



KG REDDY
College of Engineering
& Technology
AN AUTONOMOUS INSTITUTION

CELEBRATING
15
YEARS OF
BRILLIANCE

Geotechnical Engineering

LABORATORY MANUAL

Prepared by: Jagadish S H, Assistant Professor

**Department of Civil
Engineering**

Institute Vision

To become an institution which is internationally recognized for its holistic approach to engineering, innovative teaching and learning culture, research and entrepreneurial ecosystem, and sustainable social impact in the community.

Institute Mission

- To offer undergraduate and post-graduate programs which are supported through industry relevant curriculum and innovative teaching and learning processes that would help students succeed in their professional careers.
- To provide faculty and students with an ecosystem that fosters innovation, research, entrepreneurship, and international exposure through strategic partnerships with government organizations and collaboration with industries.
- To provide holistic learning environment to students which will contribute to their personal and professional growth and enable them to become leaders in their respective fields.
- To contribute to the development of the region by using our technological expertise to work with nearby communities and support them in their social and economic development

Department Vision

To be recognized for excellence in teaching, innovation, and research aimed towards betterment of society through sustainable infrastructural development.

Department Mission

- To integrate innovative teaching and learning practices that will enable students to build technical competence for working in civil engineering industries.
- To encourage innovation, research, and entrepreneurship among faculty and students that will lead to sustainable development.
- To become self-sustainable through strategic collaborations with industries and nearby communities focused on consultancy services.

Program Educational Objectives

PEO1: Graduates will be able to work in multidisciplinary teams focused on development of infrastructure, design, sustainability, construction management and all the other related fields of Civil Engineering.

PEO2: Graduates will be professionally competent through their ability to use modern civil engineering tools and manage projects in leadership positions.

PEO3: Graduates will transform into change makers who will work towards societal development and advocate for equity, social justice, and sustainable development.

Program Outcomes

PO1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization for the solution of complex engineering problems.

PO2. Problem analysis: Identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3. Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for public health and safety, and cultural, societal, and environmental considerations.

PO4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modelling to complex engineering activities, with an understanding of the limitations.

PO6. The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO7.Environment and sustainability: Understand the impact of the professional Engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10.Communication: Communicate effectively on complex engineering activities with the engineering community and with the society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO11.Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12.Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes

PSO1: Graduates will be able to plan, analyze, design safe and sustainable green infrastructure.

PSO2: Graduates will be able to utilize the latest software tools for modeling and simulation in the field of civil engineering.

PSO3: Graduates will be able to work in multidisciplinary teams to design, develop and promote smart construction related.

Geotechnical Engineering Lab

Course Objectives: The objectives of this course for the students are to:

1. To determine index & Engineering properties of locally available soils.
2. To identify the behavior of these soils under various loads.
3. To identify consolidation settlements.
4. To analyze MDD & OMC to control compaction in the field.
5. To evaluate shear strength characteristics of soil

Course Outcomes: After completion of this course, the students will be able to

CO1: Characterize & classify soils & also determine index properties.

CO2: Classify the soils by conducting sieve analysis.

CO3: Compute & analyze the consolidation settlements.

CO4: Concept of MDD & OMC to control compaction in the field.

CO5: Determine the shear strength characteristics of soil.

Department of Civil Engineering
Geotechnical Engineering Lab

Course Code: KG23ACE310

B. Tech. III Year I - Semester

LIST OF EXPERIMENTS:

1. Atterberg Limits (Liquid Limit, Plastic Limit, and shrinkage limit)
2. a) Field density by core cutter method and
b) Field density by sand replacement method.
3. Determination of Specific gravity of soil.
4. Grain size distribution by sieve analysis.
5. Permeability of soil by constant and variable head test methods.
6. Standard Proctor's Compaction Test.
7. Determination of Coefficient of consolidation (square root time fitting method).
8. Unconfined compression test.
9. Direct shear test
10. Vane shear test
11. Differential free swell index (DFSI) test

MANDATORY INSTRUCTIONS

1. Students should report to the labs concerned as per the timetable.
2. Record should be updated from time to time and the previous experiment must be signed by the faculty in charge concerned before attending the lab.
3. Students who turn up late to the labs will in no case be permitted to perform the experiment scheduled for the day.
4. After completion of the experiment, certification of the staff in-charge concerned in the observation book is necessary.
5. Students should bring a notebook of about 100 pages and should enter the readings/observations/results into the notebook while performing the experiment.
6. The record of observations along with the detailed experimental procedure of the experiment performed in the immediate previous session should be submitted and certified by the staff member in-charge.
7. The group-wise division made in the beginning should be adhered to, and no mix up of student among different groups will be permitted later.
8. The components required pertaining to the experiment should be collected from Lab- in-charge after duly filling in the requisition form.
9. When the experiment is completed, students should disconnect the setup made by them, and should return all the components/instruments taken for the purpose.
10. **Any damage of the equipment or burnout of components will be viewed seriously either by putting penalty or by dismissing the total group of students from the lab for the semester/year.**
11. Students should be present in the labs for the total scheduled duration.
12. Students are expected to prepare thoroughly to perform the experiment before coming to Laboratory.

13. Procedure sheets/data sheets provided to the students groups should be maintained neatly and are to be returned after the experiment.
14. DRESS CODE:
 - i. Boys - Formal dress with tuck in and shoes
 - ii. Girls - Formal dress
 - iii. **Apron for both boys and girls.**

Experiment – 01

ATTERBERG'S LIMITS

(A) 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.

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 almost zero 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 center 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 at the bottom of the groove for a length off.
7. A representative portion of soil is taken from the cup for water content determination.
8. Repeat the test with different moisture contents at least three more times for blows between 10 and 40.

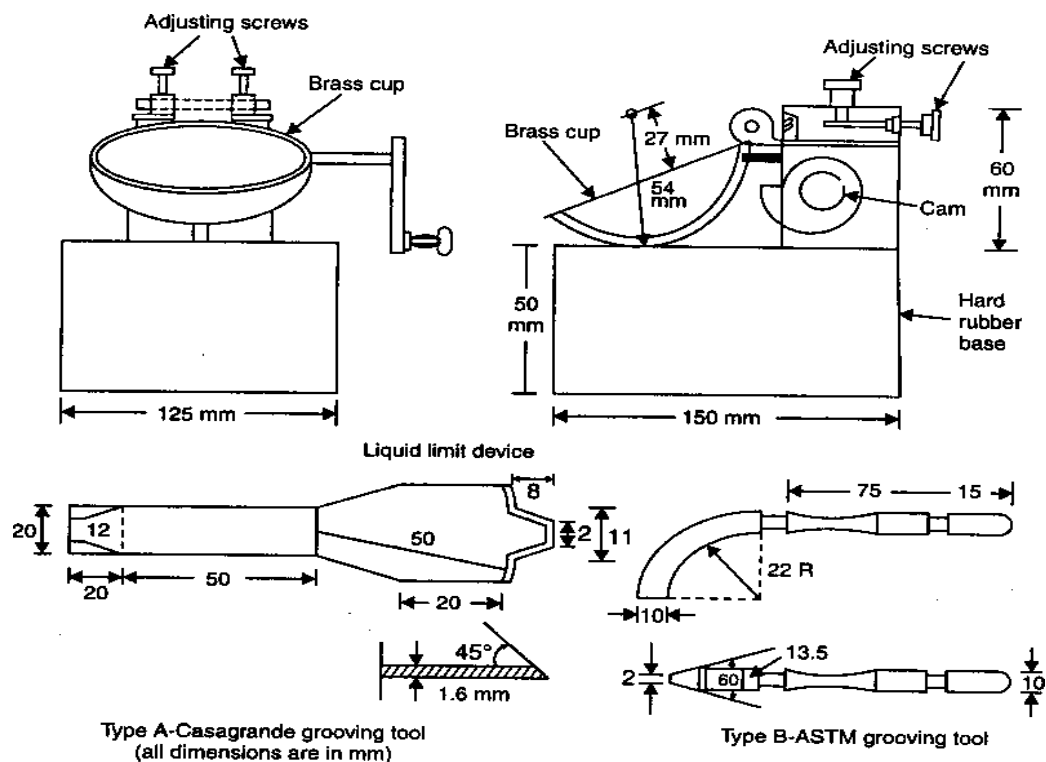


Figure 1.1 Casagrande's Liquid Limit Device

Observations:

Table 1.1 Observation and Calculation sheet for the water content determination

Determination Number	1	2	3	4
Container number				
Weight of container (g)				
Weight of container + wet soil (g)				
Weight of container + dry soil (g)				
Weight of water				
Weight of dry soil (g)				
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 $I_f = \frac{(w_2 - w_1)}{\log(N_1/N_2)} =$ _____

Experiment – 01

ATTERBERG'S LIMITS (B) 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.

Definition:-The moisture content at which the soil has the smallest plasticity is called plastic limit.

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 105⁰ and 110⁰c.

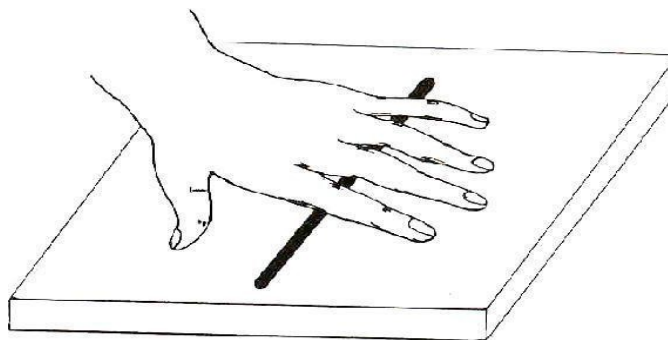


Figure 1.2 Plastic Limit Test

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 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. Knead 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 1.2 Calculation sheet for Plastic Limit determination

Container No.				
Wt. of container + lid, (g) W_1				
Wt. of container + lid + wet sample, (g) W_2				
Wt. of container + lid + dry sample, (g) W_3				
Wt. of dry sample (g) = $W_3 - W_1$				
Wt. of water in the soil (g) = $W_2 - W_3$				
Water content (%) = $\frac{(W_2 - W_3) * 100}{(W_3 - W_1)}$				

Specimen Calculations:

Result:

Average Plastic Limit for the given soil sample is _____

Experiment – 01 ATTERBERG’S LIMITS

C) DETERMINATION OF SHRINKAGE LIMIT

Objectives: To determine the shrinkage limit of the soil.

The value of shrinkage limit is used for understanding the swelling and shrinkage properties of cohesive soils. It is used for calculating the shrinkage factors which helps in the design problems of the structures made up of the soils or/and resting on soil. It gives an idea about the suitability of the soil as a construction material in foundations, roads, embankments and dams.

Specifications:

The test is specified in IS: 2720(Part 6)-1972. The 30 g soil passing 425 micron sieve is used for the test.

Equipments Required:

- a) 2 numbers of porcelain evaporating dish, about 12 cm in diameter within a flat bottom.
- b) 3 numbers of shrinkage dish made of non-corroding metal, having a flat bottom, 45 mm diameter and 15 mm high.
- c) A glass cup of about 50 mm diameter and 25 mm high.
- d) Two numbers glass plates of size 75 × 75 mm, one plate of plane glass and the other with three metal prongs.
- e) Spatula balance accurate to 0.01 g, oven etc.
- f) Mercury.
- g) Desiccator and other accessories.

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 to semi-solid state and then to solid state. The volume is also reduced by the decrease in water content. But, at a particular limit the moisture reduction causes no further volume change. A shrinkage limit test gives a quantitative indication of how much moisture can change before any significant volume change and to also indication of change in volume. The shrinkage limit

is useful in areas where soils undergo large volume changes when going through wet and dry cycles (e.g. earth dams).

Shrinkage limits are required to be determined on two types of soils, they are

- i. Remoulded soil.
- ii. Undisturbed soil.

Other shrinkage factors i.e. shrinkage ratio, volumetric shrinkage may also be calculated from the test data of shrinkage limit.

Shrinkage ratio is the ratio of a given volume change expressed as a percentage of dry volume to the corresponding change in water content above the shrinkage limit.

Volumetric Shrinkage is the decrease in volume of a soil mass when the water content is reduced from given percentage to the shrinkage limit and which is expressed as percentage of dry volume of the soil mass.

Precautions:

CAUTION : DO NOT TOUCH THE MERCURY WITH GOLD RINGS

The water content of the soil taken in shrinkage dish should be above liquid limit but within 10% from liquid limit.

- To prevent the cake from adhering to the shrinkage dish and consequent cracking of the dry soil paste, inside of the shrinkage dish should be greased with Vaseline.
- During filling the shrinkage dish with soil paste, sufficient tapping should be done to remove the entrapped air.
- The dry soil paste should be weighed soon after it has been removed from a desiccator otherwise it picks up moisture from the air.
- Test should be repeated at least three times for each sample and the average of the results thus obtained reported.
- No air should be entrapped under the dry soil paste when pressing by the glass with prongs is being carried out.

Procedure:

- a) Select a representative sample of soil of about 100 g passing through 425 IS sieve.
- b) Take 30 g out of it and place the same in an evaporating dish. Mix it thoroughly with distilled water and make it into a thin paste for readily filling into a dish free from air bubbles.

Determination of mass and volume of shrinkage dish:

- a) Take a shrinkage dish, clean it and find its mass correct to 0.1 gm (M3). = g
- b) To determine its volume, place it in an evaporating dish. Fill the shrinkage dish with mercury till the excess overflows to the evaporating dish.
- c) Coat the inside of the shrinkage dish with a thin layer of silicon grease or Vaseline. Place a part of the soil paste prepared earlier at the centre of the dish so that it may occupy about one-third of its volume.
- d) Find the mass of the wet soil with the dish immediately after filling (M1)= g
- e) Keep the dish with soil exposed to air until the color of the pat turns from black to light.
- f) Select a glass cup with a flat bottom and keep ion an evaporating dish. Fill the cup with mercury and remove the excess mercury by pressing the glass plate with three prongs firmly over the top of the cup.
- g) Remove the split over the mercury, take out the glass plate with the prongs, place the dry soil pat on the surface of the mercury.
- h) Force the soil pat into the mercury by pressing with the same glass plate with the prongs. Collect carefully the split over mercury and find its mass (Mm)= ----- g

The volume of the dry soil pat Vd is

$$Vd = Mm / 13.6.$$

Where, 13.6 is the density of mercury in g/cm³

Calculation of shrinkage limit, Ws

Mass of wet soil = Mo = (M1-M3) = ----- g

Mass of dry soil = Ms = (M2-M3) =-----g

Volume of shrinkage dish = Volume of wet soil = $V_o = \text{-----}$

Volume of dry soil = $V_d = \text{-----}$

$V_d = M_m / 13.6$ where, 13.6 g/cm^3 is the density of mercury.

Shrinkage limit, W_s is

$$W_s = ((M_o - M_s) - (V_o - V_d) \times \rho_w) / M_s$$

Shrinkage ratio, $S_r = ((V_o - V_d) / V_o)$

Shrinkage limit of undistributed soil

In this case G is known in advance. The equation to be used for determining W_s is $W_s = [(V_d / M_s) - (1 / G)] \times 100$

For the undistributed soil we need to know only the volume of an undistributed dry pot of soil sample of diameter 45 mm and thickness 15 mm. Round off its edges to prevent the entrapment of air during mercury displacement. Air dry the sample initially

and then dry over the same. Find its mass (M_s) after cooling it in a desiccator, and then its volume V_d by mercury displacement method. W_s may now be found out by use of equation

$$W_s = [(V_d / M_s) - (1 / G)] \times 100.$$

Result:

The shrinkage limit $W_s = \text{-----}$

Experiment – 02 (A)

FIELD DENSITY TEST BY CORE CUTTER METHOD

Objective:

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

Apparatus required:

1. Cylindrical core cutter, 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 weight of the soil is determined. The dry density is obtained as

$$\gamma_d = \frac{\gamma_b}{1+w}$$

Where, γ_d = Dry density

γ_b = bulk density = W/V

w = water content

W = Weight of wet soil in the cutter

V = Internal volume of the cutter

Procedure:

- 1) Determine the internal diameter and height of the core cutter to the nearest 0.25 mm.
- 2) Determine the weight (W_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 dolly 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 dolly protrudes above the soil surface.
- 5) Remove the soil surrounding the core cutter by excavating and takeout the core cutter. Some soil would project from the lower end of the cutter.
- 6) Remove the dolly. 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 (W_2).
- 8) Remove the core of the soil from the cutter. Take a representative sample for the water content determination.

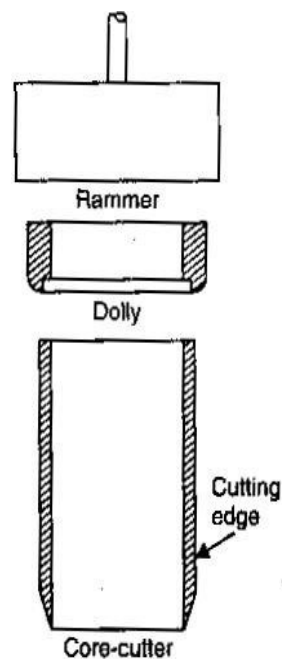


Figure 2.1 Apparatus for Core Cutter Test

Observations and Calculations:

Table 2.1 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	Weight of empty core cutter (W_1)			
4	Weight of core cutter with soil (W_2)			
5	Weight of wet soil, $W = W_2 - W_1$			
6	Volume of the cutter, V			
7	Water content (%), w			
8	Bulk Density = W / V			
9	Dry density = $\gamma_d = \frac{\gamma_b}{1+w}$			

Table 2.2 Moisture Content Calculations

Determination Number	1	2	3
Container number			
Weight of container (g)			
Weight of container + wet soil (g)			
Weight of container + dry soil (g)			
Weight of water			
Weight of dry soil (g)			
Moisture content (%)			

Result:

The field dry density of the soil is _____.

Experiment – 02 (B)

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 3litre/16.5 liter capacity mounted above a pouring cone 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 thick surrounding the open end.
4. Balance to weigh upto 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°c to 110°c.
11. A desiccators 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:

$$\gamma_d = \frac{\gamma_b}{1+w}$$

Where, γ_d = Dry density

γ_b = bulk density = W/V

w = water content

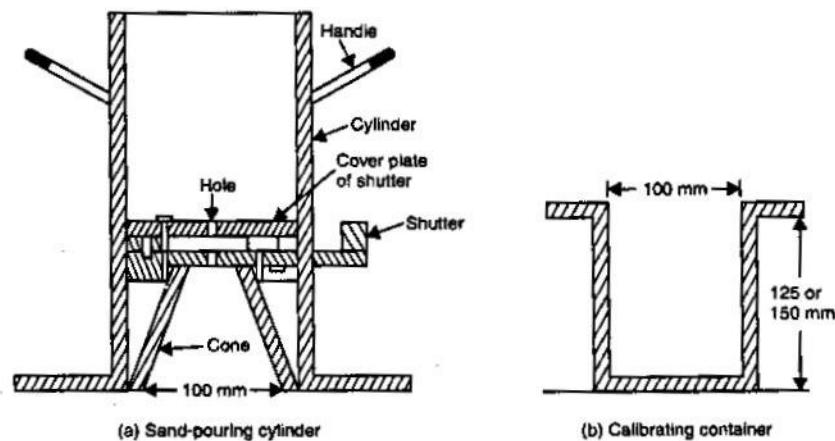


Figure 2.2 Apparatus for Sand Replacement Method

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 Sand:

3. Determine the volume (V) of the container by filling it with water to the brim. Check this volume by calculating from the measured internal dimensions of the container.
4. Place the sand pouring 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_{wet}). 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.
- 7.

Observations and Calculations:

Table 2.3 Calculation sheet for sand density determination

S.No.	Sample Details	1
	Calibration	
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 $\rho_{sand} = W_a / V$ (gm/cc)	

Table 2.4 Calculation sheet for density of soil

S. No.	Measurement of Soil Density	1
1	Weight of wet soil from hole W_{wet} 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 = $V_h = \frac{W_h}{\rho_{sand}}$	
6	Bulk density $\rho_b = \frac{W_{wet}}{V_h}$ gm/cc	
7	Water content determination	
8	Container number	
9	Weight of wet soil (g)	

10	Weight of dry soil (g)	
11	Moisture content (%)	
12	Dry density $\rho_d = \gamma_d = \frac{\gamma_b}{1+w}$ (gm/cc)	

Result:

The dry density of the given soil sample is _____.

Experiment – 03

ETERMINATION OF SPECIFIC GRAVITY

Objective:

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

Need:

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 waters 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.

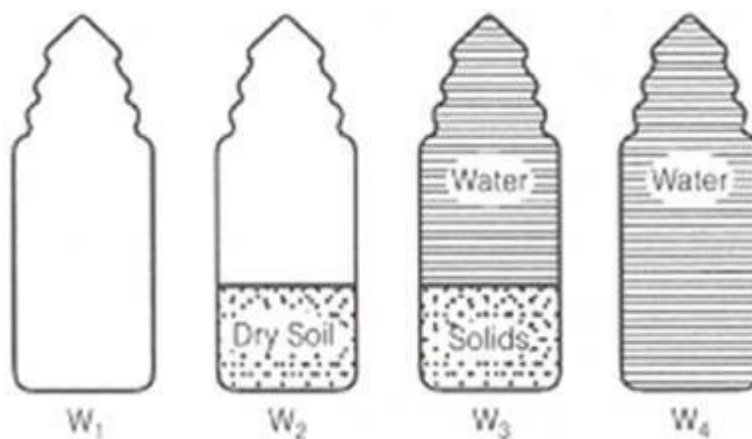


Figure 3.1 Apparatus for Specific gravity bottle

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 water baths (T_x^0).
6. Take the bottle outside and 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.

OBSERVATIONS

Table 3.1 Calculation sheet for specific gravity of soil

S. No.	Observation Number	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 °C (W_3 g)			
4	Weight of bottle + water (W_4 g) at temperature T_x °C			
	Specific gravity G at T_x °C			
	Average specific gravity at T_x °C			

CALCULATIONS

$$\begin{aligned}
 \text{Specific gravity of soil} &= \frac{\text{Density of water at } 27^\circ\text{C}}{\text{Weight of water of equal volume}} \\
 &= \frac{(W_2 - W_1)}{(W_4 - W_1) - (W_3 - W_2)} \\
 &= \frac{(W_2 - W_1)}{(W_2 - W_1) - (W_3 - W_4)}
 \end{aligned}$$

INTERPRETATION AND REPORTING

Unless or otherwise specified specific gravity values reported shall be based on water at 27°C . So the specific gravity at $27^\circ\text{C} = K \times \text{Sp. gravity at } T_x^\circ\text{C}$.

$$\text{where } K = \frac{\text{Density of water at temperature } T_x^\circ\text{C}}{\text{Density of water at temperature } T_x^\circ\text{C}}$$

The specific gravity of the soil particles lie within 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.

Result:

The specific gravity soil sample is _____.

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 3.1 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 %age retained on each sieve	% finer	Remarks
1	4.75					
2	2.36					
3	1.18					
4	0.600					
5	0.300					
6	0.150					
7	Pan					

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, obtain diameters 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.
Plot a semi-log plot between % finer in Y-axis and log particle size (in mm) in X-axis. From the graph obtain the % coarse, medium and fine sand ranges.

% Gravel ($> 4.75 \text{ mm}$) =

% Coarse sand ($4.75 - 2.00 \text{ mm}$) =

% Medium sand ($2.00 - 0.425 \text{ mm}$) =

% Fine sand ($0.425 - 0.075 \text{ mm}$) =

% Fines (silt & clay $< 0.075 \text{ mm}$) =

Uniformity coefficient $C_u = D_{60} / D_{10}$ =

Coefficient of curvature $C_c = (D_{30})^2 / D_{60} \times D_{10}$ =

Results:-

Where, D_{60} = size of particle to 60 % finer

D_{30} = size of particle to 30% finer

D_{10} = size of particle to 10% finer (also called effective size)

Designation of soil as per Indian Standard classification=

Experiment –05

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.

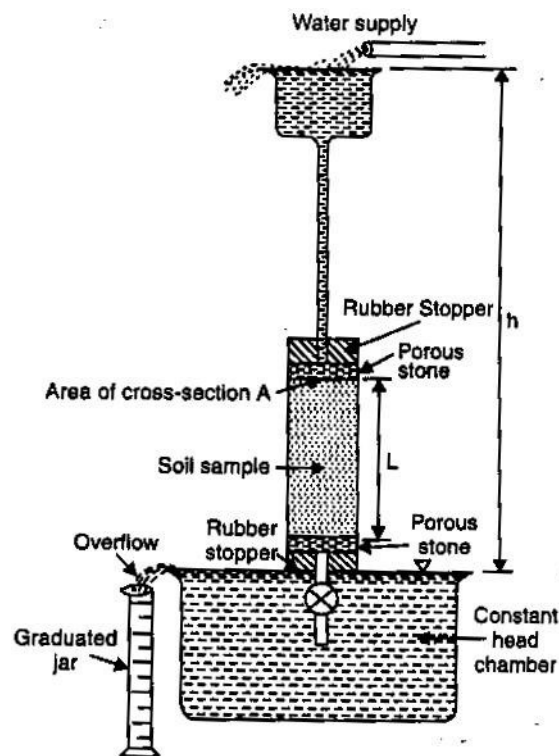


Figure 4.1 Permeability Test by Constant Head Method

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. Enough time shall be allowed for saturating soil sample, if necessary giving 24 hrs.

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 to obtain average value of permeability.

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

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

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° C. The dry density, the void ratio and the degree of saturation shall be reported. The test results should be tabulated as below:

Permeability Test Record

Details of sample

Diameter of specimen _____ cm

Length of specimen (L) _____ cm

Area of specimen (A) _____ cm²

Specific gravity of soil G_s _____

Volume of specimen (V) _____ cm³

Weight of dry specimen (W_s) _____ gm

Moisture content _____ %

Table 4.1 Observation sheet for Permeability determination

Experiment No.		1	2	3
Length of specimen	L(cm)			
Area of specimen	A(cm ²)			
Time, t	(sec)			
Quantity of water	Q(cm ³)			
Discharge, $q = Q/t$ (cm ³ /sec)				
Height of water	h(cm)			
Temperature	(°C)			

Interpretation

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

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°C .

k_t = Coefficient of permeability at $t^{\circ}\text{C}$.

V_t = Coefficient of viscosity at $t^{\circ}\text{C}$.

V_{27} = Coefficient of viscosity at 27°C .

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 is _____.

Experiment – 05

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 permeability, whereas 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 ($i \times A$)

$$[q = kiA]$$

Where, q = Rate of flow or discharge

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 unit cross-sectional area under unit hydraulic gradient.

Apparatus:

1. Permeameter with its accessories.
2. Standard soil specimen.
3. Desired 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.

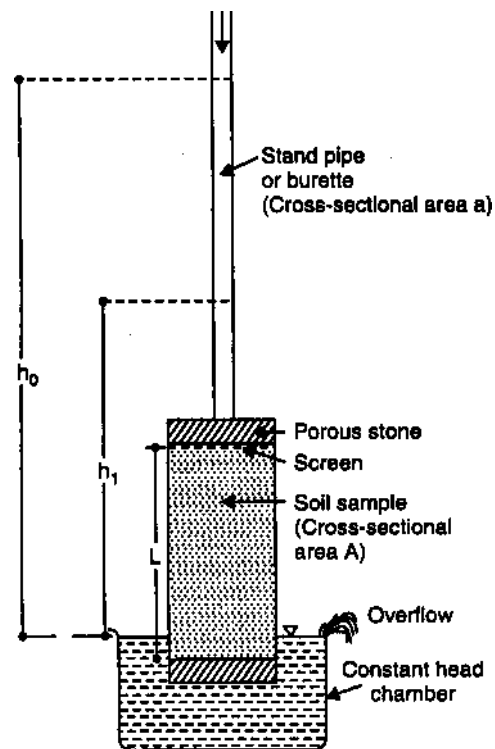


Figure 4.2 Permeability Test by Variable Head Method

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. The preparation of soil sample is as similar to that of constant head test.

Experimental Procedure:

1. Prepare the soil specimen as specified.
2. Saturate it. Desired 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 from initial head of h_1 to final head of h_2 in the stand pipe..
6. Repeat step 5 three times to determine time for different combinations of h_1 and h_2 .

Therefore the coefficient of permeability

$$k = \frac{2.3 \times a \times L \times (\log_{10} h_{21} / h_2)}{A \times t} \quad \text{cm/sec}$$

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

$$\gamma_t = \text{Viscosity of water at temperature } t^\circ \text{C}$$

$$\gamma_{27} = \text{Viscosity of water at room temperature } 27^\circ \text{C}$$

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:

Table 4.2 Observation sheet for coefficient of permeability determination

S. No	Details	1 st set	2 nd set
1	Area of stand pipe (dia. 2 cm) a		
2	Cross sectional area of soil specimen A		
3	Length of soil specimen L		
4	Initial reading of stand pipe h_1		
5	Final reading of stand pipe h_2		
6	Time t		
7	Test temperature T		
8	Coefficient of permeability at T k_t		
9	Coefficient of permeability at 27° C k_{27}		

Result:

Coefficient of the permeability is _____.

Experiment - 06

COMPACTION TEST

Scope:

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

Apparatus:

1. Proctor mould having a capacity of 1000 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. The rammer shall be equipped with a suitable arrangement to control the height of drop to a free fall.
3. Sample extruder.
4. A balance of 15 kg capacity.
5. Sensitive balance.
6. Straight edge.
7. Graduated cylinder.
8. Mixing tools such as mixing pan, spoon, towel, spatula etc.
9. Moisture tins.

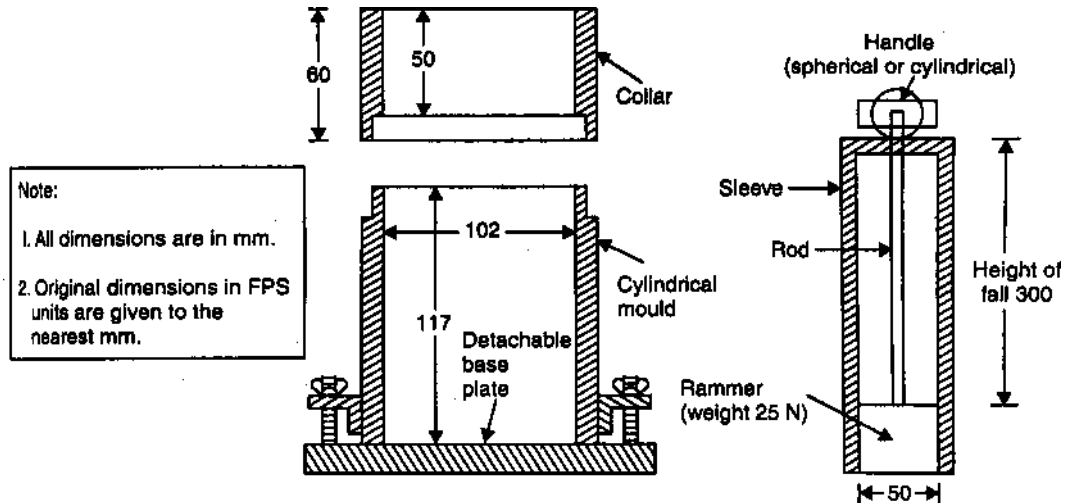


Figure 5.1 Standard Compaction Test Apparatus

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.
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 ρ_{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, representing from top, middle and bottom.
6. Repeat the above procedure by making 4 to 5 trials at different water contents, until an increase and then decrease in the weight of wet compacted soil is noticed.

Calculation:

Wet density gm/cc = weight of compacted soil / 1000

$$\text{Dry density} = \left[\frac{\gamma_b}{1+w} \right]$$

Where, w = moisture content of the soil.

Graph:

Plot the dry density (Y-axis) against moisture content in (X-axis) and find out the maximum dry density and optimum moisture content for the soil.

Observations:

Cylinder diameter _____ cm

Height _____ cm

Volume _____ c.c.

Weight of empty cylinder _____.

Table 5.1 Calculation sheet for soil dry density determination

Details	1	2	3	4	5
Water to be added (%)					
Weight of water to be added (g)					
Weight of cylinder + compacted soil (g)					
Weight of compacted soil (g)					
Container No.					
Wt. Of container + wet sample(g)					
Wt. Of container + dry sample(g)					
Wt of empty container(g)					
Water content in percentage					
Wet density (gm /cc)					
Dry density (gm/cc)					

Result: From Graph, Maximum Dry Density and Optimum Moisture Content are _____ & _____ respectively.

Experiment - 07

CONSOLIDATION TEST

Objective:

To determine the coefficient of consolidation of soil by conducting one dimensional consolidation test.

Need and scope:

The test is conducted to determine the consolidation characteristics 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 decrease 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) Remolded 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.

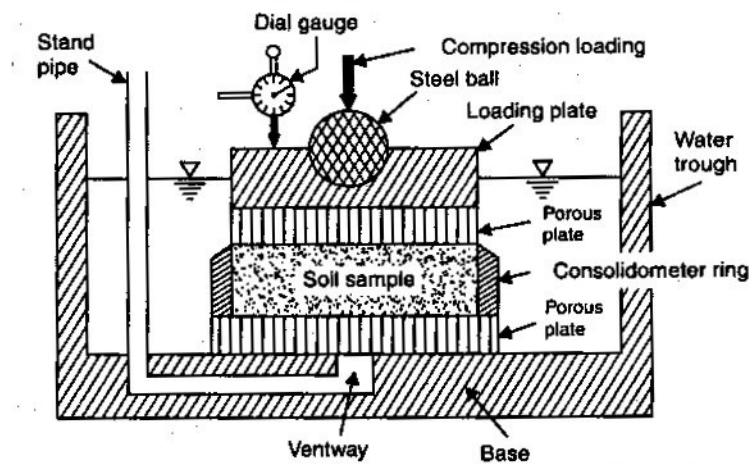


Figure 7.1 Consolidation Test Apparatus

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 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 beginning of its arm, 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^2 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 for successive load increments. The usual loading intensity are 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. Keep the specimen in oven and note the dry weight of it after 24 hrs of oven drying.

Observation and Reading:

Data and observation sheet for consolidation test pressure, compression and time.

Empty weight of ring =

Area of ring =

Diameter of ring =

Volume of ring =

Height of ring =

Specific gravity of soil sample =

Dial Gauge (least count) =

Table 7.1 Observation sheet for time- pressure of consolidation test

Pressure Intensity (Kg/cm ²)	0.1	0.2	0.5	1	2	4	8
Elapsed Time							
0.25							
1							
2.5							
4							
6.25							
9							
16							
25							
30							
1 hr							

2 hrs							
4 hrs							
8 hrs							
24 hrs							

Table 7.2 Observation Sheet for Consolidation Test: Pressure Voids Ratio

Applied pressure	Final dial reading	Dial change	Specimen height	Height of solids	Height of voids	Void ratio
0						
0.1						
0.2						
0.5						
1						
2						
4						
8						
4						
2						
1						
0.5						
0.2						
0.1						

Calculations:

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

$$[H_s = \frac{W_s * A}{G}]$$

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

$$[e = \frac{H - H_s}{H_s}]$$

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

- i. $C_v = 0.197 \frac{d^2}{t_{50}}$ (Log fitting method)
- ii. $C_v = 0.848 \frac{d^2}{t_{90}}$ (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) vs $\log p$ 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

$$\left[a_v = \frac{0.435 C_c}{\text{Avg. pressure for the increment}} \right]$$

Where, C_c = Coefficient of compressibility

6. Coefficient of permeability. It is calculated as follows

$$\left[k = \frac{c_v \cdot a_v \cdot \gamma_w}{1+e} \right]$$

Graphs:

1. Dial reading V_s log of time (or)
Dial reading V_s square root of time.
2. Voids ratio V_s $\log p$ (average pressure for the increment).

Result:

Consolidation parameters for the given soil sample are _____.

Experiment –08

UNCONFINED COMPRESSION TEST

Objective:

To determine shear parameters of cohesive soil

Need and scope:

It is not always possible to conduct the bearing capacity test in the field. Sometimes 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 remolded 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 2 t, 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.
3. Place the sampling tube extractor and push the plunger till a small length of sample moves out.
4. Trim the projected sample using a wire saw.
5. Again push the plunger of the extractor till a 75 mm long sample comes out.
6. Cutout this sample carefully and hold it on the split sampler so that it does not fall.
7. Take about 10 to 15 g of soil from the tube for water content determination.
8. Note the container number and take the net weight of the sample and the container.
9. Measure the diameter at the top, middle, and the bottom of the sample and find the average and record the same.
10. Measure the length of the sample and record.
11. 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 W_s 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. $W_w = W_s \cdot W/100$ 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 mould 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 5 mm compression.
8. Continue loading till failure is complete.
9. Draw the sketch of the failure pattern in the specimen.

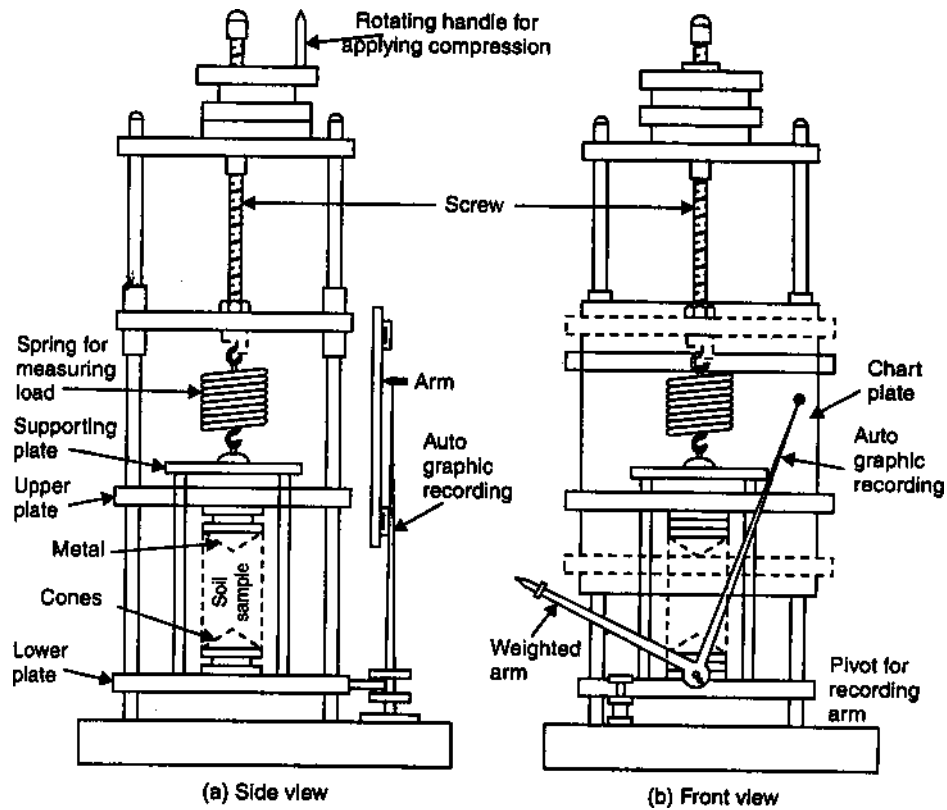


Figure 8.1 Unconfined Compression Test Apparatus

Sample details:

Type UD/D: soil description

Specific gravity (G_s) _____

Bulk density = _____ g/cc

Water content (%): _____

Degree of saturation % = _____

Diameter (D_o) of the sample: _____ cm

Area of cross-section = _____ cm^2

Initial length (L_o) of the sample: _____ cm

Experiment - 09

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.

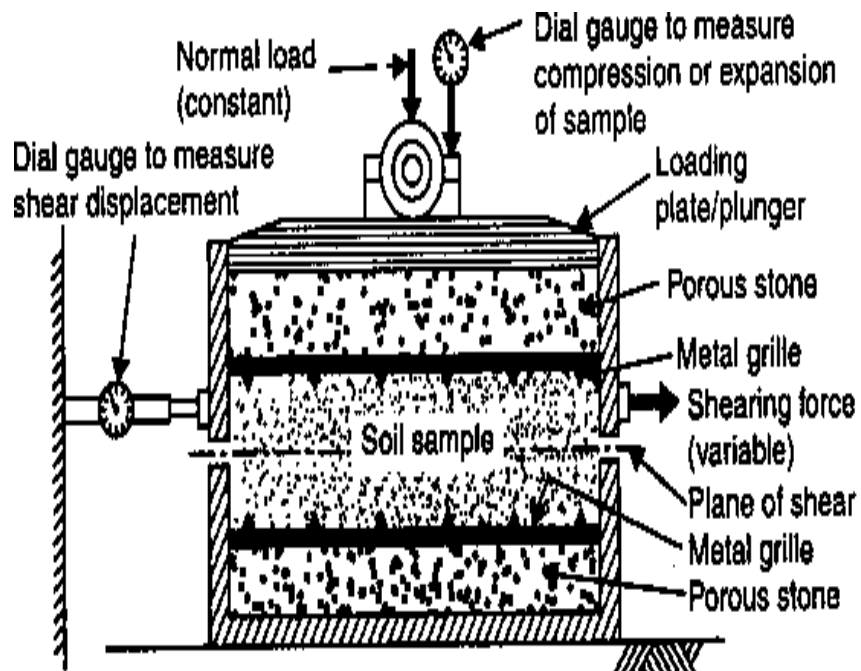
Apparatus:

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.



(a) Schematic Diagram

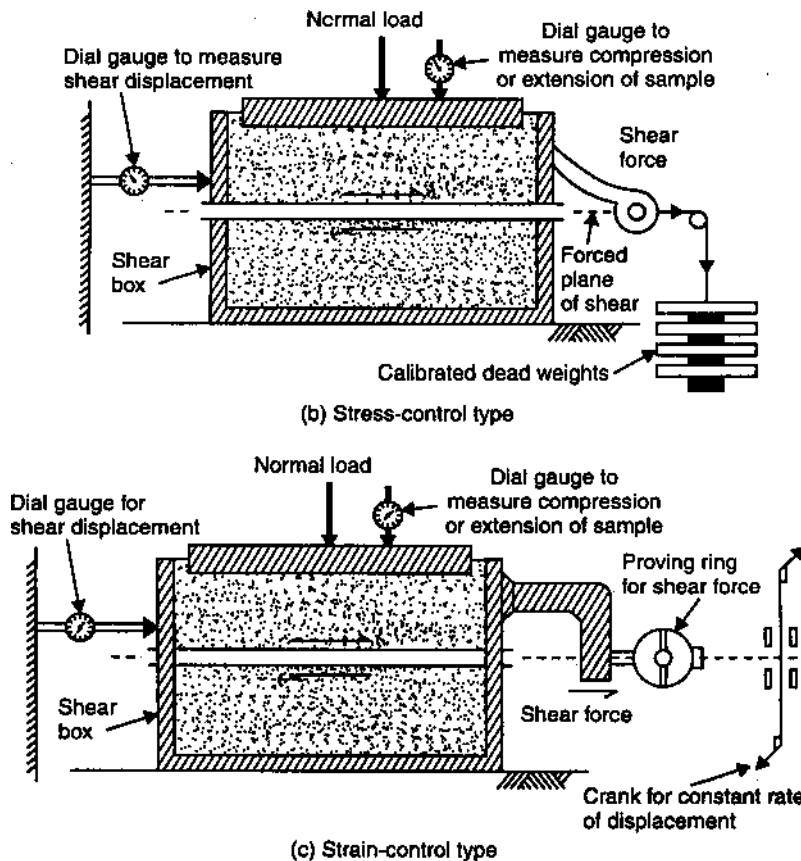


Figure 10.1 Direct Shear Apparatus

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. Repeat the experiment at two more normal stresses.
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

Direct Shear Test Observations:

Project name & location of site:

Project report No:

Location of sample:

Sample collected on:

Sample collected by:

Sample tested by:

Sample tested on:

Proving Ring constant:

Cross section area of the sample (cm^2):

Thickness of the sample (cm):

Volume of the sample:

Density of sample:

Table 10.1 Observation and Calculation sheet for shear stress determination

Proving ring constant (k)=

Least count or deformation dial guage=

Normal stress=

Shear deformation dial guage reading	Proving ring reading	Shear deformation (mm)	Shear strain (%)	Shear load (Proving ring reading * k) (kg)	Shear stress (kg/cm ²)
1	2	3	4	5	6

Normal stress, σ (kg/cm ²)	Shear stress at failure, τ_f (kg/cm ²)

Result:

Shear strength for the given soil sample is _____.

Experiment – 10

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

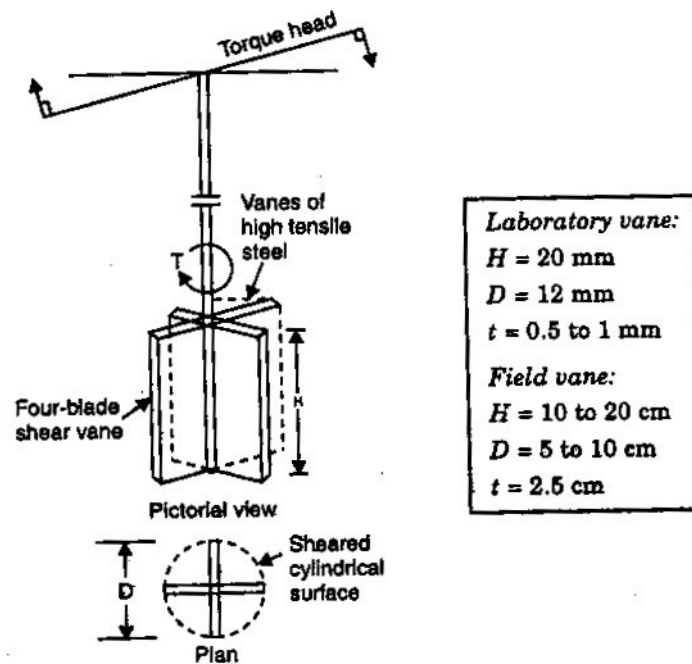


Figure 11.1 Apparatus for Vane Shear Test

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°/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:

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

Where, S= Shear strength of soil in $\frac{\text{kg}}{\text{cm}^2}$

$$T = \text{Torque in kg-cm} = \frac{\text{Spring constant} \times \text{Difference in degrees}}{180}$$

D= overall diameter of vane in cm

Table 11.1 Observation sheet for shear strength determination

S. No	Initial Reading (Deg)	Final Reading (Deg)	Difference (Deg.)	Spring constant (kg-cm)	T = $\frac{\text{Spring constant} \times \text{Difference in degrees}}{180}$	G = $\frac{1}{\pi \left(\frac{D^2 H}{2} + \frac{D^3}{6} \right)}$	S = TxG Kg/cm ²	Average 'S' Kg/cm ²

Result:

Shear strength for the given soil sample is _____

Experiment – 11

DIFFERENTIAL FREE SWELL INDEX

Objective:

It is determined by the following way as per IS: 2720 (Part XL) - 1977.

Definition:

Free Swell Index is the increase in volume of a soil, without any external constraints, on submergence in water

Principle:

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

Apparatus:

- i) Sieve 425 μ m
- ii) Oven
- iii) Balance, with an accuracy of 0.01g
- iv) Graduated glass cylinder- 2 nos., each of 100ml capacity

Procedure:

- Take two specimens of 10g each of pulverised soil passing through 425 μ m IS Sieve and oven-dry.
- Pour each soil specimen into a graduated glass cylinder of 100ml capacity.
- Pour distilled water in one and kerosene oil in the other cylinder upto 100ml mark.
- Remove entrapped air by gently shaking or stirring with a glass rod.
- Allow the suspension to attain the state of equilibrium (for not less than 24hrs.).
- Final volume of soil in each of the cylinder should be read out.
-

Reporting & results

$$\text{Free swell index} = \frac{V_d - V_k}{V_k} \times 100\%$$

where, V_d = volume of soil specimen read from the graduated cylinder containing distilled water.

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

Results:

The free swell index _____



KG REDDY

College of Engineering
& Technology

AN AUTONOMOUS INSTITUTION



CHILKUR VILLAGE, MOINABAD MANDAL,
HYDERABAD - 501504, TELANGANA.
Ph. : 94907 73777

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