT

Objective

Determine the natural moisture content of the given soil sample.

Need and scope of the experiment

In almost all soil tests natural moisture content of the soil is to be determined. The knowledge of the natural moisture content is essential in all studies of soil mechanics. To sight a few, natural moisture content is used in determining the bearing capacity and settlement. The natural moisture content will give an idea of the state of soil in the field.

Definition

The natural water content also called the natural moisture content is the ratio of the weight of water to the weight of the solids in a given mass of soil. This ratio is usually expressed as percentage.

Apparatus required

1. Non-corrodible air-tight container.
2. Electric oven, maintain the temperature between 105^0C to 110^0C.
3. Desiccator.
4. Balance of sufficient sensitivity.

Procedure

1. Clean the containers with lid dry it and weigh it (W1).
2. Take a specimen of the sample in the container and weigh with lid (W2).
3. Keep the container in the oven with lid removed. Dry the specimen to constant weight maintaining the temperature between 105^0C to 110^0C for a period varying with the type of soil but usually 16 to 24 hours.
4. Record the final constant weight (W3) of the container with dried soil sample. Peat and other organic soils are to be dried at lower temperature (say 60^0C) possibly for a longer period.

Certain soils contain gypsum which on heating loses its water if crystallization. If it is suspected that gypsum is present in the soil sample used for moisture content determination it shall be dried at not more than 80^0C and possibly for a longer time.

Observations

Table 1.1 Data and observation sheet for water content determination

S. No.	Sample No.	1	2	3
1	Weight of container with lid (W_1 gm)			
2	Weight of container with lid +wet soil (W_2 gm)			
3	Weight of container with lid +dry soil (W_3 gm)			
4	Water/Moisture content (%) $W = [(W_2 – W_3)/(W_3 – W_1)]*100$			

Result

The natural moisture content of the given soil sample is ________ .

General remarks

1. A container with out lid can be used, when moist sample is weighed immediately after placing the container and oven dried sample is weighed immediately after cooling in desiccator.
2. As dry soil absorbs moisture from wet soil, dried samples should be removed before placing wet samples in the oven.

Specimen calculations:

Experiment - 02 **Date:**

DETERMINATION OF SPECIFIC GRAVITY

Objective

Determine the specific gravity of the soil fraction passing 4.75 mm I.S sieve by density bottle.

Need and scope of the experiment

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 required

1. Density bottle of 50 ml with stopper having capillary hole.
2. Balance to weigh the materials (accuracy 10gm).
3. Wash bottle with distilled water.
4. Alcohol and ether.

Procedure

1. Clean and dry the density bottle
   a. Wash the bottle 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 empty bottle with stopper (W_1)
3. Take about 10 to 20 gm of oven soil sample which is cooled in a desiccator. Transfer it to the bottle. Find the weight of the bottle and soil (W_2).
4. Put 10ml of distilled water in the bottle to allow the soil to soak completely. Leave it for about 2 hours.
5. Again fill the bottle completely with distilled water put the stopper and keep the bottle under constant temperature (T_x^0 C).
6. Take the bottle, wipe it clean and dry note. Now determine the weight of the bottle and the contents (W_3).
7. Now empty the bottle and thoroughly clean it. Fill the bottle with only distilled water and weigh it. Let it be W_4 at temperature (T_x^0 C).
8. Repeat the same process for 2 to 3 times, to take the average reading of it.

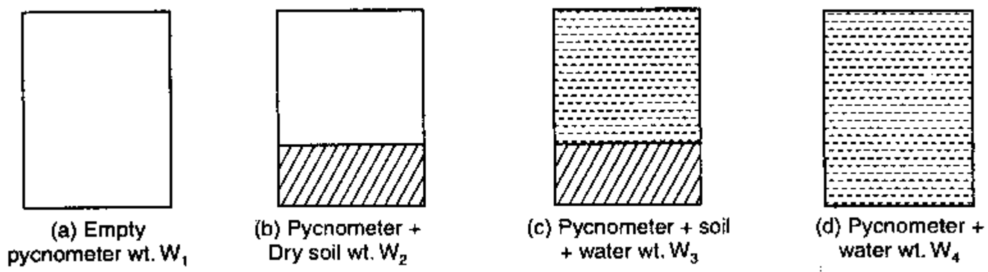

Figure 2.1 Specific Gravity test

Observations

Table 2.1 Observations for the specific gravity determination

S. No.	Observation(s)	1	2	3
1	Weight of density bottle (W_1 g)			
2	Weight of density bottle + dry soil (W_2 g)			
3	Weight of bottle + dry soil + water at temperature T_x^0 C (W_3 g)			
4	Weight of bottle + water (W_4 g) at temperature T_x^0 C			
Specific gravity G at T_x^0 C				
Average specific gravity at T_x^0 C				

Calculations

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

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

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

Interpretation

Unless or otherwise specified specific gravity values reported shall be based on water at 27^0 C. So the specific gravity at 27^0C = K*Sp. gravity at T_x^0C.

$$\text{where} \quad K - \frac{\text{Density of water at temperature } T_x^0 C}{\text{Density of water at temperature } T_x^0 C}$$

Result

The specific gravity of the given soil sample is **_______________** .

General remarks

The specific gravity of the soil particles lie with in the range of 2.65 to 2.85. Soils containing organic matter and porous particles may have specific gravity values below 2.0. Soils having heavy substances may have values above 3.0.

Specimen calculations:

Experiment - 03 **Date:**

FIELD DENSITY TEST BY 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.

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 and with known moisture content is as follows:

$$\gamma_d = \gamma_b / (1 + w)$$

γ_d = Dry density

γ_b = Bulk density

w = water content

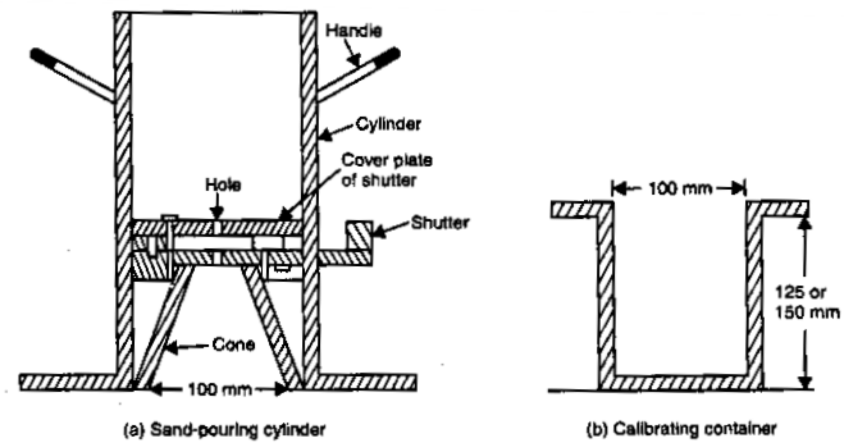

Figure 3.1 Apparatus for Sand Replacement Method

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 plate and open the shutter to allow the sand to run out and close the cylinder shutter when there is no movement of sand 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 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 sqcm 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.

Observations and calculations

Table 3.1 Calculation sheet for sand density determination

S.No.	Sample details Calibration	1	2	3
1	Weight of sand in cone (on glass plate from pouring cylinder), W_2 gm			
2	Volume of calibrating container, (V) in cc			
3	Weight of sand + cylinder before pouring in calibrating container, W_1 gm			
4	Weight of sand + cylinder after pouring in calibrating container, W_3 gm			
5	Weight of sand filled in calibrating container, $W_a = (W_1 - W_3 - W_2)$ gm			
6	Bulk density of sand, $\gamma_s = W_a / V$ gm/cc			

Table 3.2 Calculation sheet for density of soil

S. No.	Measurement of soil density			
1	Weight of wet soil from hole, W_w gm			
2	Weight of sand + cylinder before pouring into the hole & cone, W_1 gm			
3	Weight of sand + cylinder after pouring into the hole & cone, W_4 gm			
4	Weight of sand in hole, $W_h = (W_1 - W_2 - W_4)$ gm			
5	Volume of the hole in cc, $V_h = W_h / \gamma_s$			
6	Bulk density, $\gamma_b = (W_w / V_h)$ gm/cc			
	Water content determination			
7	Container number			
8	Weight of wet soil in gms			
9	Weight of dry soil in gms			
10	Moisture content (%)			
11	Dry density $\gamma_d = \gamma_b / (1+w)$ gm/cc			

Result

The dry density of the given soil sample is ________ .

General remarks

1. Great care has to be taken while calibrating the bulk density of sand.
2. The excavated hole must be equal to the volume of the calibrating container.

Specimen calculations:

Experiment – 04 **Date:**

FIELD DENSITY TEST BY CORE CUTTER METHOD

Objective

Determine the dry density of the soil by using core cutter method.

Apparatus required

1. Cylindrical core cuter, 100 mm internal diameter and 130 mm long
2. Steel rammer, mass 9kg. Overall length, with the foot and staff about 900mm
3. Steel dolly, 25 mm high and 100mm internal diameter
4. Weighing balance, accuracy 1g.
5. Palette knife
6. Straight edge, steel rule etc.

Theory

A cylindrical core cutter is a seamless steel tube. For determination of the dry density of the soil, the cutter is pressed into the soil mass so that it is filled with the soil. The cutter filled with the soil is lifted up. The mass of the soil is determined. The dry density is obtained as

$$\gamma_d = \gamma_b / (1 + w)$$

γ_d = Dry density

γ_b = Bulk density

w = water content

Procedure

1) Determine the internal diameter and height of the core cutter to the nearest 0.25 mm.
2) Determine the mass (M_1) of the cutter to the nearest gram.
3) Expose a small area of the soil mass to be tested. Level the surface, about 300 mm square in area.
4) Place dolley over the top of the core cutter and press the core cutter in to the soil mass using the rammer. Stop the process of pressing when about 15 mm of the dolley protrudes above the soil surface.
5) Remove the soil surrounding the core cutter and takeout the core cutter. Some soil would project from the lower end of the cutter.
6) Remove the dolley. Trim the top and bottom surface of the core cutter carefully using a straight edge.
7) Weigh the core cutter filled with the soil to the nearest gram (M_2).
8) Remove the core of the soil from the cutter. Take a representative sample for the water content determination.

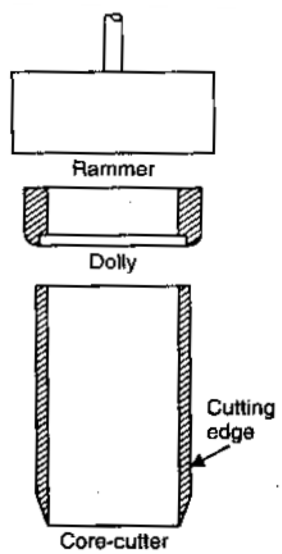

Figure 4.1 Apparatus for Core Cutter

Observations and calculations

Table 4.1 Calculation sheet for dry density of soil

S.No	Observations	Sample No.		
		1	2	3
1	Internal diameter of the Core Cutter			
2	Internal Height of the Core Cutter			
3	Mass of empty core cutter (M_1), gms			
4	Mass of core cutter with soils (M_2), gms			
5	Mass of wet soil, $M = M_2 - M_1$			
6	Volume of the cutter, V in cc			
7	Water content (%), w			
8	Bulk Density , (g/cc) = M / V			
9	Dry density = Bulk Density/ (1+ w)			

Result

The average field dry density of the soil is ______________________.

Specimen calculations:

Experiment - 05 **Date:**

GRAIN SIZE DISTRIBUTION BY SIEVE ANALYSIS

Objective

Determine the relative proportions of different grain sizes which make up a given soil mass.

Need and scope of experiment

The grain size analysis is widely used in classification of soils. The data obtained from grain size distribution curves is used in the design of filters for earth dams and to determine suitability of soil for road construction, air field etc. Information obtained from grain size analysis can be used to predict soil water movement although permeability tests are more generally used.

Apparatus

1. Balance
2. IS sieves
3. Rubber pestle and mortar
4. Manual/Mechanical Sieve shaker

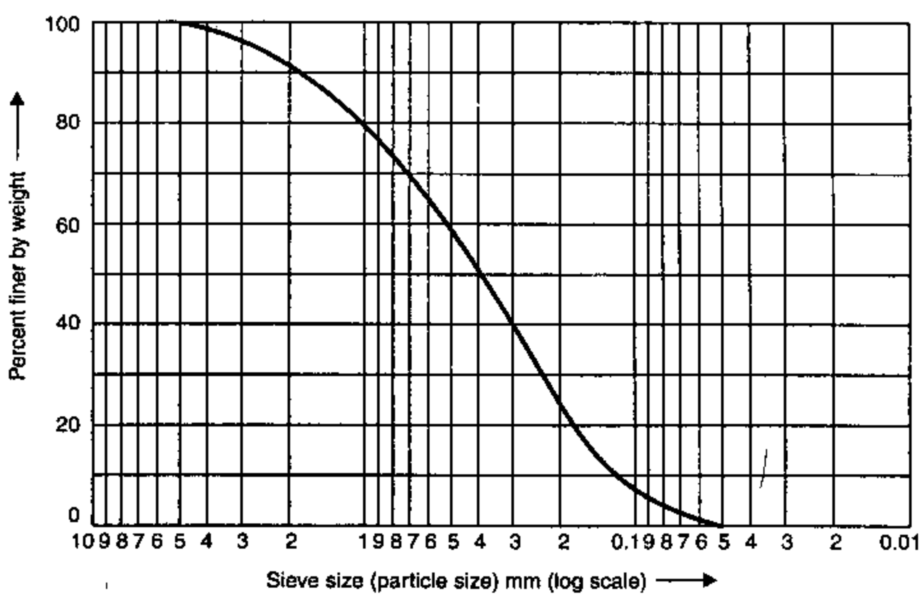

Figure 5.1 Graph for grain size sieve analysis

Procedure

1. For soil samples of soil retained on 75 micron I.S. sieve
   - (a) The proportion of soil sample retained on 75 micron I.S sieve is weighed and recorded weight of soil sample is as per I.S. 2720.
   - (b) I.S.sieves are selected and arranged in the order as shown in the table.
   - (c) The soil sample is separated into various fractions by sieving through above sieves placed in the above mentioned order.
   - (d) The weight of soil retained on each sieve is recorded.
   - (e) The moisture content of soil if above 5% it is to be measured and recorded.
2. The sieves for soil tests: 4.75 mm to 75 microns.
3. No particle of soil sample shall be pushed through the sieves.
4. The balance to be used must be sensitive to the extent of 0.1% of total weight of sample taken.

Observations

Weight of soil sample taken:

Table 5.1 Calculation sheet for soil particle % finer

S.No	I.S. sieve number or size in mm	Wt. retained in each sieve (gm)	Percentage on each sieve (%)	Cumulative percentage retained on each sieve (%)	% finer
1	4.75				
2	2.00				
3	1.00				
4	0.600				
5	0.425				
6	0.300				
7	0.150				
8	0.075				

Result from graph

Draw graph between log sieve size vs % finer. The graph is known as grading curve. Corresponding to 10%, 30% and 60% finer, diameters obtained from graph are designated as d_{10}, d_{30}, d_{60}.

Calculations

1. The percentage of soil retained on each sieve shall be calculated on the basis of total weight of soil sample taken.
2. Cumulative percentage of soil retained on each successive sieve is found and graph between log grain size of soil and % finer is drawn.

Specimen calculations:

Experiment - 06 **Date:**

GRAIN SIZE DISTRIBUTION BY HYDROMETER ANALYSIS

Objective

Determine the grain size of soils by hydrometer analysis test.

Specific objective

1. To determine the grain size distribution of soil sample containing appreciable amount of fines.
2. To draw a grain size distribution curve.

Need and scope of the experiment

For determining the grain size distribution of soil sample, usually mechanical analysis (sieve analysis) is carried out in which the finer sieve used is 75 micron or the nearer opening. If a soil contains appreciable quantities of fine fractions in (less than 75 micron) wet analysis is done. One form of the analysis is hydrometer analysis. It is very much helpful to classify the soil as per ISI classification. The properties of the soil are very much influenced by the amount of clay and other fractions.

Apparatus

1. Hydrometer
2. Glass measuring cylinder-Two of 1000 ml capacity with ground glass or rubber stoppers about 7 cm diameter and 33 cm high marked at 1000 ml volume.
3. Thermometer- To cover the range 0 to 50^{o} C with an accuracy of 0.5 ^{o}C.
4. Water bath.
5. Stirring apparatus.
6. I.S sieves apparatus.
7. Balance-accurate to 0.01 gm.
8. Oven-105 to 110.
9. Stop watch.
10. Desiccators
11. Centimeter scale.
12. Porcelain evaporating dish.
13. Wide mouth conical flask or conical beaker of 1000 ml capacity.
14. Thick funnel-about 10 cm in diameter.
15. Filter flask-to take the funnel.
16. Measuring cylinder-100 ml capacity.
17. Wash bottle-containing distilled water.
18. Filter papers.

19. Glass rod-about 15 to 20 cm long and 4 to 5 mm in diameter.
20. Hydrogen peroxide-20 volume solution.
21. Hydrochloric acid N solution-89 ml of concentrated hydrochloric acid. (Specific gravity 1.18) diluted with distilled water one litre of solution.
22. Sodium hexametaphosphate solution-dissolve 33 g of sodium hexametaphosphate and 7gms of sodium carbonate in distilled water to make one litre of solution.

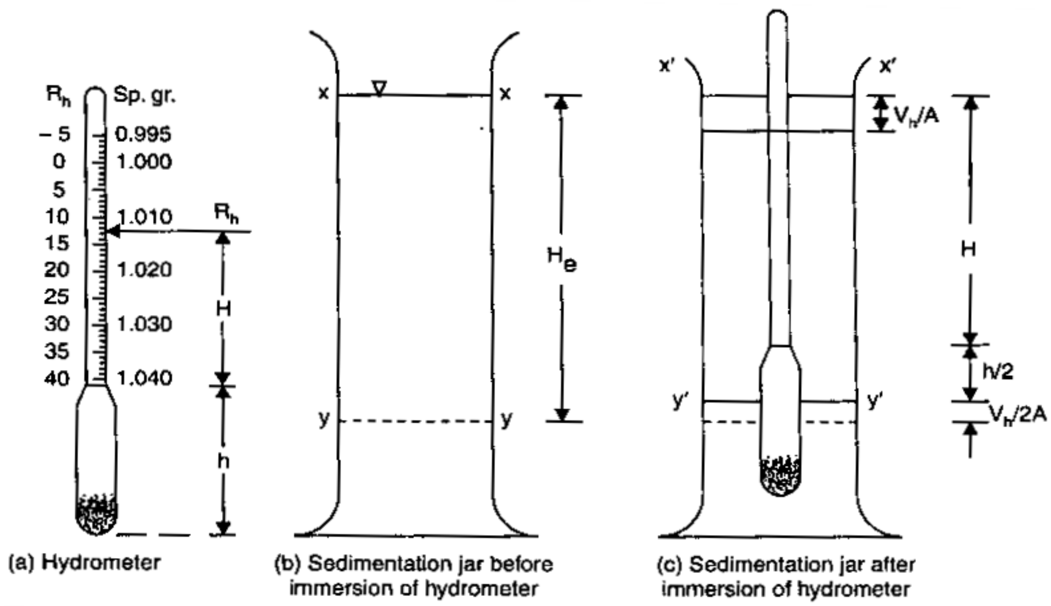

Figure 6.1 Hydrometer analysis

Calibration of hydrometer

Volume

a) Volume of water displaced: Approximately 800 ml of water shall be poured in the 1000 ml measuring cylinder. The reading of the water level shall be observed and recorded.
b) The hydrometer shall be immersed in the water and the level shall again be observed and recorded as the volume of the hydrometer bulb in ml plus volume of that part of the stem that is submerged. For practical purposes the error to the inclusion of this stem volume may be neglected.
c) From the weight of the hydrometer: The hydrometer shall be weighed to the nearest 0.1 gm.
d) The weight in gm shall be recorded as the volume of the bulb plus the volume of the stem below the 1000 ml graduation mark. For practical purposes the error due to the inclusion of this stem may be neglected.

Calibration

(a) The sectional area of the 1000 ml measuring cylinder in which the hydrometer is to used shall be determined by measuring the distance between the graduations. The sectional area is equal to the volume include between the two graduations divided by the measured distance between them.
(b) Place the hydrometer on the paper and sketch it. On the sketch note the lowest and highest readings which are on the hydrometer and also mark the neck of the bulb. Mark the center of the bulb which is half of the distance between neck of the bulb and tip of the bulb.
(c) The distance from the lowest reading to the center of the bulb is (R_h) shall be recorded ($R_h = H_L + L/2$).
(d) The distance from the highest hydrometer reading to the center of the bulb shall be measured and recorded.
(e) Draw graph hydrometer readings vs H_H and R_H. A straight line is obtained. This calibration curve is used to calibrate the hydrometer readings which are taken with in 2 minutes.
(f) From 4 minutes onwards the readings are to be taken by immersing the hydrometer each time. This makes the soil solution to rise, there by rising distance of free fall of the particle. So correction is applied to the hydrometer readings.
(g) Correction applied to the R_h and H_H

$$\frac{R_h - V_h}{A} = \frac{H_L + h/2 - V_h}{2A}$$

V_h= Volume of hydrometer bulb in ml.
A =Area of measuring cylinder in cm^2.
From these two corrected readings draw graph (straight line)

Observations

Grain Size Distribution in Soil-Data and Calculation Chart

Total weight of dry soil taken, W =
Specific Gravity of soil, G =
Wt. Of soil gone into solution, Ws =
Meniscus correction, C_n = Dispersion agent correction =
Reading in water RW =
Temperature correction =
% finer for wt. Of soil W_s gone into solution N = [(100G)/{W_s x (G /1)}] x R

Table 6.1 Calculation sheet for hydrometer analysis

Date	Time	Elapsed Time in Sec	Hydrometer reading upper Meniscus (R_h / 1000)	Corrected hydrometer Reading (1- lower meniscus Cm)	Z_r or $Z^1 r$	Velocity (Cm/sec) V = $Z^1 r/K$ or $Z^1 r$ / t	Equivalent diameter of Particle D in mm	R	N(% finer than for soil)	Remarks

Specimen calculations:

Experiment - 07 **Date:**

DETERMINATION OF LIQUID LIMIT

Objective

Determine the liquid limit for the given soil sample.

Need and scope

Liquid limit is significant to know the stress history and general properties of the soil met with construction. From the results of liquid limit the compression index may be estimated. The compression index value will help us in settlement analysis. If the natural moisture content of soil is closer to liquid limit, the soil can be considered as soft if the moisture content is lesser than liquids limit, the soil can be considered as soft if the moisture content is lesser than liquid limit. The soil is brittle and stiffer.

Theory

The liquid limit is the moisture content at which the groove, formed by a standard tool into the sample of soil taken in the standard cup, closes for 10 mm on being given 25 blows in a standard manner. At this limit the soil possess low shear strength.

Apparatus required

1. Balance
2. Liquid limit device (Casagrande's)
3. Grooving tool
4. Mixing dishes
5. Spatula
6. Electrical oven

Procedure

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 liquid limit device 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.

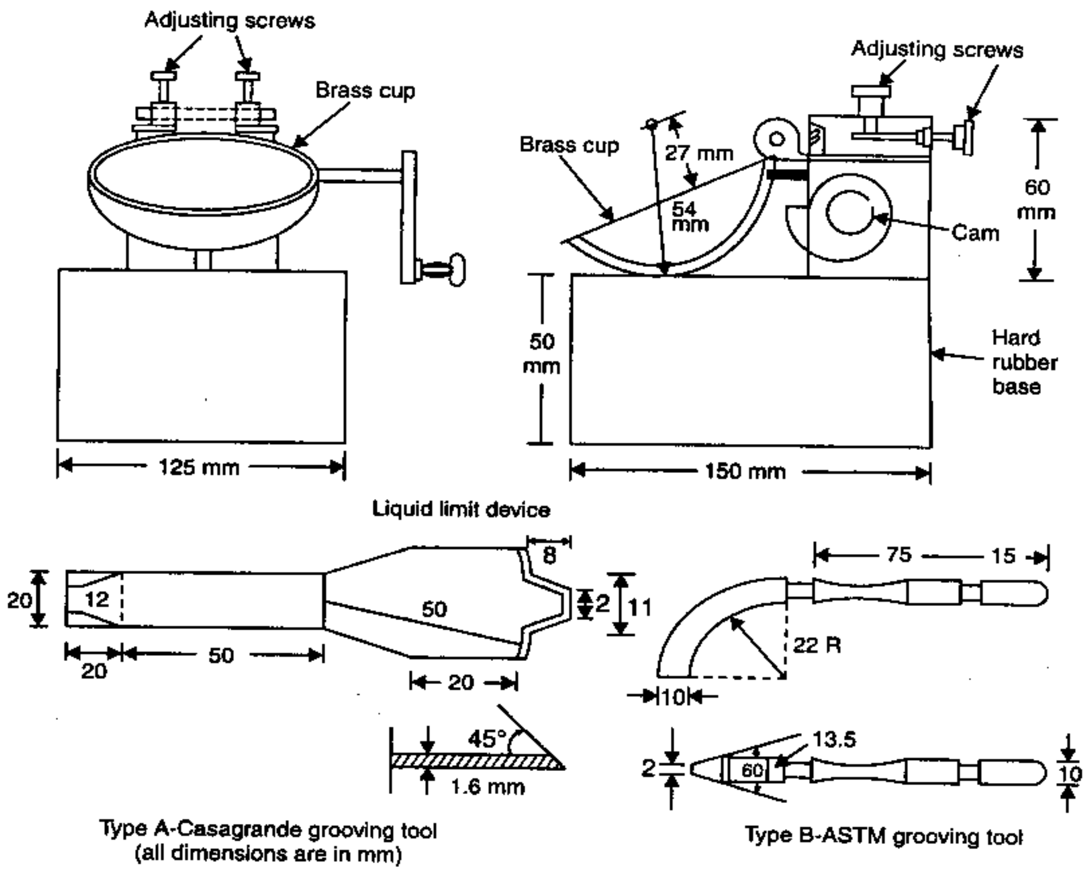

Figure 7.1 Casagrande's Liquid Limit Device

Observations

Table 7.1 Observation and Calculation sheet for the water content determination

Calculations	1	2	3	4
Container number				
Weight of empty container, gms				
Weight of container + wet soil, gms				
Weight of container + dry soil, gms				
Weight of dry soil, gms				
Moisture content (%)				
No. of blows				

Calculations

Draw a graph showing the relationship between water content (on y-axis) and number of blows (on x-axis) on semi-log graph. The curve obtained is called flow curve. The moisture content corresponding to 25 drops (blows) as read from the represents liquid limit. It is usually expressed to the nearest whole number.

Result

Liquid Limit of the given soil sample from graph is _______________

Flow index, $I_f = (W_2 - W_1) / (\log N_1/N_2)$ = slope of the flow curve.

Specimen calculations:

Experiment - 08 **Date:**

DETERMINATION OF PLASTIC LIMIT

Objective

Determine the plastic limit for the given soil sample.

Need and scope

Soil is used for making bricks, tiles and soil cement blocks in addition to its use as foundation for structures.

Apparatus required

1. Porcelain dish.
2. Glass plate for rolling the specimen.
3. Air tight containers to determine the moisture content.
4. Balance of capacity 200gm and sensitive to 0.01gm.
5. Oven thermostatically controlled with interior of non-corroding material to maintain the temperature around 105^0 and 110^0c.

Procedure

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 molded 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 at least 3 times and take the average of the results calculated to the nearest whole number.

Observations

Compare the diameter of thread at intervals with the rod. When the diameter reduces to 3 mm, note the surface of the thread for cracks.

Table 8.1 Calculation sheet for plastic limit determination

Observations	**1**	**2**	**3**
Wt. of container with lid, (gms) W_1			
Wt. of container with lid + wet sample, (gms) W_2			
Wt. of container with lid + dry sample, (gms) W_3			
Wt. of dry sample (gms) = $W_3 - W_1$			
Wt. of water in the soil (gms) = $W_3 - W_2$			
Water content (%) = $[(W_3 - W_2) / (W_3 - W_1)] * 100$			

Result

Average Plastic Limit for the given soil sample is ________________

Specimen calculations:

Experiment - 09 **Date:**

DETERMINATION OF SHRINKAGE LIMIT

Objective

Determine the shrinkage limit and calculate the shrinkage ratio for the given soil sample.

Theory

As the soil loses moisture, either in its natural environment, or by artificial means in laboratory it changes from liquid state to plastic state, from plastic state to semi-solid state and then to solid state. Volume changes also occur with changes in water content. But there is particular limit at which any moisture change does not cause soil any volume change.

Need and scope

Soils which undergo large volume changes with change in water content may be troublesome. Usually volume changes may not be equal.
A shrinkage limit test should be performed on a soil.

1. 1. To obtain a quantitative indication of how much change in moisture can occur before any appreciable volume changes occurs.
2. To obtain an indication of change in volume.
3. The shrinkage limit is useful in areas where soils undergo large volume changes when going through wet and dry cycles (as in case of earth dams)

Apparatus

1. Evaporating Dish. Porcelain, about 12cm diameter with flat bottom.
2. Spatula
3. Shrinkage Dish. Circular, porcelain or non-corroding metal dish (3 nos) having a flat bottom and 45 mm in diameter and 15 mm in height internally.
4. Straight Edge. Steel, 15 cm in length.
5. Glass cup. 50 to 55 mm in diameter and 25 mm in height, the top rim of which is ground smooth and level.
6. Glass plates. Two, each 75mm, 75 mm one plate shall be of plain glass and the other shall have prongs.
7. Sieves. 2mm and 425- micron IS sieves.
8. Oven-thermostatically controlled.
9. Graduate-Glass, having a capacity of 25 ml and graduated to 0.2 ml and 100 cc one-mark flask.
10. Balance-Sensitive to 0.01 g minimum.
11. Mercury. Clean, sufficient to fill the glass cup to over flowing.
12. Wash bottle containing distilled water.

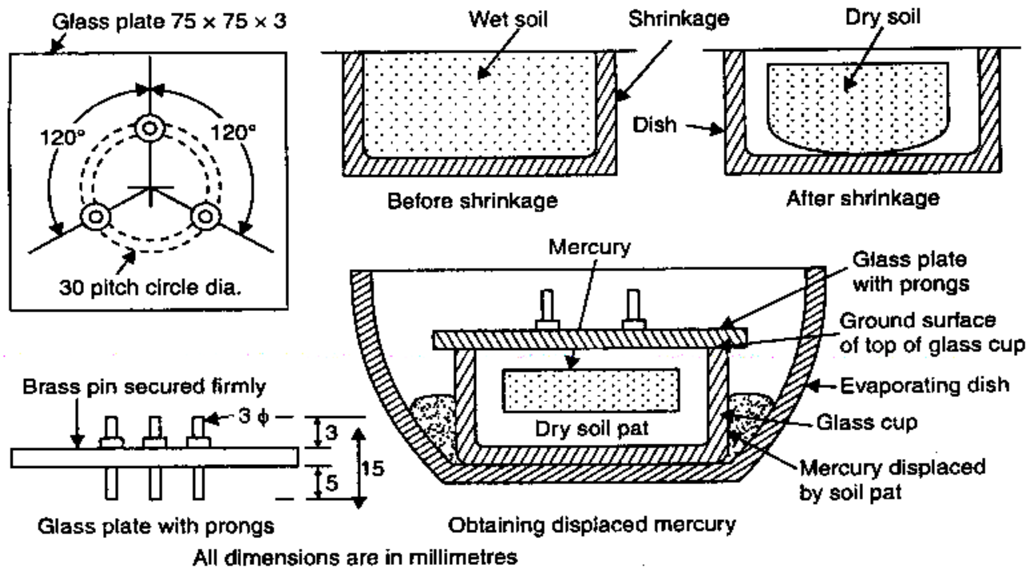

Figure 9.1 Shrinkage Limit Device

Procedure

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 the above soil sample in the evaporating dish and thoroughly mixed with distilled water and make a creamy paste.
   Use water content some where 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.
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 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.

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.

Caution

Do not touch the mercury with gold rings.

Tabulation and results

Table 9.1 Calculation sheet for shrinkage limit determination

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

Result

Average Shrinkage Limit for the given soil sample is ________

Specimen calculations:

Experiment - 10 **Date:**

PERMEABILITY TEST BY CONSTANT HEAD

Objective

Determine the coefficient of permeability of a given soil sample by using constant head method.

Need and scope

The knowledge of this property is much useful in solving problems involving yield of water bearing strata, seepage through earthen dams, stability of earthen dams, and embankments of canal bank affected by seepage, settlement etc.

Planning and organization

1. Preparation of the soil sample for the test
2. Finding the discharge through the specimen under a particular head of water.

Definition of coefficient of permeability

The rate of flow under laminar flow conditions through a unit cross sectional area of porous medium under unit hydraulic gradient is defined as coefficient of permeability.

Apparatus

1. Permeameter mould of non-corrodible material having a capacity of 1000 ml, with an internal diameter of 100mm and internal effective height of 127.3 mm.
2. The mould shall be fitted with a detachable base plate and removable extension counter.
3. Compacting equipment: 50 mm diameter circular face, weight 2.76 kg and height of fall 310 mm as specified in I.S 2720 part VII 1965.
4. Drainage bade: A bade with a porous disc, 12 mm thick which has the permeability 10 times the expected permeability of soil.
5. Drainage cap: A porous disc of 12 mm thick is having a fitting for connection to water inlet or outlet.
6. Constant head tank: A suitable water reservoir capable of supplying water to the permeameter under constant head.
7. Graduated glass cylinder to receive the discharge.
8. Stop watch to note the time.
9. A meter scale to measure the head differences and length of specimen.

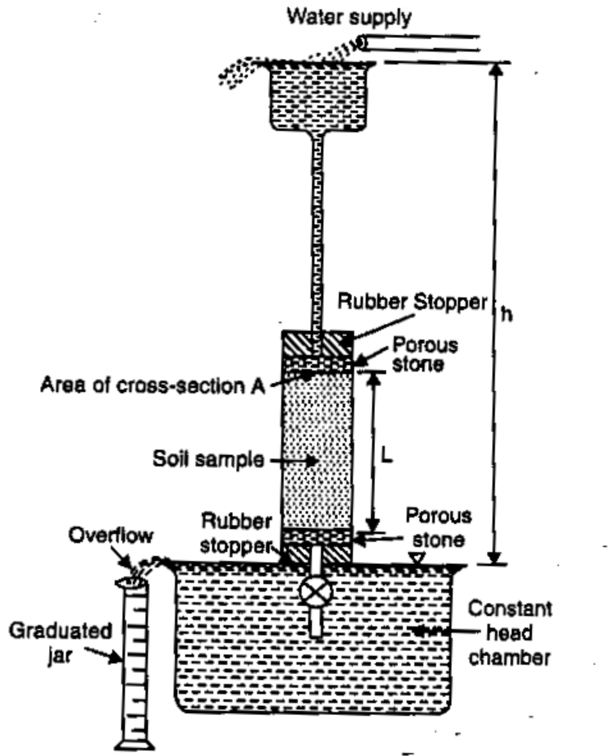

Figure 10.1 Permeability test by constant head method

Preparation of specimen for testing

A. Undisturbed soil sample

1. Note down the sample number, borehole number and its depth at which the sample was taken.
2. Remove the protective cover (paraffin wax) from the sampling tube.
3. Place the sampling tube in the sample extraction frame, and push the plunger to get a cylindrical form sample not longer than 35 mm in diameter and having height equal to that of mould.
4. The specimen shall be placed centrally over the porous disc to the drainage base.
5. The angular space shall be filled with an impervious material such as cement slurry or wax, to provide sealing between the soil specimen and the mould against leakage from the sides.
6. The drainage cap shall then be fixed over the top of the mould.
7. Now the specimen is ready for the test.

B. Disturbed soil sample

1. A 2.5 kg sample shall be taken from a thoroughly mixed air dried or oven dried material.
2. The initial moisture content of the 2.5 kg sample shall be determined. Then the soil shall be placed in the air tight container.
3. Add required quantity of water to get the desired moisture content.
4. Mix the soil thoroughly.
5. Weigh the empty permeameter mould.
6. After greasing the inside slightly, clamp it between the compaction base plate and extension collar.
7. Place the assembly on a solid base and fill it with sample and compact it.
8. After completion of a compaction the collar and excess soil are removed.
9. Find the weight of mould with sample.
10. Place the mould with sample in the permeameter, with drainage base and cap having discs that are properly saturated.

Test procedure

1. For the constant head arrangement, the specimen shall be connected through the top inlet to the constant head reservoir.
2. Open the bottom outlet.
3. Establish steady flow of water.
4. The quantity of flow for a convenient time interval may be collected.
5. Repeat three times for the same interval.

Observation and recording

The flow is very low at the beginning, gradually increases and then stands constant. Constant head permeability test is suitable for cohesion less soils. For cohesive soils falling head method is suitable.

Computation of result

Coefficient of permeability for a constant head test is given by

$$k = \frac{qL}{Ak}$$

where k = coefficient of permeability in cm/sec

q = Discharge cm^3/sec

L = Length of specimen in cm

A = Cross-sectional area of specimen in cm^2

H = Constant head causing flow in cm.

Presentation of data

The coefficient of permeability is reported in cm/sec at 27^{o} C. The dry density, the void ratio and the degree of saturation shall be reported. The test results should be tabulated as below:

Details of sample

Diameter of specimen : _________ cm

Length of specimen (L) : __________ cm

Area of specimen (A) : __________ cm^2

Specific gravity of soil G_s : ___________

Volume of specimen (V) : __________ cm^3

Weight of dry specimen (W_s) : __________ gm

Moisture content : ____________%

Table 10.1 Observation sheet for permeability determination

S. No.	Observations	1	2	3
1	Length of specimen, L (cm)			
2	Area of specimen, A (cm^2)			
3	Time, t (sec)			
4	Discharge, q (cm^3)			
5	Height of water, h (cm)			
6	Temperature, (^{o} C)			

Interpretation

1. Coefficient of Permeability $= \frac{qL}{Ah}$

Discharge = Quantity of water collected (ml)/Time interval (sec)

2. The temperature correction shall be applied by the following formula :

$k_{27} = k_t \times V_t / V_{27}$

where k_{27} = coefficient of permeability at 27^0 C.

k_t = Coefficient of permeability at t^0 C.

V_t = Coeficient of viscosity at t^0C

V_{27} = Coefficient of viscosity at 27^0C.

3. Void Ratio, $e = \frac{VG_s \gamma_w - W_s}{W_s}$

where V = Volume of specimen in cm^3

G_s = Specific gravity of specimen

W_s = weight of dry specimen

γ_w = Density of water

γ_d = Dry density of soil sample

4. Degree of saturation

$S_r = G_s\, w/e$

Where w = Moisture content

e = Voids ratio.

Result

Coefficient of the Permeability for the soil sample is ___________________________.

Specimen calculations:

Experiment - 11 **Date:**

PERMEABILITY TEST BY FALLING HEAD METHOD

Objective

Determine the coefficient of permeability of the given soil sample, using falling head method.

Need and scope

The test results of the permeability experiments are used

1. To estimate ground water flow.
2. To calculate seepage through dams.
3. To find out the rate of consolidation and settlement of structures.
4. To plan the method of lowering the ground water table.
5. To calculate the uplift pressure and piping.
6. To design the grouting.
7. To design pits for recharging.
8. And also for soil freezing tests.

Thus the study of seepage of water through soil is very important, with wide field applications.

The falling head method of determining permeability is used for soil with low discharge, where as the constant head permeability test is used for coarse-grained soils with a reasonable discharge in a given time. For very fine-grained soil, capillarity permeability test is recommended.

Principle of the experiment

The passage of water through porous material is called seepage. A material with continuous voids is called a permeable material. Hence permeability is a property of a porous material which permits passage of fluids through interconnecting conditions. Hence permeability is defined as the rate of flow of water under laminar conditions through a unit cross-sectional area perpendicular to the direction of flow through a porous medium under unit hydraulic gradient and under standard temperature conditions.

The principle behind the test is Darcy's law for laminar flow. The rate of discharge is proportional to (i x A)

$$q = k\ i\ A$$

Where, q= Discharge per unit time.
A=Total area of c/s of soil perpendicular to the direction of flow.
i=hydraulic gradient.
k=Darcy's coefficient of permeability
= the mean velocity of flow that will occur through the cross-sectional area under unit hydraulic gradient.

Apparatus

1. Permeameter with its accessories.
2. Standard soil specimen.
3. Deaired water.
4. Balance to weigh up to 1 gm.
5. I.s sieves 4.75 mm and 2 mm.
6. Mixing pan.
7. Stop watch.
8. Measuring jar.
9. Meter scale.
10. Thermometer.
11. Container for water.
12. Trimming knife etc.

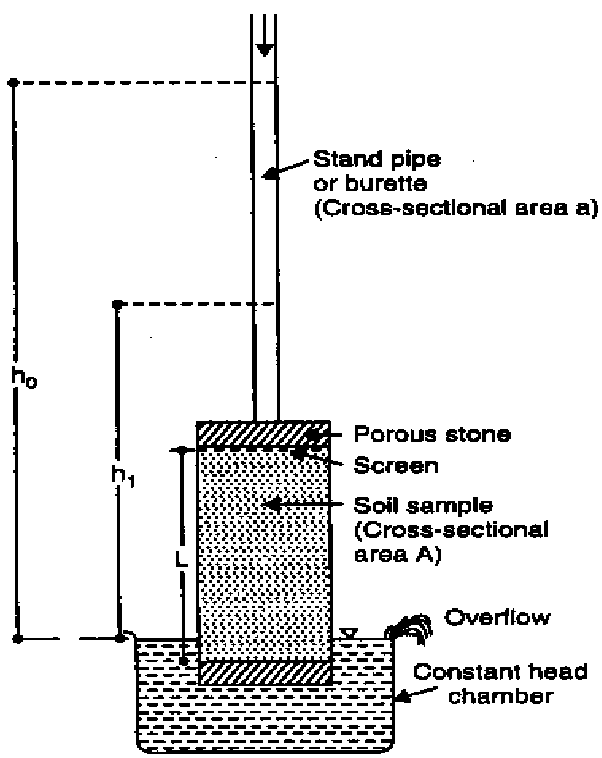

Figure 11.1 Permeability test by variable head Method

Knowledge of equipment

(a) The permeameter is made of non-corrodible material with a capacity of 1000 ml, with an internal diameter of 100/0.1 mm and effective height of 127.3/ 0.1 mm.
(b) The mould has a detachable base plate and a removable exterior collar.
(c) The compacting equipment has a circular face with 50 mm diameter and a length of 310 mm with a weight of 2.6 kg.
(d) The drainage base is a porous disc, 12 mm thick with a permeability 10 times that of soil.
(e) The drainage cap is also a porous disc of 12 mm thickness with an inlet/outlet fitting.
(f) The container tank has an overflow valve. There is also a graduated jar to collect discharge.
(g) The stand pipe arrangements are done on a board with 2 or 3 glass pipes of different diameters.

Preparation of the specimen

The preparation of the specimen for this test is important. There are two types of specimen, the undisturbed soil sample and the disturbed or made up soil sample.

A. Undisturbed soil specimen

The preparation of the sample is as follows.

1. Note down-sample no., borehole no., depth at which sample is taken.
2. Remove the protective cover (wax) from the sampling tube.
3. Place the sampling tube in the sample extractor or and push the plunger to get a cylindrical shaped specimen not larger than 85 mm diameter and height equal to that of the mould.
4. This specimen is placed centrally over the drainage disc of base plate.
5. The annular space in between the mould and specimen is filled with an impervious material like cement slurry to block the side leakage of the specimen.
6. Protect the porous disc when cement slurry is poured.
7. Compact the slurry with a small tamper.
8. The drainage cap is also fixed over the top of the mould.
9. The specimen is now ready for test.

B. Disturbed specimen

The disturbed specimen can be prepared by static compaction or by dynamic compaction.

(a) Preparation of statically compacted (disturbed) specimen

1. Take 800 to 1000 gms of representative soil and mix with water to O.M.C determined by I.S Light Compaction test. Then leave the mix for 24 hours in an airtight container.
2. Find weight W of soil mix for the given volume of the mould and hence find the dry density γ_d *for* $W = \gamma_d (1+W)V$ *by weighing correct to* 1 *gm.*
3. Now, assemble the permeameter for static compaction. Attach the 3 cm collar to the bottom end of 0.3 liters mould and the 2 cm collar to the top end. Support the mould assembly over 2.5 cm end plug, with 2.5 cm collar resting on the split collar kept around the 2.5 cm- end plug. The inside of the 0.3 lit. Mould is lightly greased.
4. Put the weighed soil into the mould. Insert the top 3 cm end plug into the top collar, tamping the soil with hand.
5. Keep, now the entire assembly on a compressive machine and remove the split collar. Apply the compressive force till the flanges of both end plugs touch the corresponding collars. Maintain this load for 1 mt and then release it.
6. Then remove the top 3 cm plug and collar place a filter paper on fine wire mesh on the top of the specimen and fix the perforated base plate.
7. Turn the mould assembly upside down and remove the 2.5 cm end plug and collar. Place the top perforated plate on the top of the soil specimen and fix the top cap on it, after inserting the seating gasket.
8. Now the specimen is ready for test.

(b) Preparation of dynamically compacted disturbed sample

1. Take 800 to 1000 gm of representative soil and mix it with water to get O.M.C, if necessary. Have the mix in airtight container for 24 hours.
2. Assemble the permeameter for dynamic compaction. Grease the inside of the mould and place it upside down on the dynamic compaction base. Weigh the assembly correct to a gram (w). Put the 3 cm collar to the other end.
3. Now, compact the wet soil in 2 layers with 15 blows to each layer with a 2.5 kg dynamic tool. Remove the collar and then trim off the excess. Weigh the mould assembly with the soil (W_2).
4. Place the filter paper or fine wore mesh on the top of the soil specimen and fix the perforated base plate on it.
5. Turn the assembly upside down and remove the compaction plate. Insert the sealing gasket and place the top perforated plate on the top of soil specimen. And fix the top cap.
6. Now, the specimen is ready for test.

Experimental procedure

1. Prepare the soil specimen as specified.
2. Saturate it. Deaired water is preferred.
3. Assemble the permeameter in the bottom tank and fill the tank with water.
4. Inlet nozzle of the mould is connected to the stand pipe. Allow some water to flow until steady flow is obtained.

5. Note down the time interval t for a fall of head in the stand pipe h.
6. Repeat step 5 three times to determine t for the same head.
7. Find a by collecting q for the stand pipe. Weigh it correct to 1 gm and find a from q/h=a.

Therefore the coefficient of permeability

$$k = \frac{2.3 \times a \times L \times (\log_{10} h_1 / h_2)}{A \times t} \quad cm/\sec$$

K at standard temperature of $27^\circ C = K \times \gamma_t / \gamma_{27}$

γ_t = Viscosity of water at temperature, $t\ ^0C$

γ_{27} = Viscosity of water at room temperature $27^0 C$

Interpretation of the result

There are high values, medium values and low values for permeability

$K > 10^{-1}$ cm/sec, the permeability is high

$= 10^{-1}$ cm/sec, it is medium

$< 10^{-1}$ cm/sec, it is low.

Observations

Sample No. — *Moulding water content* :

Dry density : — μ_{27} =

Specific gravity : — γ_{27} =

voids ratio :

Table 11.1 Observation sheet for coefficient of permeability determination

S. No	Observations	1	2	3
1	Area of stand pipe, a, cm			
2	Cross sectional area of soil specimen A			
3	Length of soil specimen L , cm			
4	Initial reading of stand pipe h_1, cm			
5	Final reading of stand pipe h_2, cm			
6	Time, t, sec			
7	Coefficient of permeability (cm/sec) at 27^o C k_{27}			

Result

Coefficient of the permeability is ____________________.

General remarks

1. During test there should be no volume change in the soil, there should be no compressible air present in the voids of soil i.e. soil should be completely saturated. The flow should be laminar and in a steady state condition.

2. Coefficient of permeability is used to assess drainage characteristics of soil, to predict rate of settlement founded on soil bed.

Specimen calculations:

Experiment - 12 **Date:**

STANDARD COMPACTION TEST

Scope

Determination of the relationship between the moisture content and density of soils compacted in a mould of a given size.

Apparatus

1. Proctor mould having a capacity of 944 cc with an internal diameter of 100mm and effective height of 127.3mm. The mould shall have a detachable collar assembly and a detachable base plate.
2. Rammer: A mechanical operated metal rammer of weight of 2.6kg, drop of 310mm for standard test. Rammer with weight of 4.9 kg, drop of 450mm for modified proctor test is used. The rammer shall be equipped with a suitable arrangement to control the height of drop to a free fall.
3. The rammer shall be equipped with a suitable arrangement to control the height of drop to a free fall.
4. Sample extruder.
5. A balance of 15 kg capacity.
6. Sensitive balance.
7. Straight edge.
8. Graduated cylinder.
9. Mixing tools such as mixing pan, spoon, towel, spatula etc.
10. Moisture tins.

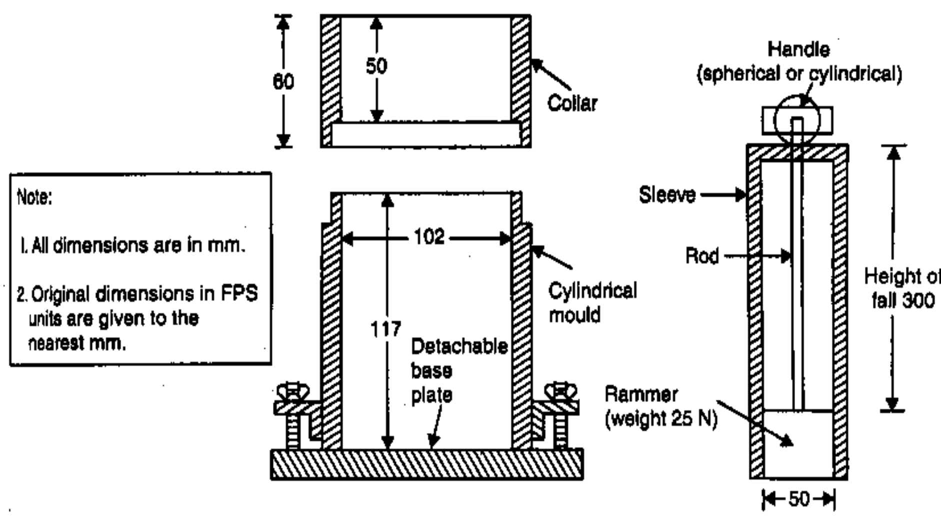

Figure 12.1 Standard compaction test apparatus

Procedure

1. Take a representative oven-dried sample, approximately 3kg in the given pan. Thoroughly mix the sample with sufficient water to dampen it to approximately four to six percentage points below optimum moisture content.
2. Weigh the proctor mould without base plate and collar. Fix the collar and base plate. Place the soil in the Proctor mould and compact it in 3 layers giving 25 blows per layer with the 2.6 kg rammer falling through for standard compaction. And 5 layers giving 25 blows per layer with the heavy rammer falling through for modified test.
3. Remove the collar, trim the compacted soil even with the top of the mould by means of the straight edge and weigh.
4. Divide the weight of the compacted specimen and record the result as the wet weight γ_{wet} in grams per cubic centimeter of the compacted soil.
5. Remove the sample from the mould and slice vertically through and obtain a small sample for moisture determination.
6. Thoroughly break up the remainder of the material and add water in sufficient amounts to increase the moisture content of the soil sample by one or two percentage points and repeat the above procedure for each increment of water added.
7. Continue this series of determination until there is either a decrease or no change in the wet unit weight of the compacted soil.

Calculation

Wet density (gm/cc) = Weight of compacted soil / Volume of the mould

Dry density = Wet density/(1+w)

where w is the moisture content(%) of the soil.

Plot the dry density against moisture content and find out the maximum dry density and optimum moisture for the soil.

Observations

Compaction mould internal diameter : ___________cm

Height of the mould : ___________cm

Volume of the mould : ____________cc

Weight of empty mould : ____________ gm

Table 12.1 Calculation sheet for soil dry density determination

Calculations	1	2	3	4	5
Water added (%)					
Weight of water added (ml)					
Weight of cylinder + compacted soil (gms)					
Weight of compacted soil (gms)					
Determination of Moisture content					
Empty Container No.					
Wt. of empty container in gms					
Wt. of container + wet soil in gms					
Wt. of container + dry soil in gms					
Water content (%)					
Wet density (gm /cc)					
Dry density (gm/cc)					

Result

From Graph, Maximum Dry Density and Optimum Moisture Content are ________________ & __________________ respectively.

Specimen calculations:

Experiment - 13 **Date:**

VANE SHEAR TEST

Objective

Determine the shear strength of a given soil specimen.

Need and scope

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/cm^2) 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.

Equipment

1. Vane shear apparatus
2. Specimen
3. Specimen container
4. Calipers

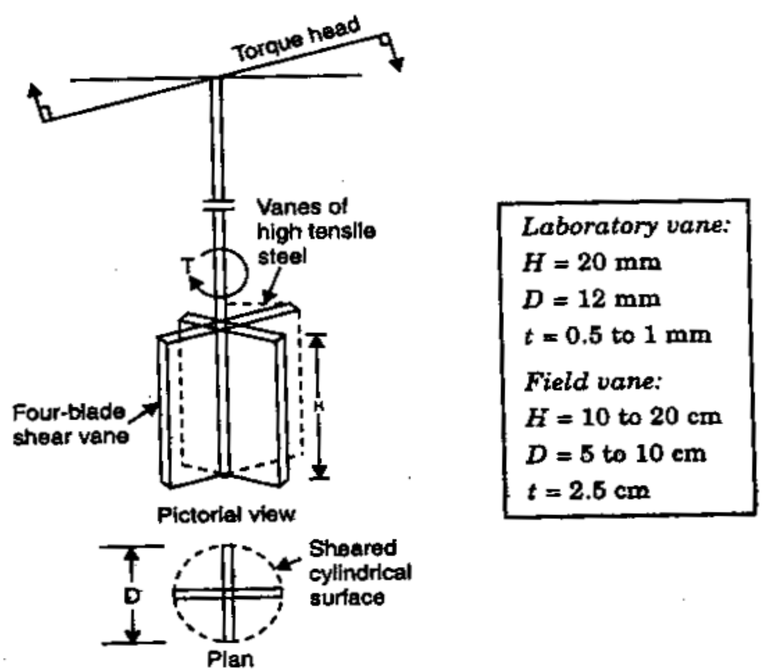

Figure 13.1 Apparatus for vane shear test

Experimental procedure

1. Prepare two or three specimens of the soil sample of dimensions of at least 37.5 mm diameter and 75 mm length in specimen.(L/D ratio 2 or 3).
2. Mount the specimen container with the specimen on the base of the vane shear apparatus. If the specimen container is closed at one end, it should be provided with a hole of about 1 mm diameter at the bottom.
3. Gently lower the shear vanes into the specimen to their full length without disturbing the soil specimen. The top of the vanes should be at least 10 mm below the top of the specimen. Note the readings of the angle of twist.
4. Rotate the vanes at a uniform rate say 0.1^o/s by suitable operating the torque application handle until the specimen fails.
5. Note the final reading of the angle of twist.
6. Find the value of blade height in cm.
7. Find the value of blade width in cm.

Calculations & observations

Shear strength, $S = \frac{T}{\pi(D^2 H/2 + D^3/6)}$

Where S = shear strength of soil in kg/cm2

T = torque in cm kg

D = overall diameter of vane in cm

T = spring constant / 180o x difference in degrees.

Table 13.1 Observation sheet for shear strength determination

S.No	Initial reading (Degrees)	Final reading (Degrees)	Difference (Degrees)	T=Spring Constant* difference/180 Kg-cm	G=1/π(D^2 H/2 + D^3/6)	S=TxG Kg/cm^2	Average 'S' Kg/cm^2	Spring constant Kg-cm

Result

Shear strength for the given soil sample is ______________________________.

General Remarks

This test is useful when the soil is soft and its water content is nearer to liquid limit.

Specimen calculations:

Experiment - 14 **Date:**

DIRECT SHEAR TEST

Objective

Determine the shearing strength of the soil using the direct shear apparatus.

Need and scope

In many engineering problems such as design of foundation, retaining walls, slab bridges, pipes, sheet piling, the value of the angle of internal friction and cohesion of the soil involved are required for the design. Direct shear test is used to predict these parameters quickly. The laboratory reports cover the laboratory procedures for determining these values for cohesionless soils.

Apparatus

1. Direct shear box apparatus
2. Loading frame (motor attached)
3. Dial gauge
4. Proving ring
5. Tamper
6. Straight edge
7. Balance to weigh up to 200 mg
8. Aluminum container
9. Spatula

Knowledge of equipment

Strain controlled direct shear machine consists of shear box, soil container, loading unit, proving ring, dial gauge to measure shear deformation and volume changes. A two piece square shear box is one type of soil container used.

A proving ring is used to indicate the shear load taken by the soil initiated in the shearing plane.

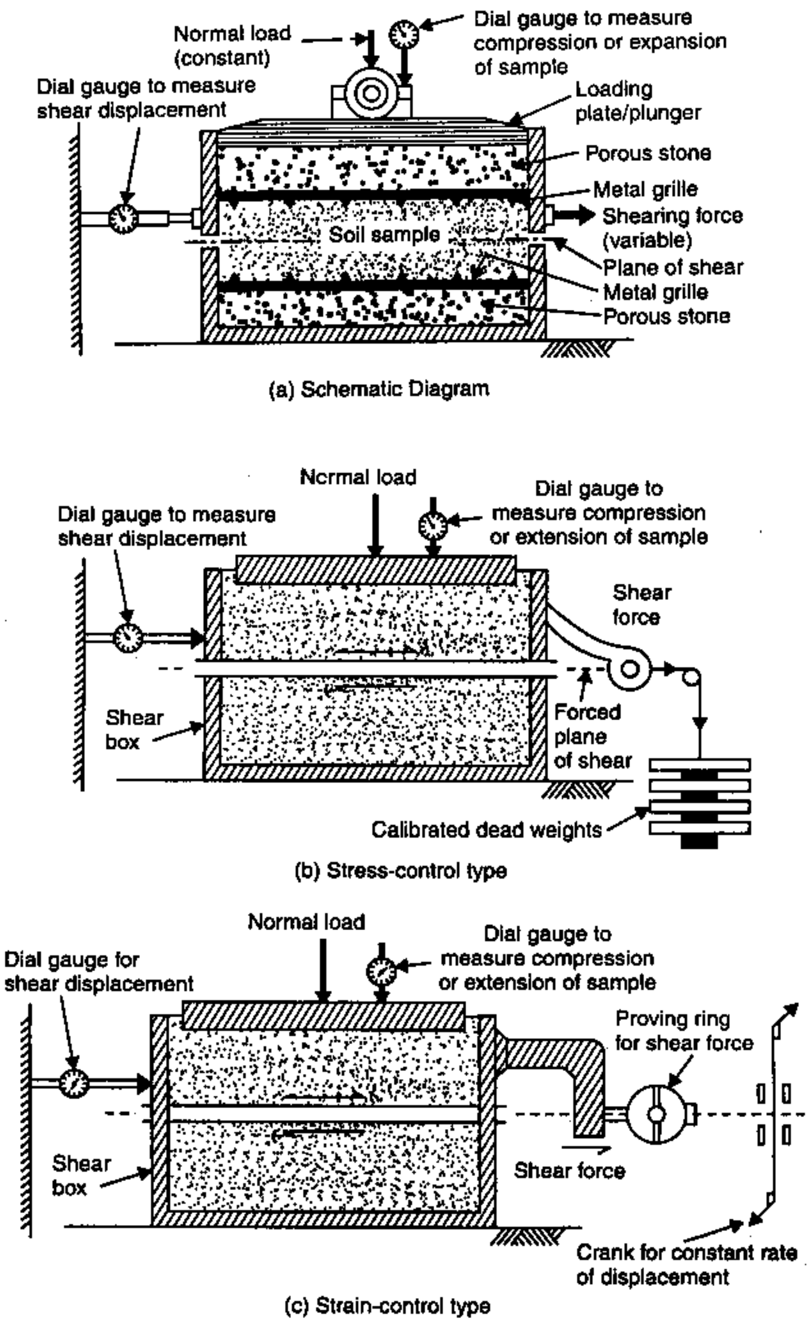

Figure 14.1 Direct shear apparatus

Procedure

1. Check the inner dimension of the soil container.
2. Put the parts of the soil container together.
3. Calculate the volume of the container. Weigh the container.
4. Place the soil in smooth layers (approximately 10 mm thick). If a dense sample is desired tamp the soil.

5. Weigh the soil container, the difference of these two is the weight of the soil. Calculate the density of the soil.
6. Make the surface of the soil plane.
7. Put the upper grating on stone and loading block on top of soil.
8. Measure the thickness of soil specimen.
9. Apply the desired normal load.
10. Remove the shear pin.
11. Attach the dial gauge which measures the change of volume.
12. Record the initial reading of the dial gauge and calibration values.
13. Before proceeding to test check all adjustments to see that there is no connection between two parts except sand/soil.
14. Start the motor. Take the reading of the shear force and record the reading.
15. Take volume change readings till failure.
16. Add 5 kg normal stress 0.5 kg/cm^2 and continue the experiment till failure
17. Record carefully all the readings. Set the dial gauges zero, before starting the experiment

Data calculation sheet for direct shear test

Observations

Proving Ring constant : _______________

Least count of the dial gauge : ________________

Dimensions of shear box : ________________

Table 14.1 Observation sheet for shear stress

S.No	Normal Stress (kg/cm^2)	Proving Ring Reading	Shear Load = Proving Ring reading x L.C Kg	Shear stress = Shear Load / Area of Shear box (kg/cm^2)
1				
2				
3				

Result

Shear parameters (c & ϕ) for the given soil sample from graph are _________________.

General Remarks

1. In the shear box test, the specimen is not failing along its weakest plane but along a predetermined or induced failure plane i.e. horizontal plane separating the two halves of the shear box. This is the main draw back of this test. Moreover, during loading, the state of stress cannot be evaluated. It can be evaluated only at failure condition i.e. Mohr's circle can be drawn at the failure condition only. Also failure is progressive.
2. Direct shear test is simple and faster to operate. As thinner specimens are used in shear box, they facilitate drainage of pore water from a saturated sample in less time. This test is also useful to study friction between two materials. One material in lower half of box and another material in the upper half of box.
3. The angle of shearing resistance of sands depends on state of compaction, coarseness of grains, particle shape and roughness of grain surface and grading. It varies between 28^o (uniformly graded sands with round grains in very loose state) to 46^o (well graded sand with angular grains in dense state).
4. The volume change in sandy soil is a complex phenomenon depending on gradation, particle shape, state and type of packing, orientation of principal planes, principal stress ratio, stress history, magnitude of minor principal stress, type of apparatus, test procedure, method of preparing specimen etc. In general loose sands expand and dense sands contract in volume on shearing. There is a void ratio at which either expansion contraction in volume takes place. This void ratio is called critical void ratio. Expansion or contraction can be inferred from the movement of vertical dial gauge during shearing.
5. The friction between sand particles is due to sliding and rolling friction and interlocking action.

The ultimate values of shear parameter for both loose sand and dense sand approximately attain the same value so, if angle of friction value is calculated at ultimate stage, slight disturbance in density during sampling and preparation of test specimens will not have much effect.

Specimen calculations:

Experiment - 15 **Date:**

UNCONFINED COMPRESSION TEST

Objective

Determine the shear strength of the soil.

Need and scope

It is not always possible to conduct the bearing capacity test in the field. Some times it is cheaper to take the undisturbed soil sample and test its strength in the laboratory. Also to choose the best material for the embankment, one has to conduct strength tests on the samples selected. Under these conditions it is easy to perform the unconfined compression test on undisturbed and remoulded soil sample. Investigate experimentally the strength of a given soil sample.

Planning and organization

Find out the diameter and length of the specimen.

Equipment

1. Loading frame of capacity of 2t, with constant rate of movement. (note the least count of the dial gauge attached to the proving ring)
2. Proving ring of 0.01 kg sensitivity for soft soils; 0.05 kg for stiff soils
3. Soil trimmer
4. Frictionless end plates of 75 mm diameter (perspex plate with silicon grease coating)
5. Evaporating dish (aluminum container)
6. Soil sample of 75 mm length
7. Dial gauge (0.01 mm accuracy)
8. Balance of capacity 200 g and sensitivity to weigh 0.01 g
9. Oven thermostatically controlled with interior of non-corroding material to maintain the temperature at the desired level
10. Sample extractor and split sampler
11. Dial gauge (sensitivity 0.01mm)
12. Vernier calipers

Experimental procedure (specimen)

In this test, a cylinder of soil without lateral support is tested to failure in simple compression, at a constant rate of strain. The compressive load per unit area required to fail the specimen as called unconfined compressive strength of the soil.

Preparation of specimen for testing

(A) Undisturbed specimen

1. Note down the sample number, borehole number and the depth at which the sample was taken.
2. Remove the protective cover (paraffin wax) from the sampling tube.
1. Place the sampling tube extractor and push the plunger till a small length of sample moves out.
2. Trim the projected sample using a wire saw.
3. Again push the plunger of the extractor till a 75 mm long sample comes out.
4. Cutout this sample carefully and hold it on the split sampler so that it does not fall.
5. Take about 10 to 15 g of soil from the tube for water content determination.
6. Note the container number and take the net weight of the sample and the container.
7. Measure the diameter at the top, middle, and the bottom of the sample and find the average and record the same.
8. Measure the length of the sample and record.
9. Find the weight of the sample and record.

(B) Disturbed sample

1. For the desired water content and the dry density, calculate the weight of the dry soil Ws required for preparing a specimen of 3.8 cm diameter and 7.5 cm long.
2. Add required quantity of water W_w to this soil. $W_w = W_S - W/100$ gm
3. Mix the soil thoroughly with water.
4. Place the wet soil in a tight thick polythene bag in a humidity chamber and place the soil in a constant volume mould, having an internal height of 7.5 cm and internal diameter of 3.8 cm.
5. After 24 hours take the soil from the humidity chamber and place the soil in a constant volume mould, having an internal height of 7.5 cm and internal diameter of 3.8 cm.
6. Place the lubricated moulded with plungers in position in the load frame.
7. Apply the compressive load till the specimen is compacted to a height of 7.5 cm.
8. Eject the specimen from the constant volume mould.
9. Record the correct height, weight and diameter of the specimen.

Test procedure

1. Take two frictionless bearing plates of 75 mm diameter.
2. Place the specimen on the base plate of the load frame (sandwiched between the end plates).
3. Place a hardened steel ball on the bearing plate.
4. Adjust the center line of the specimen such that the proving ring and the steel ball are in the same line.
5. Fix a dial gauge to measure the vertical compression of the specimen.
6. Adjust the gear position on the load frame to give suitable vertical displacement.
7. Start applying the load and record the readings of the proving ring dial and compression dial for every 0.5 mm compression.
8. Continue loading till failure is complete.
9. Draw the sketch of the failure pattern in the specimen.

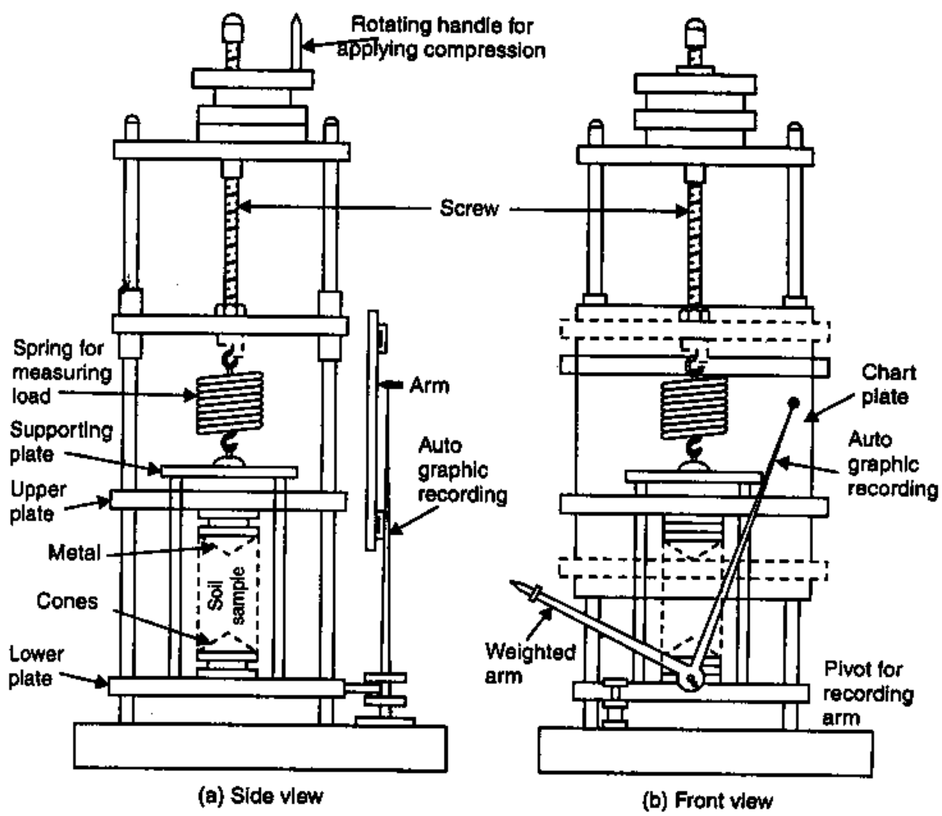

Figure 15.1 Unconfined compression test apparatus

Sample details

Dry density : ________________
Water content : ________________
Diameter (D_o) of the sample : ________________cm
Area of cross-section : ________________cm^2
Initial length (L_o) of the sample : ________________ cm

Table 15.1 Calculation sheet for compressive stress determination

Compression dial reading (Div)	Compression dial reading (L) (mm)	Strain(e) = L * 100/L_o (%)	Area (A) = A_o /(1-e) $(cm)^2$	Proving ring reading (Div)	Axial load = Proving Ring reading x L.C (kg)	Compressive stress = Axial load/Area (kg/cm^2)

Results

Unconfined compression strength of the soil = q_u = ___________________________

Shear strength of the soil = $q_u/2$ = ______________________________

General remarks

Minimum three samples should be tested; correlation can be made between unconfined strength and field SPT value N. Up to 6% strain the readings may be taken at every min (30 sec).

Specimen calculations:

Experiment - 16 **Date:**

UNDRAINED TRIAXIAL TEST

Objective

To find the shear parameters of the soil by undrained triaxial test.

Need and scope

The standard consolidated undrained test is compression test, in which the soil specimen is first consolidated under all round pressure in the triaxial cell before failure is brought about by increasing the major principal stress.

It may be performing with or without measurement of pore pressure although for most applications the measurement of pore pressure is desirable.

Knowledge of equipment

A constant rate of strain compression machine of which the following is a brief description of one is in common use.

a) A loading frame in which the load is applied by yoke acting through an elastic dynamometer, more commonly called a proving ring which used to measure the load. The frame is operated at a constant rate by a geared screw jack. It is preferable for the machine to be motor driven, by a small electric motor.

b) A hydraulic pressure apparatus including an air compressor and water reservoir in which air under pressure acting on the water raises it to the required pressure, together with the necessary control valves and pressure dials.

A triaxial cell is to take 3.8 cm dia and 7.6 cm long samples, in which the sample can be subjected to an all round hydrostatic pressure, together with a vertical compression load acting through a piston. The vertical load from the piston acts on a pressure cap. The cell is usually designed with a non-ferrous metal top and base connected by tension rods and with walls formed of Perspex.

Apparatus for preparation of the sample

a) 3.8 cm (1.5 inch) internal diameter 12.5 cm (5 inches) long sample tubes.
b) Rubber ring.
c) An open ended cylindrical section former, 3.8 cm inside dia, fitted with a small rubber tube in its side.
d) Stop clock.

e) Moisture content test apparatus.
f) A balance of 250 gm capacity and accurate to 0.01 gm.

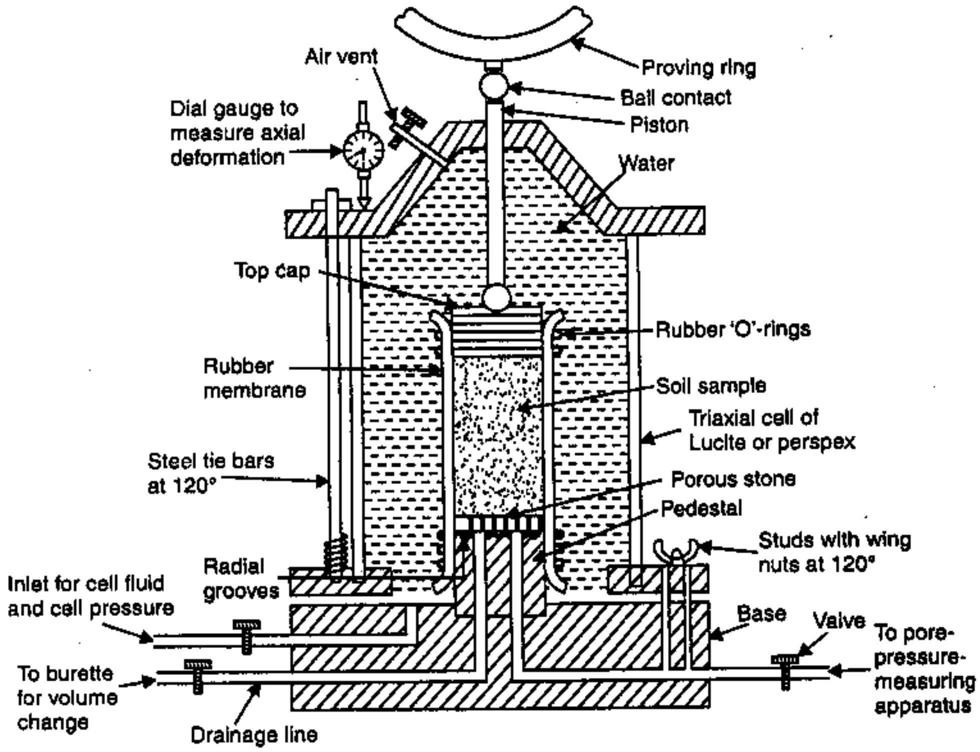

Figure 16.1 Tri axial test apparatus

Experimental procedure

1. The sample is placed in the compression machine and a pressure plate is placed on the top. Care must be taken to prevent any part of the machine or cell from jogging the sample while it is being setup, for example, by knocking against this bottom of the loading piston. The probable strength of the sample is estimated and a suitable proving ring selected and fitted to the machine.

2. The cell must be properly set up and uniformly clamped down to prevent leakage of pressure during the test, making sure first that the sample is properly sealed with its end caps and rings (rubber) in position and that the sealing rings for the cell are also correctly placed.

3. When the sample is setup water is admitted and the cell is fitted under water escapes from the beed valve, at the top, which is closed. If the sample is to be tested at zero lateral pressure water is not required.

4. The air pressure in the reservoir is then increased to raise the hydrostatic pressure in the required amount. The pressure gauge must be watched during the test and any necessary adjustments must be made to keep the pressure constant.

5. The handle wheel of the screw jack is rotated until the under side of the hemispherical seating of the proving ring, through which the loading is applied, just touches the cell piston.

6. The piston is then removed down by handle until it is just in touch with the pressure plate on the top of the sample, and the proving ring seating is again brought into contact for the begging of the test.

Observations

1. The machine is set in motion (or if hand operated the hand wheel is turned at a constant rate) to give a rate of strain 2% per minute.
2. The strain dial gauge reading is then taken and the corresponding proving ring reading is taken the corresponding proving ring chart. The load applied is known.
3. The experiment is stopped at the strain dial gauge reading for 15% length of the sample or 15% strain.

Size of specimen:

Length: Proving ring constant:

Diameter: Initial area L:

Initial Volume: Strain dial gauge least count (const):

Table 16.1 Tabulation sheet for triaxial test

Cell pressure kg/cm^2	Strain dial	Proving ring reading	Load on sample kg	Corrected area cm^2	Deviator stress
0.5	0 50 100 150 200 250 300 350 400 450				
1.0	0 50 100 150 200 250 300 350 400 450				
1.5	0 50 100 150 200 250 300 350 400 450				

Table 16.2 Tabulation sheet for shear strength determination

Sample No.	Wet bulk density gm/cc	Cell pressure kg/cm^2	Compressive stress at failure	Strain at failure	Moisture content	Shear strength (kg/cm^2)	Angle of shearing resistance
1 2 3							

Result

Shear parameters for the given soil sample are ________________________.

General remarks

a) It is assumed that the volume of the sample remains constant and that the area of the sample increases uniformly as the length decreases. The calculation of the stress is based on this new area at failure, by direct calculation, using the proving ring constant and the new area of the sample. By constructing a chart relating strain readings, from the proving ring, directly to the corresponding stress.

b) The strain and corresponding stress is plotted with stress abscissa and curve is drawn. The maximum compressive stress at failure and the corresponding strain and cell pressure are found out.

c) The stress results of the series of triaxial tests at increasing cell pressure are plotted on a mohr stress diagram. In this diagram a semicircle is plotted with normal stress as abscissa shear stress as ordinate.

d) The condition of the failure of the sample is generally approximated to by a straight line drawn as a tangent to the circles, the equation of which is $\tau = C + \alpha \tan\phi$. The value of cohesion, C is read of the shear stress axis, where it is cut by the tangent to the mohr circles, and the angle of shearing resistance (ϕ) is angle between the tangent and a line parallel to the shear stress.

Specimen calculations:

Experiment - 17 **Date:**

CONSOLIDATION TEST

Objective

Determine the settlements due to primary consolidation of soil by conducting one dimensional test.

Need and scope

The test is conducted to determine the settlement due to primary consolidation. To determine the following

1. Rate of consolidation under normal load.
2. Degree of consolidation at any time.
3. Pressure-void ratio relationship.
4. Coefficient of consolidation at various pressures.
5. Compression index.

From the above information it will be possible for us to predict the time rate and extent of settlement of structures founded on fine-grained soils. It is also helpful in analyzing the stress history of soil. Since the settlement analysis of the foundation depends mainly on the values determined by the test, this test is very important for foundation design.

Planning and organization

1. Consolidometer consisting essentially
   a) A ring of diameter = 60mm and height = 20mm
   b) Two porous plates or stones of silicon carbide, aluminum oxide or porous metal.
   c) Guide ring.
   d) Outer ring.
   e) Water jacket with base.
   f) Pressure pad.
   g) Rubber basket.
2. Loading device consisting of frame, lever system, loading yoke dial gauge fixing device and weights.
3. Dial gauge to read to an accuracy of 0.002mm.
4. Thermostatically controlled oven.
5. Stopwatch to read seconds.
6. Sample extractor.
7. Miscellaneous items like balance, soil trimming tools, spatula, filter papers, sample containers.

Principle

When a compressive load is applied to soil mass, a decrease in its volume takes place, the decease in volume of soil mass under stress is known as compression and the property of soil mass pertaining to its tendency to decrease in volume under pressure is known as compressibility. In a saturated soil mass having its void filled with incompressible water, decrease in volume or compression can take place when water is expelled out of the voids. Such a compression resulting from a long time static load and the consequent escape of pore water is termed as consolidation.

Then the load is applied on the saturated soil mass, the entire load is carried by pore water in the beginning. As the water starts escaping from the voids, the hydrostatic pressure in water gets gradually dissipated and the load is shifted to the soil solids which increases effective on them, as a result the soil mass decrease in volume. The rate of escape of water depends on the permeability of the soil.

1) From the sample tube, eject the sample into the consolidation ring. The sample should project about one cm from outer ring. Trim the sample smooth and flush with top and bottom of the ring by using a knife. Clean the ring from outside and keep it ready from weighing.
2) Remoulded sample:
   a) Choose the density and water content at which sample has to be compacted from the moisture density relationship.
   b) Calculate the quantity of soil and water required to mix and compact.
   c) Compact the specimen in compaction mould in three layers using the standard rammers.
   d) Eject the specimen from the mould using the sample extractor.

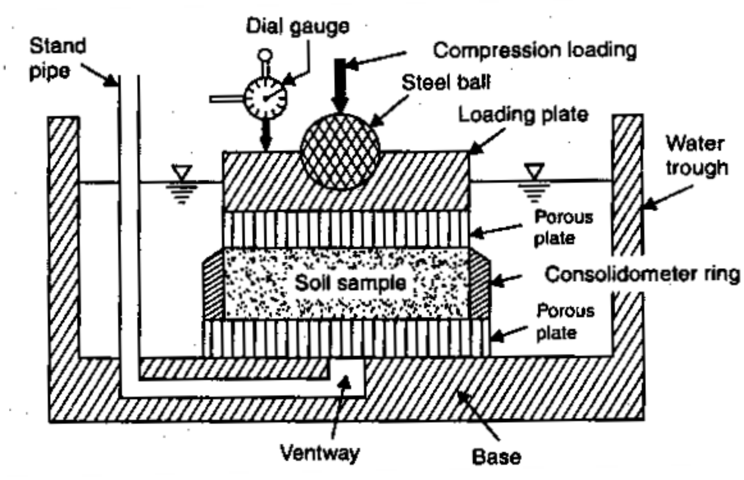

Figure 17.1 Consolidation test apparatus

Procedure

1. Saturate two porous stones either by boiling in distilled water about 15 minute or by keeping them submerged in the distilled water for 4 to 8 hrs. Wipe away excess water. Fittings of the consolidometer which is to be enclosed shall be moistened.
2. Assemble the consolidometer, with the soil specimen and porous stones at top and bottom of specimen, providing a filter paper between the soil specimen and porous stone. Position the pressure pad centrally on the top porous stone.
3. Mount the mould assembly on the loading frame, and center it such that the load applied is axial.
4. Position the dial gauge to measure the vertical compression of the specimen. The dial gauge holder should be set so that the dial gauge is in the begging of its releases run, allowing sufficient margin for the swelling of the soil, if any.
5. Connect the mould assembly to the water reservoir and the sample is allowed to saturate. The level of the water in the reservoir should be at about the same level as the soil specimen.
6. Apply an initial load to the assembly. The magnitude of this load should be chosen by trial, such that there is no swelling. It should be not less than 50 g/cm^3 for ordinary soils & 25 g/cm^2 for very soft soils. The load should be allowed to stand until there is no change in dial gauge readings for two consecutive hours or for a maximum of 24 hours.
7. Note the final dial reading under the initial load. Apply first load of intensity 0.1 kg/cm^2 start the stop watch simultaneously. Record the dial gauge readings at various time intervals. The dial gauge readings are taken until 90% consolidation is reached. Primary consolidation is gradually reached within 24 hrs.
8. At the end of the period, specified above take the dial reading and time reading. Double the load intensity and take the dial readings at various time intervals. Repeat this procedure fir successive load increments. The usual loading intensity is as follows 0.1, 0.2, 0.5, 1, 2, 4 and 8 kg/cm^2.
9. After the last loading is completed, reduce the load to the value of the last load and allow it to stand for 24 hrs. Reduce the load further in steps of the previous intensity till an intensity of 0.1 kg/cm^2 is reached. Take the final reading of the dial gauge.
10. Reduce the load to the initial load, keep it for 24 hrs and note the final readings of the dial gauge.
11. Quickly dismantle the specimen assembly and remove the excess water on the soil specimen in oven, note the dry weight of it.

Observation and reading

Empty weight of ring: Area of ring:

Diameter of ring: Volume of ring:

Height of ring: Dial Gauge (least count):

Table 17.1 Observation sheet for time-pressure of consolidation test

Pressure Intensity (Kg/cm^2) / Elapsed Time (min)	0.1	0.2	0.5	1	2	4	8
0.25							
1							
4							
6.25							
9							
16							
25							
36							
49							
64							
81							
100							

Table 17.2 Observation sheet for consolidation test

Pressure Intensity (Kg/cm^2) / Elapsed Time (min)	0.1	0.2	0.5	1	2	4	8
1							
2							
5							
10							
20							
30							
45							
60							
90							

Calculations

1. Height of solids (H_S) is calculated from the equation

$$H_S = W_S/G * A$$

2. Void ratio. Voids ratio at the end of various pressures are calculated from equation

$$e = (H - H_S)/H_S$$

3. Coefficient of consolidation. The Coefficient of consolidation at each pressures increment is calculated by using the following equations:

i. $C_v = 0.197\ d^2/t_{50}$ (Log fitting method)
ii. $C_v = 0.848\ d^2/t_{90}$ (Square fitting method)

In the log fitting method, a plot is made between dial readings and logarithmic of time, the time corresponding to 50% consolidation is determined.
In the square root fitting method, a plot is made between dial readings and square root of time and the time corresponding to 90% consolidation is determined. The values of C_v are recorded in table.

4. Compression Index. To determine the compression index, a plot of voids ratio (e) V_s log t is made. The initial compression curve would be a straight line and the slope of this line would give the compression index C_c.

5. Coefficient of compressibility. It is calculated as follows

$a_v = 0.435\ C_c$/Avg. pressure for the increment

where C_c = Coefficient of compressibility

6. Coefficient of permeability. It is calculated as follows

$K = C_v.a_v$ *(unit weight of water)/(1+e).

Graphs

1. Dial reading V_S log of time or
   Dial reading V_S square root of time.
2. Voids ratio V_S logσ (average pressure for the increment).

Result

Consolidation parameters for the given soil sample are ________.

General remarks

1. While preparing the specimen, attempts has to be made to have the soil strata orientated in the same direction in the consolidation apparatus.
2. During trimming care should be taken in handling the soil specimen with least pressure.
3. Smaller increments of sequential loading have to be adopted for soft soils.

Specimen calculations:

Experiment - 18 **Date:**

CALIFORNIA BEARING RATIO TEST

Objective

Determine the California bearing ratio by conducting a load penetration test in the laboratory.

Need and scope

The California bearing ratio test is penetration test meant for the evaluation of sub grade strength of roads and pavements. The results obtained by these tests are used with the empirical curves to determine the thickness of pavement and its component layers. This is the most widely used method for the design of flexible pavement.

This instruction sheet covers the laboratory method for the determination of CBR. Of undisturbed and remoulded /compacted soil specimens, both in soaked as well as unsoaked state.

Planning and organization

Equipments and tool required are

1. Cylindrical mould with inside dia 150 mm and height 175 mm, provided with a detachable extension collar 50 mm height and a detachable perforated base plate 10 mm thick.
2. Spacer disc 148 mm in dia and 47.7 mm in height along with handle.
3. Metal rammers. Weight 2.6 kg with a drop of 310 mm (or) weight 4.89 kg a drop 450 mm.
4. Weights. One annular metal weight and several slotted weights weighing 2.5 kg each, 147 mm in dia, with a central hole 53 mm in diameter.
5. Loading machine. With a capacity of at least 5000 kg and equipped with a movable head or base that travels at an uniform rate of 1.25 mm/min. Complete with load indicating device.
6. Metal penetration piston 50 mm dia and minimum of 100 mm in length.
7. Two dial gauges reading to 0.01 mm.
8. Sieves. 4.75 mm and 20 mm I.S. Sieves.
9. Miscellaneous apparatus, such as a mixing bowl, straight edge, scales soaking tank or pan, drying oven, filter paper and containers.

Definition of CBR

It is the ratio of force per unit area required to penetrate a soil mass with standard circular piston at the rate of 1.25 mm/min. to that required for the corresponding penetration of a standard material.

C.B.R. = Test load/Standard load * 100

The following Table gives the standard loads adopted for different penetrations for the standard material with a C.B.R. value of 100%

Table 18.1 Values of penetration vs standard load

Penetration of plunger (mm)	Standard load (kg)
2.5	1370
5	2055
7.5	2630
10	3180
12.5	3600

The test may be performed on undisturbed specimens and on remoulded specimens who may be compacted either statically or dynamically.

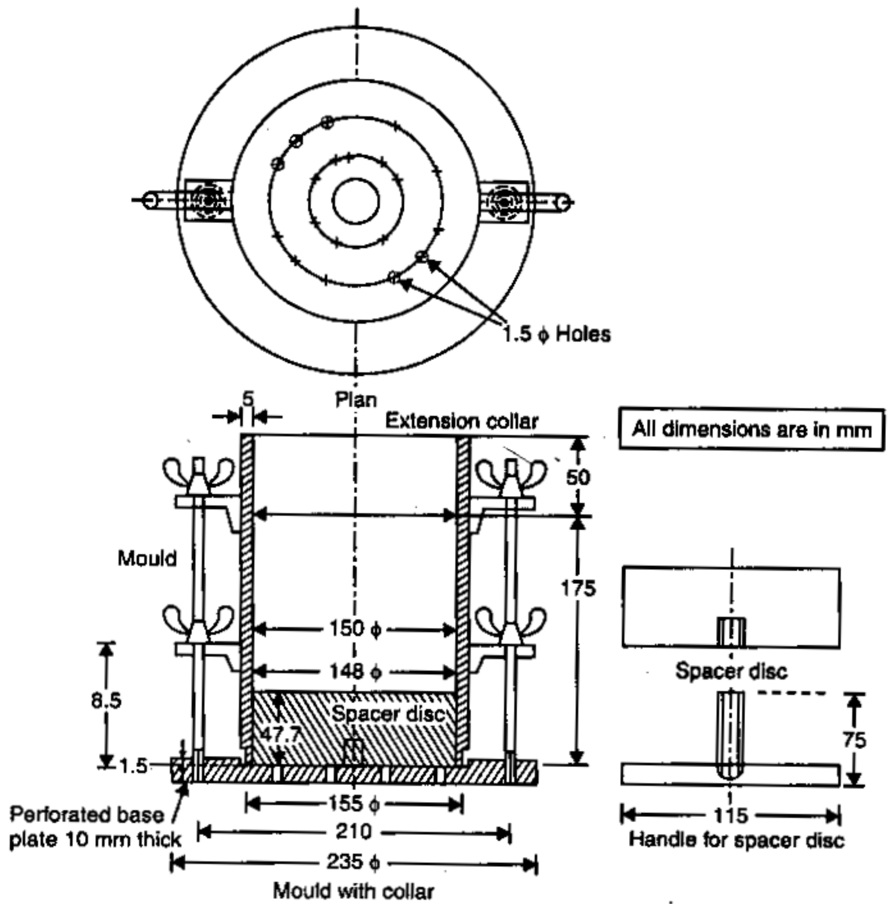

Figure 18.1 CBR Test

Preparation of test specimen

(A) Undisturbed specimen

Attach the cutting edge to the mould and push it gently into the ground. Remove the soil from the outside of the mould which is pushed in. When the mould is full of soil, remove it from weighing the soil with the mould or by any field method near the spot.
Determine the density

(B) Remoulded specimen

Prepare the remoulded specimen at Proctor's maximum dry density or any other density at which C.B.R. is required. Maintain the specimen at optimum moisture content or the field moisture as required. The material used should pass 20 mm I.S. sieve but it should be retained on 4.75 mm I.S. sieve. Prepare the specimen either by dynamic compaction or by static compaction.

Dynamic compaction

1. Take about 4.5 to 5.5 kg of soil and mix thoroughly with the required water.
2. Fix the extension collar and the base plate to the mould. Insert the spacer disc over the base (See Fig.38). Place the filter paper on the top of the spacer disc.
3. Compact the mix soil in the mould using either light compaction or heavy compaction. For light compaction, compact the soil in 3 equal layers, each layer being given 55 blows by the 2.6 kg rammer. For heavy compaction compact the soil in 5 layers, 56 blows to each layer by the 4.89 kg rammer.
4. Remove the collar and trim off soil.
5. Turn the mould upside down and remove the base plate and the displacer disc.
6. Weigh the mould with compacted soil and determine the bulk density and dry density.
7. Put filter paper on the top of the compacted soil (collar side) and clamp the perforated base plate on to it.

Static compaction

1. Calculate the weight of the wet soil at the required water content to give the desired density when occupying the standard specimen volume in the mould from the expression.

   W =desired dry density * (1+w) V
2. Where W = Weight of the wet soil
3. w = desired water content
4. V = volume of the specimen in the mould = 2250 cm^3 (as per the mould available in laboratory)
5. Take the weight W (calculated as above) of the mix soil and place it in the mould.
6. Place a filter paper and the displacer disc on the top of soil.
7. Keep the mould assembly in static loading frame and compact by pressing the displacer disc till the level of disc reaches the top of the mould.
8. Keep the load for some time and then release the load. Remove the displacer disc.
9. The test may be conducted for both soaked as well as unsoaked conditions.
10. If the sample is to be soaked, in case of compaction, put a filter paper on the top of the soil and place the adjustable stem and perforated plate on the top of filter paper.
11. Put annular weights to produce a surcharge equal to weight of base material and pavement expected in actual construction. Each 2.5 kg weight is equivalent to 7 cm construction. A minimum of two weights should be put.
12. Immerse the mould assembly and weights in a tank of water and soak it for 96 hours. Remove the mould from tank.
13. Note the consolidation of the specimen.

Procedure for penetration test

1. Place the mould assembly with the surcharge weights on the penetration test machine.
2. Seat the penetration piston at the center of the specimen with the smallest possible load, but in no case in excess of 4 kg so that full contact of the piston on the sample is established.
3. Set the stress and strain dial gauge to read zero. Apply the load on the piston so that the penetration rate is about 1.25 mm/min.
4. Record the load readings at penetrations of 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 7.5, 10 and 12.5 mm. Note the maximum load and corresponding penetration if it occurs for a penetration less than 12.5 mm.
5. Detach the mould from the loading equipment. Take about 20 to 50 g of soil from the top 3 cm layer and determine the moisture content.

Observations

For dynamic compaction

Optimum water content (%) :
Weight of mould + compacted specimen gms :
Weight of empty mould gms :
Weight of compacted specimen gms :
Volume of specimen cm^3 :
Bulk density g/cc :
Dry density g/cc :

For static compaction

Dry density g/cc :
Moulding water content % :
Wet weight of the compacted soil, (W) g :
Period of soaking for 96 hrs. (4days) :

For penetration test

Calibration factor of the proving ring 1 Div. = ________ kg
Surcharge weight used (kg)
Water content after penetration test %
Least count of penetration dial 1 Div. = 0.01 mm

If the initial portion of the curve is concave upwards, apply correction by drawing a tangent to the curve at the point of greatest slope and shift the origin. Find and record the correct load reading corresponding to each penetration.

$$C.B.R. = P_T/P_S * 100$$

Where P_T = Corrected test load corresponding to the chosen penetration from the load penetration curve.

P_S = Standard load for the same penetration taken from the table above.

Table 18.2 Tabulation for CBR test

Penetration dial		**Load dial**		**Corrected load**
Readings (Div)	Penetration (mm)	Proving ring reading (Div)	Load = Proving ring reading * L.C (kg)	

Result

C.B.R. for the soil specimen is ______________________

General remarks

The C.B.R. values are usually calculated for penetration of 2.5 mm and 5 mm. Generally the C.B.R. value at 2.5 mm will be greater than value at 5 mm and in such a case/the former shall be taken as C.B.R. for design purpose. If C.B.R. for 5 mm exceeds that for 2.5 mm, the test should be repeated. If identical results follow, the C.B.R. corresponding to 5 mm penetration should be taken for design.

Specimen calculations:

Experiment - 19 **Date:**

RELATIVE DENSITY TEST

Objective

Determine the relative density for a given cohesionless material.

Planning and Organization

Equipments and tool required are

1. Cushioned steel vibrating deck 75x75 cm size, R.P.M : 3600 ; under a 115 kg load, 440V, 3 phase supply.
2. Two cylindrical metallic moulds, 3000 cc and 15000 cc.
3. 10 mm thick surcharge base plate with handle separately for each mould. Surcharge weights, one for each size having a weight equal to 140gms/sq.cm.
4. Dial gauge holder, which can be slipped into the eyelets on the moulds sides.
5. Guide sleeves with clamps for each mould separately.
6. Calibration bar 75x300x3 mm.

Definitions

Relative density or density index is the ratio of the difference between the void ratios of a cohesionless soil in its loosest state and existing natural state to the difference between its void ratio in the loosest and densest states.

$$\text{Relative Density} = \frac{e_{ma} - e}{e_{max} - e_{min}}$$

Where,
e_{max} = void ratio of coarse grained soil (cohesionless) in its loosest state.
e_{min} = void ratio of coarse grained soil (cohesionless) in its densest state.
e =void ratio of coarse grained soil (cohesionless) in its natural existing state in the field.

Theory

Porosity of a soil depends on the shape of grain, uniformity of grain size and condition of sedimentation. Hence porosity itself does not indicate whether a soil is in loose or dense state. This information can only be obtained by comparing the porosity or void ratio of the given soil with that of the same soil in its loosest and densest possible state and hence the term, relative density is introduced.

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

$We\ have,\ e = V_v / V_s$

$and \quad \gamma_d = G\gamma_w/(1+e)$

$\therefore e = G\gamma_w / \gamma_d - 1$

$So, e\ is\ inversely\ proporational\ to\ its\ dry\ density\ (\gamma_d)$

$$Relative\ Density = \frac{\frac{1}{(\gamma_d)_{min}} - \frac{1}{(\gamma_d)}}{\frac{1}{(\gamma_d)_{min}} - \frac{1}{(\gamma_d)_{max}}}$$

Relative density is an arbitrary character of sandy deposit. In real sense, relative density expresses the ratio of actual decrease in volume of voids in a sandy soil to the maximum possible decrease in the volume of voids i.e how far the sand under investigation can be capable to the further densification beyond its natural state. Determination of relative density is helpful in compaction of coarse grained soils and in evaluating safe bearing capacity in case of sandy soils.
For very dense gravelly sand, it is possible to obtain relative density greater the one. This means that such natural dense packing could not be obtained in the laboratory.

Procedure

Calibration of mould

1. Measure inside diameter of mould at different depths using a bore gauge and take the average.
2. Keep the mould on a flat surface or flat plate. Measure the height at different positions and take the average (accuracy = 0.025 mm).
3. Calculate the volume.
4. Fill the mould with distilled water till over flowing takes place.
5. Slid thick glass plate over the top surface of mould.
6. Weigh the water filling the mould.
7. Note the temperature of water.
8. Obtain density of water for the above temperature from physical tables.
9. Calculate the volume of the mould which is weight of water filling the mould /density of water.

Preparation of the Sample:

1. Dry the soil sample in a thermostatically controlled electric oven.
2. Cool in the sample in a desicator.
3. Segregate soil lumps with out breaking individual particles

4. Sieve it through the required sieve size.

Minimum Density:

The mould is weighed accurately (W). Pour the dry pulverized soil into the mould through a funnel in a steady stream. The spout is adjusted so that the free fall of soil particle is always 25 mm. While pouring soil the spout must have a spiral motion from the rim to the centre. The process is continued to fill up the mould with soil up to about 25mm above the top. It is then leveled, with the soil and weight is recorded (W_1).

$$Volume\ of\ mould\ \ V\ cc$$
$$Mass\ of\ dry\ soil\ M_s = (W_1 - W)\ gm$$
$$(\gamma_d)_{min} = M_s / V\ g/cc$$
$$e_{max} = G\gamma_w / (\gamma_d)_{min} - 1$$

Maximum Density:

Weigh the empty mould (W). Put the collar on top of the mould and clamp it. Fill the mould with the oven dried soil sample till 1/2 or 2/3 of the collar is filled. Place the mould on the vibrating deck and fix it with nuts and bolts. Then place the surcharge weight on it. The vibrator is allowed to run for 8 minutes. Then mould is weighed with the soil and weight is recorded (W_2).

$$Volume\ of\ mould\ \ V\ cc$$
$$Mass\ of\ dry\ soil\ M_s = (W_2 - W) \quad gm$$
$$(\gamma_d)_{max} = M_s / V \quad g/cc$$
$$e_{min} = G\gamma_w / (\gamma_d)_{max} - 1$$

Natural Density:

Weigh the mould with dry soil. Knowing the volume of the mould and weight of dry soil natural density, γ_d, can be calculated.

$$e = G\gamma_w / (\gamma_d) - 1$$
$$Relative\ Density = \frac{e_{max} - e}{e_{max} - e_{min}}$$

Specimen calculations:

Specimen calculations

Note: The specimen calculation values mentioned below are different for different soil samples taken for laboratory testing.

Exp No: 01 DETERMINATION OF MOISTURE CONTENT

Calculation sheet for moisture content determination

S. No.	Sample No.	1	2	3
1	Weight of container with lid (W_1 gm)	48	47	48
2	Weight of container with lid +wet soil (W_2 gm)	183	70	84
3	Weight of container with lid +dry soil (W_3 gm)	148	65	68
4	Water/Moisture content (%) $W = [(W_2–W_3)/(W_3–W_1)]*100$	35	65	68

Result

The Average of natural moisture content of the given soil sample is 45.58%.

Exp No: 03 FIELD DENSITY TEST BY SAND REPLACEMENT METHOD

Calculation sheet for sand density determination

S.No.	Sample details Calibration	
1	Weight of sand in cone (on glass plate from pouring cylinder) W_2 gm	320
2	Volume of calibrating container (V) in cc	1138.83
3	Weight of sand + cylinder before pouring in calibrating container W_1 gm	7030
4	Weight of sand + cylinder after pouring in calibrating container W_3 gm	5010
5	Weight of sand filled in calibrating container $W_a = (W_1-W_3-W_2)$ gm	1700
6	Bulk density of sand $\gamma_s = W_a / V$ gm/cc	1.493

Calculation sheet for density of soil

S. No.	Measurement of soil density	
1	Weight of wet soil from hole W_w gm	2411
2	Weight of sand + cylinder before pouring into the hole & cone, W_1 gm	7030
3	Weight of sand + cylinder after pouring into the hole & cone, W_4 gm	5020
4	Weight of sand in hole $W_h = (W_1 - W_2 - W_4)$ gm	1690
5	Volume of the hole in cc = $V_h = W_h / \gamma_s$	1131.95
6	Bulk density $\gamma_b = (W_w / V_h)$ gm/cc	2.13
7	Water content determination	
8	Container number	17
9	Weight of wet soil in gms	80
10	Weight of dry soil in gms	78
11	Moisture content (%)	6.67
12	Dry density $\gamma_d = \gamma_b / (1+w)$ gm/cc	1.996

Result

The dry density for the given soil sample is 1.996 g/cc

Exp No: 04 FIELD DENSITY TEST BY CORE CUTTER METHOD
Calculation sheet for density determination

S.No	Observations	Sample
		1
1	Internal diameter of the Core Cutter (cm)	10
2	Internal Height of the Core Cutter (cm)	12.7
3	Mass of empty core cutter (M_1) (gms)	1125
4	Mass of core cutter with soils (M_2) (gms)	3115
5	Mass of wet soil in (gms) $M = M_2\text{-}M_1$	1990
6	Volume of the cutter, V in cc	996.95
7	Water content (%), w	10.5
8	Bulk Density = M / V g/cc	1.996
9	Dry density = Bulk Density/ (1+ w) g/cc	1.806

Result

The field dry density of the soil is 1.806 g/cc.

Exp No: 5 GRAIN SIZE DISTRIBUTION BY SIEVE ANALYSIS

Calculation sheet for grain size distribution

S. No	I.S sieve number or size in mm	Wt. Retained in each sieve (gm)	Cummulative weight retained on each sieve	% retained on each sieve	% finer than
1	4.75	8	8	1.6	98.4
2	2.00	166	174	34.8	65.2
3	1.00	101	275	55.0	45.0
4	0.600	72	347	69.4	30.6
5	0.425	55	402	80.4	19.6
6	0.300	35	437	87.4	12.6
7	0.150	20	457	91.4	8.6
8	0.075	40	497	99.4	0.6

Result from graph

D_{10}=0.2mm
D_{30}=0.6mm
D_{60}=2.0mm
Uniformity coefficient = Cu= D_{60}/D_{10} =2.0/0.2=10
Coefficient of curvature= Cc= $(D_{30})2/D_{60}xD_{10}$= $(0.6)^2/(2.0x0.2)$ = 0.9

Exp No: 07 DETERMINATION OF LIQUID LIMIT

Observation and calculation sheet for the water content determination

Determination Number	**1**	**2**	**3**	**4**
Container number	13	9	10	6
Weight of container in gm	54	54	48	55
Weight of container + wet soil in gm	61	60	56	62
Weight of container + dry soil in gm	59	58	53	59
Weight of water (%)	35	40	45	50
Weight of dry soil in gm	5	4	5	4
Moisture content (%)	40	50	60	75
No. of blows	50	38	30	22

Result

Liquid Limit of the given soil sample from graph is 70%.

Experiment No: 08 DETERMINATION OF PLASTIC LIMIT

Calculation sheet for plastic limit determination

Container No.	1
Wt. of container + lid, (gms) W_1	31
Wt. of container + lid + wet sample, (gms) W_2	39
Wt. of container + lid + dry sample, (gms) W_3	37
Wt. of dry sample (gms) = W_3 -W_1	6
Wt. of water in the soil (gms) = W_3 - W_2	2
Water content (%) = (W_3 -W_2) / (W_3 - W_1) * 100	33.33

Result

Plastic Limit for the given soil sample is 33.33%

Exp No: 12 STANDARD COMPACTION TEST

Calculation sheet for soil dry density determination

Details	1	2	3	4	5
Water to be added (percent)	6	8	10	12	14
Weight of water to be added (gm)	180	240	300	360	420
Weight of cylinder + compacted soil (gm)	3971	4092	4205	4.285	4165
Weight of compacted soil (gms)	1761	1882	1995	2.075	1955
Container No.	14	6	11	10	7
Wt. Of container + wet soil in gms	103	109	84	100	103
Wt. Of container + dry soil in gms	98	101	80	94	96
Wt of empty container in gms.	53	50	50	54	52
Water content in percentage	11.12	15.68	13.34	15	15.9
Average moisture content (percent)	14.2				
Wet density (gm /cc)	1.86	1.99	2.11	2.2	2.07
Dry density (gm/cc)	1.67	1.72	1.86	1.91	1.79

Result

From the Graph Maximum Dry Density and Optimum Moisture Content are 1.9 g/cc & 14% respectively.