METHODIST
COLLEGE OF ENGINEERING & TECHNOLOGY
(An UGC-AUTONOMOUS INSTITUTION)
Accredited by NAAC with A+ and NBA
Affliated to Osmania University & Approved by AICTE
Estd : 2008

LABORATORY MANUAL

SOIL MECHANICS LABORATORY

BE V Semester

A.Y: 2024-25

NAME: ____

ROLL NO: ______________________ **SECTION:** ____________________

ACADEMIC YEAR: ________________ **BATCH:** ____________________

DEPARTMENT OF CIVIL ENGINEERING

Empower youth- Architects of Future

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CERTIFICATE

This is to certify that this is a bonafide record of the work done by Mr./Ms. ____bearing Roll No.__________________________ of B.E.________ Year______ Semester ________________________Branch in the____________________Laboratory During the Academic Year ____

Date:

Internal Examiner HOD External Examiner

VISION

To produce ethical, socially conscious and innovative professionals who would contribute to sustainable technological development of the society.

MISSION

To impart quality engineering education with latest technological developments and interdisciplinary skills to make students succeed in professional practice.

To encourage research culture among faculty and students by establishing state of art laboratories and exposing them to modern industrial and organizational practices.

To inculcate humane qualities like environmental consciousness, leadership, social values, professional ethics and engage in independent and lifelong learning for sustainable contribution to the society.

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DEPARTMENT OF CIVIL ENGINEERING

LABORATORY MANUAL

SOIL MECHANICS LABORATORY

Prepared
By
Ms. M. Madhuri

Assistant Professor

DEPARTMENT OF CIVIL ENGINEERING

VISION

To evolve into a Centre of excellence for imparting holistic civil engineering education contributing towards sustainable development of the society.

MISSION

- To impart quality civil engineering education blended with contemporary and interdisciplinary skills.
- To provide enhanced learning facilities and professional collaborations to impart a culture of continuous learning.
- To involve in trainings and activities on communication skills, teamwork, professional ethics, environmental protection and sustainable development.

DEPARTMENT OF CIVIL ENGINEERING

PROGRAM EDUCATIONAL OBJECTIVES

The Graduates of the programme shall be able to:

PEO 1: Engage in planning, analysis, design, construction, operation and maintenance of built environment.

PEO 2: Apply the knowledge of civil engineering to pursue research or to engage in professional practice.

PEO 3: Work effectively as individuals and as team members in multidisciplinary projects with organizational and communication skills.

PEO 4: Demonstrate the spirit of lifelong learning and career enhancement aligned to professional and societal needs.

DEPARTMENT OF CIVIL ENGINEERING

PROGRAM OUTCOMES

Engineering Graduates will be able to:

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

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

PO3. Design/development of solutions: Design solutions for complex civil engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the 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 modeling to complex civil 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 civil engineering practice.

PO7. Environment and sustainability: Understand the impact of the professional civil 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 civil 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 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

Civil Engineering Graduates will be able to:

PSO 1. Investigate properties of traditional and latest construction materials using standard testing methods.

PSO 2. Use AutoCAD, STAAD Pro, ETABS, Revit Architecture and ANSYS software for computer aided structural analysis and design.

PSO 3. Describe the principles of sustainable development and green buildings for environmental preservation.

Laboratory Code of Conduct

1. Students should report to the concerned labs as per the time table schedule.
2. Students who turn up late to the labs will in no case be permitted to perform the experiment scheduled for the day.
3. Students should bring a note book of about 100 pages and should enter the readings/observations into the note book while performing the experiment.
4. After completion of the experiment, signature of the concerned staff in-charge in the observation book is necessary.
5. Staff member in-charge shall award 40 marks for each experiment based on continuous evaluation and will be entered in the continuous internal evaluation sheet.
6. The record of observations along with the detailed experimental procedure of the experiment performed in the immediate last session should be submitted and certified by the staff member in-charge.
7. Not more than three students in a group are permitted to perform the experiment on a set-up for equipment-based labs.
8. The components required pertaining to the experiment should be collected from the stores in-charge, only after duly filling in the requisition form/log register.
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 burn-out of components will be viewed seriously by either charging penalty or 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 required to prepare thoroughly to perform the experiment before coming to Laboratory.
13. Procedure sheets/data sheets provided to the students, if any, should be maintained neatly and returned after the completion of the experiment.

DO'S AND DONT'S

Do's

1. Students are expected to prepare thoroughly to perform the experiment before coming to laboratory.
2. Always perform the experiment precisely as directed by the faculty.
3. Don't forget to bring observation notes, calculator and other pencil accessories before coming to laboratory
4. Record should be updated from time to time and the previous experiment must be signed by the faculty in-charge before attending the lab.
5. After completion of the experiment, signature of the faculty in-charge in the observation book is necessary.
6. The components required pertaining to the experiment should be collected from lab technician after duly filling in the requisition form.
7. Handover all the accessories /material / instruments to the lab technician before leaving the laboratory
8. Wear shoes and apron while performing the experiment
9. Keep silence in the laboratory.
10. Bring observation note books, lab manuals and other necessary things for the class.
11. Use tools for mixing soil and water
12. Check the instruments for proper working conditions while taking and returning the same.
13. Thoroughly clean your laboratory work space at the end of the laboratory session.
14. Maintain silence and clean environment in the lab

Do's

1. Do not operate the machines without the permission of the staff
2. Do not put hands or head while equipment is in running condition.
3. Do not fix or remove the test specimen while the main is switch on.
4. Do not spill the soil, water and aggregates on the floor.
5. Don't use mobile phones during lab hours
6. Don't use instruments without permission
7. Don't be late for the lab session

Course Code	Course Title						Core/ Elective
2PC555CE	Soil Mechanics Lab						Core
Prerequisite	Contact Hours per Week				CIE	SEE	Credits
	L	T	D	P			
	-	-	-	2	40	60	1

List of Experiments:

DETERMINATION OF INDEX PROPERTIES:

1. Determination of Specific Gravity of soil solids using Density bottle method.
2. Determination of Specific Gravity of Soil Solids using Pycnometer method.
3. Determination of water content using Pycnometer method.
4. Determination of Liquid limit using Casagrande ‘s standard Liquid Limit device.
5. Determination of Plastic limit.
6. Sieve Analysis for plotting Particle size distribution curve.
7. Determination of Field Density using Sand Replacement Method.
8. Determination of Field Density by core cutter method.

DETERMINATION OF ENGINEERING PROPERTIES:

9. Determination of Compaction Characteristics.
10. a) Determination of Co-efficient of Permeability by Constant Head Permeameter test.
    b) Determination of Co-efficient of Permeability by Variable Head Permeameter test.
11. Determination of shear strength, parameters by Direct Shear Test

DEMONSTRATION OF TEST PROCEDURE:

12. Unconfined Compression Test.
13. Vane Shear Test

Name of the laboratory course: Soil Mechanics Laboratory
Course code: 2PC555CE

Course Outcomes

After completing this course, the student will be able to:

CO No.	Course Outcome	Taxonomy Level
555.1	Determine Specific gravity and field density of different soils by test results, interpret and validate the same	**Applying**
555.2	Analyze particle size distribution of soil by conducting sieve analysis test.	**Analyzing**
555.3	Analyze the behavior of soils with water by conducting tests.	**Analyzing**
555.4	Analyze shear strength of soils on application of stress in laboratory.	**Analyzing**
555.5	Determine permeability and compaction characteristics of various soils.	**Applying**

CO-PO mapping:

PO / CO	PO 1	PO 2	PO 3	PO 4	PO5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
555.1	3								3	3					
555.2	3	3							3	3					
555.3	3	3							3	3					
555.4	3	3							3	3					
555.5	3								3	3					
C555	**3**	**3**							**3**	**3**					

Name of the laboratory course: Soil Mechanics Laboratory **Course code:** 2PC555CE

Experiments mapping to COs & Pos

S. No	Name of the Experiment	COs	POs
1	Determine the specific gravity of fine-grained soil sample by density bottle methods.	CO1	PO1, PO9, PO10
2	Determination of Specific Gravity of Soil Solids using Pycnometer method.	CO1	PO1, PO9, PO10
3	Determination of water content using Pycnometer method.	CO3	PO1, PO2, PO9, PO10
4	Determination of Liquid limit using Casagrande 's standard Liquid Limit device.	CO3	PO1, PO2, PO9, PO10
5	Determination of Plastic limit.	CO3	PO1, PO2, PO9, PO10
6	Sieve Analysis for plotting Particle size distribution curve.	CO2	PO1, PO2, PO9, PO10
7	Determination of Field Density using Sand Replacement Method.	CO1	PO1, PO9, PO10
8	Determination of Field Density by core cutter method.	CO1	PO1, PO9, PO10
9	Determination of Compaction Characteristics.	CO5	PO1, PO9, PO10
10	a) Determination of Co-efficient of Permeability by Constant Head Permeameter test. b) Determination of Co-efficient of Permeability by Variable Head Permeameter test.	CO5	PO1, PO9, PO10
11	Determination of shear strength, parameters by Direct Shear Test	CO4	PO1, PO2, PO9, PO10
12	Unconfined Compression Test.	CO4	PO1, PO2, PO9, PO10
13	Vane Shear Test	CO4	PO1, PO2, PO9, PO10

Name of the laboratory course: Soil Mechanics Laboratory **Course code:** 2PC555CE

INDEX

Faculty Sign **HOD-CE**

Experiment – 1
Determination of Specific Gravity of Soil Solids by "Density Bottle Method"

Aim: To determine the specific gravity by density bottle method.

Apparatus Required

1. Density bottle of 100ml (cm^3) capacity with a stopper.
2. Balance accurate to 0.05g.
3. Distilled water
4. Wash bottle

Specification: IS 2720 (Part III) – 1980 is the standard recommended to determine specific gravity of fine-grained soils. The value ranges from 2.60 to 2.80. The average of the values obtained shall be taken as the specific gravity of the soil particles and shall be reported to the nearest 0.01 precision. If the two results differ by more than 0.03 the tests shall be repeated.

Theory: Specific gravity of soil solids (G) is defined as the ratio of the mass of a given volume of solids to the mass of equal volume of water at 4^0C. (The mass density of water at 4^0C is, one gram/ml or 1000 kg/m^3.)

Equation for specific gravity, G:

$$G= (W_2-W_1)/((W_2-W_1)-(W_3-W_4))$$

where

W_1= weight of empty bottle

W_2= weight of bottle + dry soil

W_3= weight of bottle + soil + water

W_4= weight of bottle + water

Note: This method is normally used for fine-grained soils. The method may also be used for medium and coarse-grained soils, if the coarse particles are grained to pass 4.75-mm IS sieve before using.

Procedure

1. Find the weight of the empty, clean and dry density bottle with stopper. Let it be W_1.
2. Take 10-15g of oven dried soil and put into the density bottle. Weight it with stopper. Let this weight be W_2.
3. Add water in the density bottle. Remove the entrapped air by stirring or by applying vacuum.
4. Fill water up to top of density bottle.
5. Find the weight of density bottle, soil and filled water up to top of density bottle with stopper. Let it be W_3. Note down temperature of contents of density bottle.
6. Empty, clean and dry the density bottle then fills the density bottle by distilled water upto top with stopper. Let it be W_4.

Observations and Calculations

Weight of dry soil=W_2-W_1

Weight of equal volume of water =(W_2-W_1) - (W_3-W_4)

Specific gravity,

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

Table: Specific Gravity (Density Bottle Method) Model calculations

Observation No.	1	2	3
Weight of density bottle, W_1(g)	41.302g		
Weight of density bottle with dry soil, W_2(g)	54.103 g		
Weight of density bottle with soil and water filled up to top, W_3(g)	99.082 g		
Weight of density bottle filled with water only, W_4(g)	91.112 g		
W_2-W_1	12.801 g		
W_3-W_4	7.970 g		
G	2.65		

Specimen calculations: $G=(W_2-W_1)/((W_2-W_1)-(W_3-W_4))$

Result: Average G= ___________

Verification/ Validation: The value of specific gravity for the existing soil falls in the range 2.6 to 2.75. If there is any variation, check under the 'specification' provided and re-do the experiment to get accurate results.

Conclusion: The experiment is conducted as per the procedure laid down. The specific gravity of soil solids = _________. The value falls in the range 2.6 to 2.80. The type of soil is _____ as per the specification.

Precautions

1. Soil grains whose specific gravity is to be determined should be completely dry.
2. If on drying soil lumps are formed, they should be broken to its original size.
3. Inaccuracies in weighing and failure to completely eliminate the entrapped air are the main sources of error. Both should be avoided.
4. While cleaning the density bottle, please be careful as there may be glass grains projecting out and it may tear the skin.
5. Make sure, you handle the density bottle without falling on your legs or floor. Hence, handle the equipment with care.

Figures:

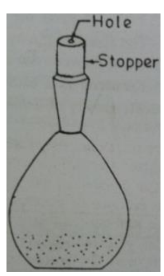

Figure: Density Bottle

Viva Questions

1. Which method is accurate in determining specific gravity of soil solids?
2. What are the steps involved in determining specific gravity using density bottle method?
3. How many grams of soil need to be taken for the test?
4. What is the specification required for the test?
5. What is the equation to determine the specific gravity?
6. Which method is accurate in determining specific gravity of soil solids?
7. What are the steps involved in determining specific gravity using density bottle method?
8. How much grams of soil need to be taken for the test?
9. What is the definition of Specific Gravity?

Experiment – 2
Determination of Specific Gravity of solids by using "Pycnometer Method"

Aim: To determine specific gravity of solids by using "Pycnometer method".

Apparatus Required

1. Pycnometer of capacity 500cm^3 to 1000cm^3 with conical brass cap
2. Balance accurate to 0.1g
3. 4.75 mm IS sieve
4. Glass rod
5. Distilled water
6. Vacuum pump

Theory: The pycnometer method can be used for the determination of the specific gravity of solid particles of both fine grained and coarse-grained soils. The specific gravity of solids is determined using the relation

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

Procedure

1. Find the weight of a clean and dry Pycnometer with its cap and washer. Let it be W_1.
2. Take about 200g of oven dried soil sample in the Pycnometer. Find the weight of Pycnometer with dry soil and its cap and washer. Let it be W_2.
3. Add water in the Pycnometer such that the Pycnometer is half filled with soil and water.
4. Stir the soil water properly. After stirring connect the Pycnometer with vacuum pump for about 10 to 20 minutes.
5. Fill the Pycnometer up to top and find the weight of soil water with its cap and washer. Let it be W_3.
6. Clean the Pycnometer and then fill it with water up to top.
7. Find the weight of the Pycnometer filled with water with its cap and washer. Let it be W_4.

Observations and Model Calculations

The Specific Gravity is obtained from the following expression:

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

Table: Pycnometer Method

Observation No.	1	2	3
Weight of Pycnometer with cap and washer, W_1(g)	580		
Weight of Pycnometer + dry soil, W_2(g)	800		
Weight of Pycnometer + dry soil + water, W_3(g)	1707		
Weight of Pycnometer + Water, W_4(g)	1570		
Specific Gravity G	2.65		

Result

Average Specific Gravity from above equation, G =………

Conclusion: Pycnometer method is a simple method to determine the specific gravity of a soil. Experiment is carried out using the soil specimen collected from the college itself. All foreign matters are removed, clods broken and water content we got for the soil specimen is ________. Comparing with the oven drying method, the value is _________.

Precautions

1. Inaccuracies in weighing and failure to completely eliminate the entrapped air are the main sources of error. Both should be avoided.
2. While cleaning the Pycnometer bottle, please be careful as there may be glass grains projecting out and it may tear the skin.
3. Make sure, that you handle the density bottle without falling on your legs or floor. Hence, handle the equipment with utmost care.

Figures

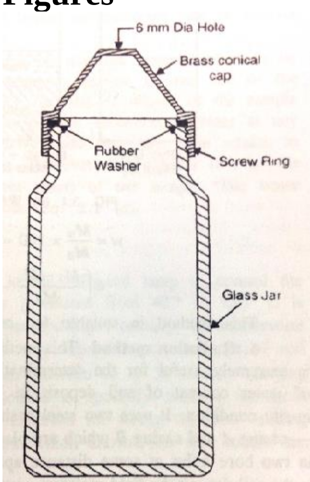

Figure.1: Pycnometer Bottle

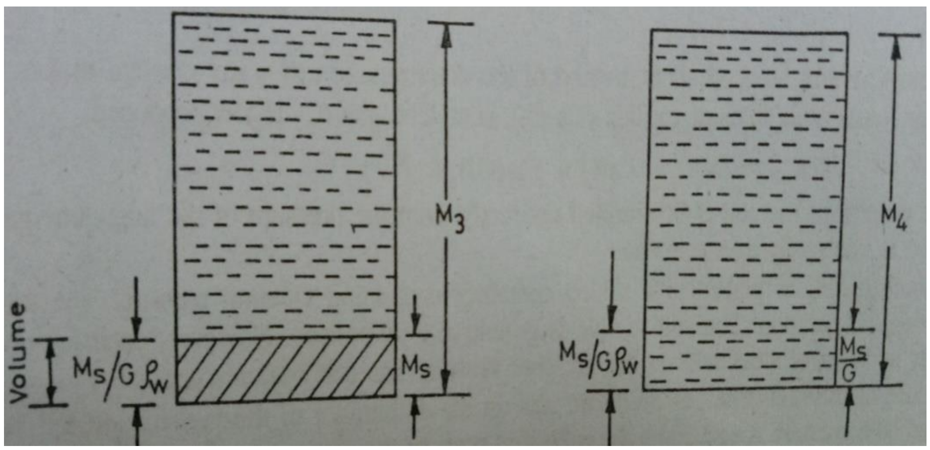

Figure.2: Pycnometer Method

Viva Questions

1. A pycnometer is used to determine?
2. Other than pycnometer, is there any other method to determine water content?
3. Which method is more accurate to determine water content, oven drying method or pycnometer method?
4. If there are lots of clods in the soil, what would happen to the result? Is it advisable to have lots of organic matter in the soil?
5. Explain the procedure to determine the water content using pycnometer?
6. Draw the schematic diagram of the three-phase system based on the result.
7. Is there a possibility of error by this method? In that case, what need to be done?
8. Which method gives the water content value rapidly, pycnometer method or oven drying method?

Experiment – 3

Determination of Water Content by "Pycnometer Method"

Aim: To determine water content using "Pycnometer method".

Apparatus Required

7. Pycnometer of capacity 500cm^3 to 1000cm^3 with conical brass cap
8. Balance accurate to 0.1g
9. 4.75 mm IS sieve
10. Glass rod
11. Distilled water

Specifications: This test is done as per IS: 2720 (Part II) – 1973. This method is suitable for coarse grained soils from which the entrapped air can be easily removed.

Theory: A Pycnometer is a glass jar of about 1-liter capacity, fitted with a brass conical cap by means of a screw type cover. The cap has a small hole of about 6mm diameter at its apex. For many soils, the water content may be an extremely important index used for establishing the relationship between the way a soil behaves and its properties. The consistency of a fine-grained soil largely depends on its water content. The water content is also used in expressing the phase relationships of air, water, and solids in a given volume of soil.

Water content, w of a soil mass is defined as the ratio of mass of water in the voids to the mass of solids:

Water content, W% = $[((W_2-W_1)/(W_3-W_4))\times(((G-1)/G)-1)]\times100$

Where, W_1= Weight of empty pycnometer in grams

W_2 = Weight of pycnometer + wet soil in grams

W_3 = Weight of pycnometer + dry soil in grams

W_4 = Weight of pycnometer + water in grams

Procedure

8. Find the weight of a clean and dry Pycnometer with its cap and washer. Let it be W_1.
9. Take about 200 to 400g of wet soil sample in the Pycnometer. Find the weight of Pycnometer with wet soil and its cap and washer. Let it be W_2.
10. Add water in the Pycnometer such that the Pycnometer is half filled with soil and water.
11. Stir the soil water properly. After stirring connect the Pycnometer with vacuum pump for about 10 to 20 minutes.
12. Fill the Pycnometer up to top and find the weight of soil water with its cap and washer. Let it be W_3.
13. Clean the Pycnometer and then fill it with water up to top.
14. Find the weight of the Pycnometer filled with water with its cap and washer. Let it be W_4.

Observations and Model Calculations

The water content is obtained from the following expression:

$$w\ \% = \left[\left(\frac{W_2 - W_1}{W_3 - W_4}\right)\left(\frac{G-1}{G}\right) - 1\right] X100\%$$

Table: Pycnometer Method

Observation No.	**1**	**2**	**3**
Weight of Pycnometer with cap and washer, W_1(g)	636		
Weight of Pycnometer + wet soil, W_2(g)	936		
Weight of Pycnometer + wet soil + water, W_3(g)	1712		
Weight of Pycnometer + Water, W_4(g)	1550		
Water content, w%	11.46%		

Result

Average water content from above equation, w =………%

Verification/ Validation: Soil mass is generally a three-phase system. It consists of solid particles, liquid and gas. The phase system may be expressed in SI units either in terms of mass volume or weight volume relationships. Water content value is 0% for dry soil and its magnitude can exceed 100%.

Conclusion: Pycnometer method is a simple method to determine the water content of a soil. Experiment is carried out using the soil specimen collected from the college itself. All foreign matters are removed, clods broken and water content we got for the soil specimen is ________. Comparing with the oven drying method, the value is _________.

Precautions

4. Inaccuracies in weighing and failure to completely eliminate the entrapped air are the main sources of error. Both should be avoided.
5. While cleaning the Pycnometer bottle, please be careful as there may be glass grains projecting out and it may tear the skin.
6. Make sure, that you handle the density bottle without falling on your legs or floor. Hence, handle the equipment with utmost care.

Figures

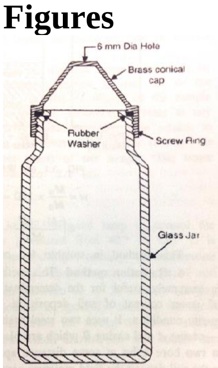

Figure.1: Pycnometer Bottle

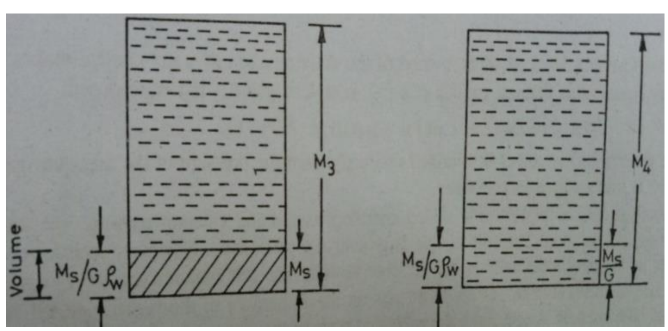

Figure.2: Pycnometer Method

Viva Questions

9. A pycnometer is used to determine?
10. Other than pycnometer, is there any other method to determine water content?
11. Which method is more accurate to determine water content, oven drying method or pycnometer method?
12. If there are lots of clods in the soil, what would happen to the result? Is it advisable to have lots of organic matter in the soil?
13. Explain the procedure to determine the water content using pycnometer?
14. Draw the schematic diagram of the three-phase system based on the result.
15. Is there a possibility of error by this method? In that case, what need to be done?
16. Which method gives the water content value rapidly, pycnometer method or oven drying method?

Experiment – 4

Determination of Liquid Limit using Casagrande's Standard Liquid Limit device

Aim: To determine liquid limit of fine soil by using Casagrande's Apparatus

Apparatus Required

1. Casagrande's liquid limit apparatus
2. Grooving tool
3. Spatula
4. Mixing dish or bowl
5. Balance, sensitive to 0.01g
6. Sieve 0.425mm

Specifications: This test is done to determine liquid limit of soil as per IS: 2720(Part 5)-1985. After receiving the soil sample, it is dried in air or in oven (maintained at a temperature of 600^{0} C). If clods are there in soil sample, then it is broken with the help of wooden mallet. The soil passing 425-micron sieve is used in this test.

Theory: Consistency of fine-grained soils may be defined as the relative ease with which a soil can be remoulded. Consistency limits may be categorized into three limits called Atterberg limits. They are 1) Liquid limit 2) Plastic limit and 3) Shrinkage limit

Liquid limit is the moisture content that defines where the soil changes from a plastic to a viscous fluid state. Other limits will be discussed during corresponding experiments.

Procedure

1. Clean, dry and make soil free the bowl of liquid limit device.
2. Keep the height of drop of bowl equal to 10 mm.
3. Take about 250 g of dry soil sample passing 0.425 mm sieve.
4. Mix the soil with water on a glass plate with a spatula until the mixture is uniform and behaves as a soft paste.
5. Place 50 to 80g of soil paste in the bowl and level it off to a depth of approximately 1 cm i.e., 10 mm.
6. Cut a groove through the sample from back to front dividing the paste in the bowl into two equal halves. Consider Casagrande's tool for a normal fine-grained soil and ASTM tool for sandy fine-grained soil.
7. Turn the handle of Casagrande's device at a steady rate of two revolutions per second. Continue turning until two halves of soil pat come in contact at the bottom of the groove along a distance of 13 mm. Note the number of blows. The groove should come in contact due to flow of soil not due to sliding.
8. Repeat steps 3 to 7 for four to five times. Note down the number of drops and water content each time. It is recommended that the water content should be varied such that the number of drops are between 15 to 30.

Figures

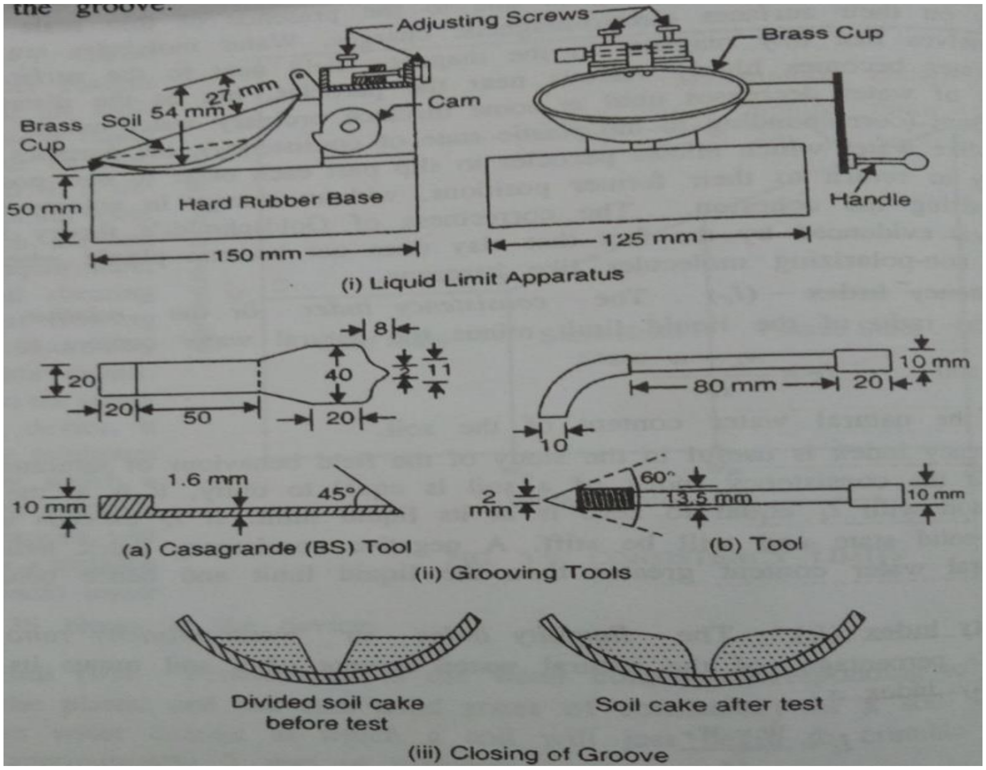

Figure: Liquid Limit Apparatus

Observations and Model Calculations

Table: Liquid Limit

S. No	% of Water	No. of Blows
1	25	1000
2		
3		

Plot log N on x-axis and water content, w on y-axis. From plot find the water content for 25number of blows. This gives liquid limit.

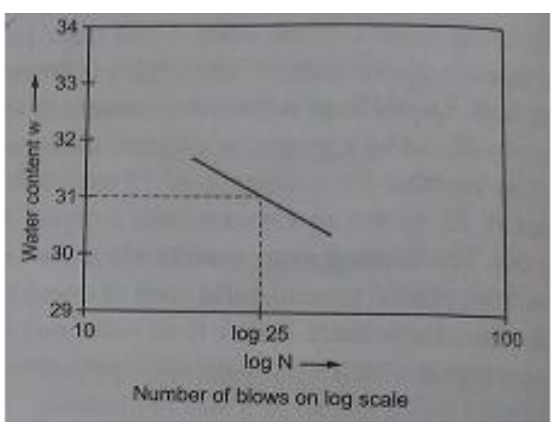

Figure: Liquid Limit Result

Result: From the graph drawn, flow index

$$I_f = \frac{(w_1 - w_2)}{\log\left(\frac{N2}{N1}\right)} = \_\_\_\_\_\_ \qquad \text{Liquid Limit} = \_\_\_\_\_\_$$

Verification/Validation: 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 is brittle and stiffer. Hence if the points on the graph are obtained scattered, we need to draw the linear curve at the mean. Flow index indicates the rate at which the soil loses shearing resistance with an increase in the water content.

Precautions

1. Soil used for liquid limit determination should not be oven dried prior to testing.
2. In LL test the groove should be closed by the flow of soil and not by slippage between the soil and the cup
3. After mixing the water to the soil sample, sufficient time should be given to permeate the water throughout out the soil mass
4. Wet soil taken in the container for moisture content determination should not be left open in the air, the container with soil sample should either be placed in desiccators or immediately be weighed.
5. After performing each test, the cup and grooving tool must be cleaned.
6. The number of blows should be just enough to close the groove.
7. The number of blows should be between 10 and 40.

Viva Questions

1. Define consistency of the soil. How is it measured?
2. What is liquid limit of soil?
3. What is the apparatus used to determine the liquid limit?
4. When a soil sample is given, what is the procedure to determine the liquid limit of the sample?
5. In a liquid limit test, the moisture content at 10 blows was 70% and that at 100 blows were 20%. The liquid limit of the soil, is?

Experiment – 5

Determination of Plastic Limit of the Soil

Aim: To determine the plastic limit of soil. The plastic limit of fine-grained soil is the water content of the soil below which it ceases to be plastic. It begins to crumble when rolled into threads of 3mm dia.

Apparatus Required

1. Glass or plastic plate
2. Metal rod of 3mm diameter
3. Spatula
4. Balance sensitive to 0.01g

Specifications: This test is done to determine the plastic limit of soil as per IS: 2720 (Part 5) 1985. Take out 30g of air-dried soil from a thoroughly mixed sample of the soil passing through 425µm IS Sieve. Mix the soil with distilled water in an evaporating dish and leave the soil mass for 24hrs.

Theory: The plastic limit is the moisture content that defines where the soil changes from a semi-solid to a plastic state. It may also be defined as that water content at which soil starts crumbling when rolled into threads of 3mm diameter. Use the paste from liquid limit test and begin drying. May add dry soil or spread on plate and air dry.

Procedure

1. Take about 20 g of soil for plastic limit test. The soil should pass through 0.425 mm IS sieve.
2. Mix the soil with distilled water thoroughly to get soil paste.
3. Make the soil paste into a ball of diameter 10 to 20 mm.
4. Convert the ball of soil into a thread by rolling it under the fingers against the glass surface. Roll the thread such that the thread is of 3 mm diameter. Measure the diameter of the thread by metal rod of 3 mm diameter.
5. Repeat steps 1 to 4 with three more fresh samples.

Observations and Calculations

Average plastic limit, $W_p =$

Natural water content, w=

Plasticity index (I_p)= Liquid limit -Plastic limit

$= (W_L - W_P) \dots\dots\%$

Consistency index = $\frac{W_L - w}{I_p}$

Liquidity index = $\frac{w - W_P}{I_p}$

Result: The Plastic limit of soil (average water content) is________________.

Plasticity index = $w_p - w_l$

Verification/Validations: Determine the plasticity index I_p, which is the difference between liquid limit and plastic limit. Following table list the standard values:

Soil Type	w_l	w_p	I_p
Sand			Non-Plastic
Silt	30-40	20-25	10-15
Clay	40-150	25-50	15-100

Conclusions: The plastic limit of the soil = ____ and plasticity index = ____
The type of soil is _____.

Precautions

1. The soil used in liquid limit test should not be oven dried.
2. The groove made in the soil in liquid limit test should close 13mm by flow of soil from either side and not by slippage.
3. The lid of container should be made tight immediately after putting the soil in the container.
4. Add water in the different soil sample such that the numbers of blows range from 15 to 35 to close the groove made by 13mm.

Viva Questions

1. What is meant by IS soil classification?
2. What is A-line?
3. What is liquidity index and consistency index?
4. Define plastic limit of soil?
5. How is plastic limit computed in laboratory?
6. What is the practical significance of determining plastic limit of the soil?
7. What is plasticity index?
8. What is toughness index?

Experiment – 6

Sieve Analysis for Particle Size Distribution Curve

Aim: To determine grain size distribution of a soil by sieve analysis.

Apparatus Required

1. For fine sieve analysis: IS sieves 4.75, 2, 1, 0.6, 0.425, 0.300, 0.150 and 0.075mm and pan.
2. Balance accurate to 0.1g
3. Weights
4. Sieve shaker
5. Trays
6. Pan
7. Wire brush

Theory: 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 generally used. The method is applicable to dry soil passing through 4.75 mm size sieve less than 10 % passing through 75-micron sieve.

Percentage retained on any sieve = (weight of soil retained / total weight)

Cumulative percentage retained = sum of percentages retained on any sieve on all coarser sieves

Percentage finer than any sieve = 100 percent minus cumulative Size, N percentage retained.

Procedure

Fine Sieve Analysis

1. Arrange the set of sieves such that 4.75mm sieve is at the top and 0.075mm sieve is at the bottom.
2. Put pan at the bottom of 0.075mm sieve.
3. Put the soil passing 4.75mm sieve on top sieve and then cover it.
4. Put the set of sieves with pan and cover in the sieve shaker.
5. Shake the sieves for 10minutes.
6. Find the weight of soil retained on each sieve.

For both coarse grained analysis and fine-grained analysis find the percentage of soil retained on each sieve; cumulative percentage retained and percentage finer. Particle size distribution curve is obtained by plotting particle size on x-axis on log scale and percentage finer on y-axis.

Observations and Model Calculations

Table: Fine Sieve Analysis

Weight of soil taken for analysis = 400g

IS sieve size (mm) [1]	Weight of soil retained (g) [2]	Percentage weight retained [3] = [1]/Total weight	Cumulative percentage retained [4] Sum of wt retained	Percentage finer (N) [5] = 100-[4]

1. Plot curve between percentage finer and grain size on semi-log graph
2. Find particle size for 10% finer, D_{10}; particle size for 30% finer, D30; particle size for 60%, finer, D_{60}.
3. Find Uniformity coefficient, C_u

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

4. Find coefficient of curvature, C_c

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

Result: C_u=________ C_c=_________

Conclusions: The uniformity coefficient, Cu = ___ and Cc =_____.

The type of soil is ____________________________________

Precautions

1. The temperature of oven should be between 105 to 110^0C.
2. The soil should not come out while shaking the sieves in sieve shaker.
3. Determine percentage finer with respect to total soil taken.

Figures

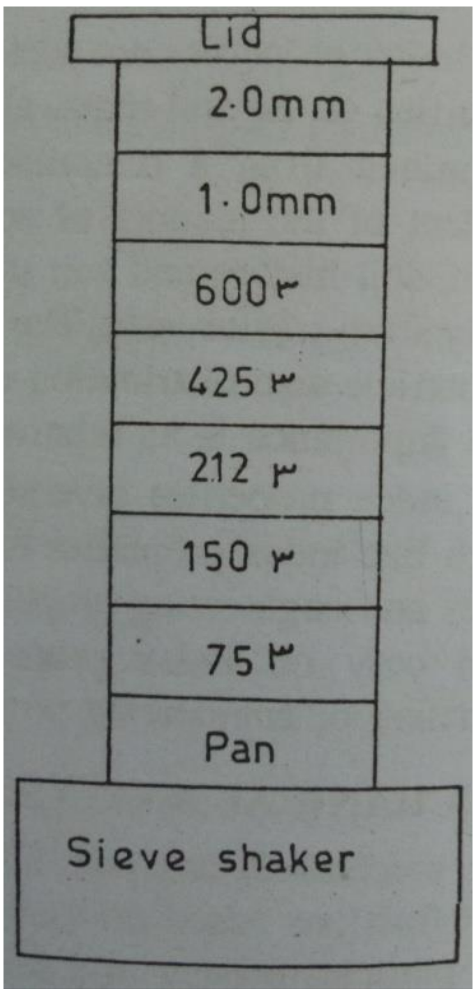

Figure.1: Stacking of Sieves

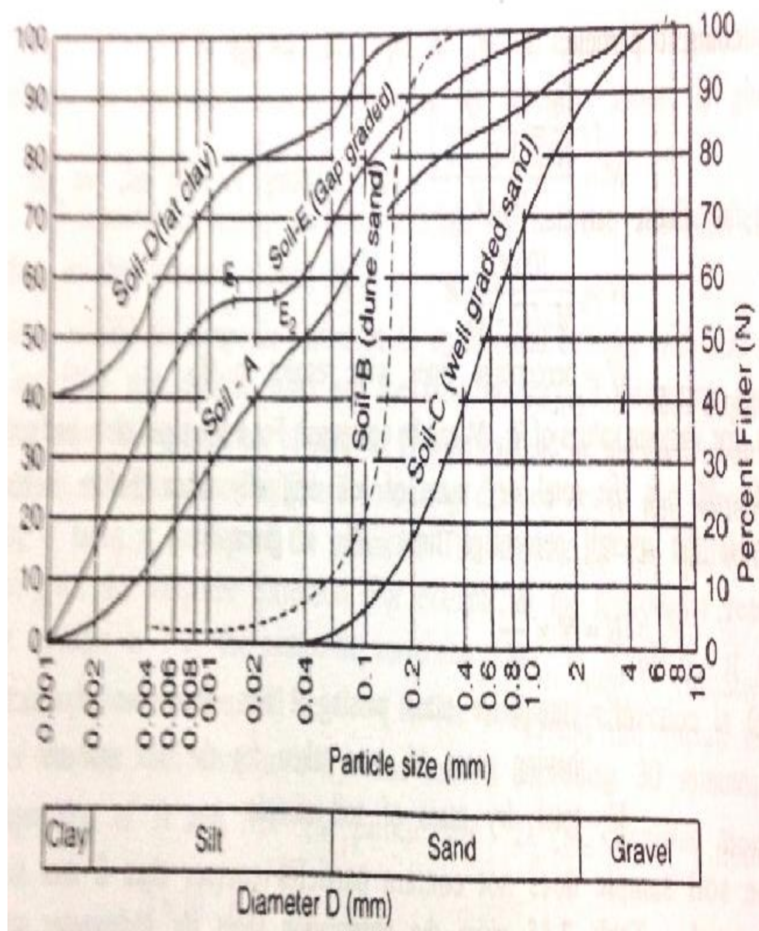

Figure.2: Gradation curve of Soil

Verification/Validations: For the soil to be well graded the value of coefficient of uniformity C_u has to be greater than 4 and C_c should be in the range of 1 to 3. So higher the value of C_u the larger the range of the particle sizes in the soil. So, if the C_u value is high, it indicates that the soil mass consists of different ranges of particle sizes.

Viva Questions

1. Define the grain size analysis and what is the silt size?
2. What is uniformity coefficient? What is the significance on computing the same?
3. What is the most basic classification of soil?
4. What are the methods of soil gradation or grain size distribution?
5. How to compute D_{10}, D_{30} and D_{60} of soil using sieve analysis?
6. How to compute C_c and C_u?
7. What is poorly graded, gap graded and well graded soil?

Experiment – 7

Determination of Field Density of Soil by Sand Replacement Method

Aim: To determine the field density of soil by sand replacement method.

Apparatus Required

1. Sand pouring cylinder
2. 30cm square metal tray with 10cm hole in the center
3. Cylindrical calibration container
4. Balance
5. Oven
6. Glass plate
7. Clean oven dried sand passing 600µ sieve i.e., 0.600mm sieve.

Specifications: This test is done to determine the in-situ density of soil by core cutter method as per IS-2720-Part-28 (1975). In order to conduct the test, select uniformly graded clean sand passing through 600µ IS sieve and retained on 400µ IS sieve.

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. In sand replacement method, a small cylindrical pit is excavated and the weight of the soil excavated from the pit is measured. Sand whose density is known is filled into the pit. By measuring the weight of sand required to fill the pit and knowing its density, the volume of pit is calculated.

Knowing the weight of soil excavated from the pit and the volume of pit, the density of soil is calculated. Therefore, in this experiment there are two stages, namely

1. Calibration of sand density
2. Measurement of soil density

Field density is defined as weight per unit volume of soil mass in the field at in-situ conditions.
Equations are:

$\rho_d = \rho_t/(1+w)$ gm/cm³ (OR) $\gamma_d = \gamma_t/(1+w)$ kN/m³

Where, ρ_d = dry density,

γ_d = dry unit weight,

ρ_t = field moist density,

γ_t =field moist weight,

w =water constant,

γ_w = unit weight of water = 9.81 kN/m³

The basic equations in determination of density using sand replacement method are:

$$V_h = W_s/(G\times\rho_w)$$

$$\rho_t = M/V_h$$

$$\rho_d = \rho_t/(1+w)$$

Where, V_h = Volume of hole made in the field.

W_s = weight of the sand that fills the hole.

W = weight of moist soil removed from the hole.

w = moisture content of soil removed from the hole.

ρ_t = moist soil in-situ density.

ρ_d = dry density of the soil.

G = specific gravity of the solids.
ρ_w = density of the water.

Procedure

Determination of Density of Sand in Laboratory

1. Measure the internal diameter and height of the calibrating container and find its volume. Let it be V_c.
2. Find the weight of sand pouring cylinder filled with sand. Let it be W_1.
3. Place the sand pouring cylinder on glass plate and open its shutter. The sand falls and fills the cone of sand pouring cylinder. Close the shutter when cone is completely filled by sand. Find the weight of sand pouring cylinder with remaining sand. Let it be W_2.
4. Put the sand pouring cylinder concentrically on the top of the calibrating container. Open the shutter. Sand falls and fills the calibrating container and cone completely. Close the shutter. Find the weight of sand pouring cylinder with remaining sand. Let it be W_3.
5. Find the density of sand.

Determine of Water Content

1. Weigh the metal tray having central hole. Let the weight be W_1.
2. Place the metal tray with central hole on levelled ground.
3. Excavated soil of diameter equal to the diameter of hole and depth approximately 15cm.
4. Put the excavated soil in tray and find its weight. Let the weight of tray and soil be W_2'.
5. Put the tray with soil in oven. Find the weight of tray with dry soil. Let it be W_3'.
6. Determine water content.

Density of Soil in the Field

1. Fill the sand pouring cylinder by sand and weight it. Let the weight be W_1.
2. Put the pouring cylinder over the hole and open the shutter until the sand fills completely the hole and cone, close the shutter. Find the weight of sand poring cylinder with remaining sand. Let it be W_2.
3. Subtract the weight of sand in cone to W_1-W_2. It gives the weight of sand filed in the hole. Let it be W_{hole}.
4. Find the volume of hole by dividing the weight of sand filled in the hole by density of sand. Let this volume be V_{hole}.
5. Find density of soil, dividing the weight of soil excavated from hole by volume of hole. It gives the density of soil in field.
6. Let the density be γ_b.

Observations and Calculations

Table 1: Determination of Density of Sand in Laboratory (Model calculations)

Observations	1	2	3
1. Volume of calibrating container V_c (cm^3)	1178.09		
2. Weight of pouring cylinder + sand, W_1(g)	8221.5		
3. Weight of pouring cylinder with remaining sand, W_2(g) (After filling the cone)	7829		
4. Weight of pouring cylinder with remaining sand after filling calibrating container and cone, W_3(g)	5777		
5. Weight of sand filled in cylinder in cone =(W_1- W_2) (g)	329.5		
6. Weight of sand filled in cylinder and container = (W_2-W_3) (g)	2052		
7. Weight of sand in calibrating container W_c= [(W_2-W_3) -(W_1-W_2)]	1659.5		
8. Hence, density of sand $\gamma_d = \frac{W_c}{V_c}\ (g/cm^3)$	1.408g/cm^3		

Table 2: Field Density of Soil (Model calculations)

Observations	1	2	3
Weight of pouring cylinder filled with sand = W_1(g)	8099.5		
Weight of pouring cylinder with sand after filling the hole and cone = W_4(g)	6822		
Weight of sand filled in cone = W_{cone}(g)	392.5		
Weight of sand filled in hole W_{hole}(g) = - [(W_1-W_4)- W_{cone}] (g)	885		
Volume of hole =$V_{hole} = \frac{W_{hole}}{\gamma_d}$ Where γ_d is density of sand	628.55		
Weight of soil excavated from the pit, W_W (g)	1208		
Hence, density of soil, $r_d\left(\frac{g}{cm^3}\right) = \frac{Weight\ of\ excavated\ soil}{Volume\ of\ hole} = \frac{W_W}{V_{hole}}$	1.92g/cm^2		

Result: The In-situ density of the soil is ----------g/cm^3

Conclusions: The dry density of the soil is ________g/cc. Comparing with the in-situ density by core cutter method, more or less the same value is achieved. The type of soil is ---------------

Precaution

1. Do not leave loose material in the hole.
2. There should be no vibration.
3. Take average volume of density as density varies from point to point.
4. In no case the side of hole should cave in.

Figures

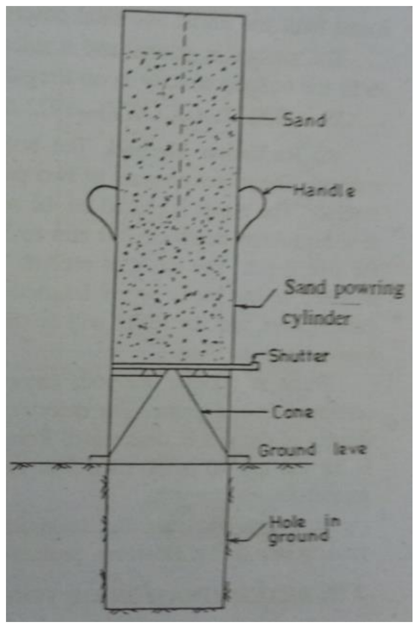

Figure: Sand Replacement Method

Verification and Validations: Sand replacement method is an indirect method of finding the density of soil. The basic principle is to measure the in-situ volume of hole from which the material was excavated from the weight of sand with known density filling in the hole. The in-situ density of material is given by the weight of the excavated material divided by the in-situ volume. The dry density of most soils varies within the range of 1.5-1.8 g/cm^3. In sandy soils, dry density can be as high as 1.7 g/cm^3; in clayey soils and aggregated loams, it can be as low as 1.5 g/cm^3.

Viva Questions

1. What is the objective of sand replacement method?
2. What is the relationship that can be established between the dry density with known moisture content?
3. What is the apparatus that are needed in this test?
4. What is the significance of determining the in-situ density of the soil?
5. Depth of hole is kept to 15 cm in the field. Why?

Experiment – 8

Determination of Field Density by Core Cutter Method

Aim: To determine the field density by core cutter method.

Apparatus Required

1. Cylindrical core cutter of diameter 10cm and height 12.74 cm
2. Steel dolly
3. Balance
4. Straight edge
5. Knife
6. Steel rammer

Specifications: This test is done to determine the in-situ dry density of soil by core cutter method as per IS-2720-Part-29 (1975). Core cutter method in particular, is suitable for soft to medium cohesive soils, in which the cutter can be driven. It is not possible to drive the cutter into hard and boulder soils.

Theory: Field density is used in calculating the stress in the soil due to its overburden pressure. It is needed in estimating the bearing capacity of soil foundation system, settlement of footing, earth pressures behind the retaining walls and embankments. Stability of natural slopes, dams, embankments and cuts is checked with the help of density of soil. It is the density that controls the field compaction of soils. Permeability of soils depends upon its density. Relative density of cohesion less soils is determined by knowing the dry density of soil in natural, loosest and densest states. Void ratio, porosity and degree of saturation need the help of density of soil.

Field density is defined as weight per unit volume of soil mass in the field at insitu conditions. In the spot adjacent to that where the field density by sand replacement method has been determined or planned, drive the core cutter using the dolly over the core cutter. Stop ramming when the dolly is just proud of the surface. Dig out the cutter containing the soil out of the ground and trim off any solid extruding from its ends, so that the cutter contains a volume of soil equal to its internal volume which is determined from the dimensions of the cutter. The weight of the contained soil is found and its moisture content determined.

Equations are;

$\rho_d = \rho_t/(1+w)$ gm/cm³ (OR) $\gamma_d = \gamma_t/(1+w)$ kN/m³

Where, ρ_d = dry density in g/cm^3,

γ_d= dry unit weight in g/cm^3,

ρ_t = field moist density in g/cm^3,

γ_t =field moist unit weight in g/cm^3,

w =water content,

γ_w = unit weight of water = 9.81 kN/m³

Procedure

1. Find the weight of the core cutter; Let it be W_1.
2. Measure internal diameter and height of the core cutter. Find internal volume of core cutter. Let it beV_0.
3. In the field, clean and level the ground where density is to be determined.
4. Push the cylindrical core cutter into the soil to its complete depth by gently ramming it by rammer.
5. Excavate the soil around the core cutter and remove the excavated soil.

6. Lift the core cutter up carefully so that no soil comes out of the core cutter. The soil must be projected up and down of the core cutter.
7. Trim the bottom and top surface of the sample very carefully.
8. After cleaning the outside of the core cutter, determine the weight of core cutter with soil. Let it be W_2.
9. Take the empty weight of can. Let it be W_3.

Observations and Calculations

Weight of core cutter, W_1 =______ (g)
Weight of core cutter with soil, W_2 =_____(g)
Weight of wet soil, $W_{wet} = W_2 - W_1$ =______ (g)
Volume of soil = Internal volume of core cutter, V_0=_____ (cm^3)
Bulk density of soil (γ_b)

$$= \frac{W_{wet}}{V_0}$$

$$= \frac{W_2 - W_1}{V_0} \ldots . (g/cm^3)$$

Repeat the above steps for 3 to 4 samples for be leveled ground.

Table: Observations and Calculations (Model Calculations)

S. No	Observations & Calculations	Determination No		
		1	2	3
1	Weight of empty cutter (W_1), gms	1120		
2	Weight of cutter + wet soil (W_2), gms	3217		
3	Volume of core cutter (Vc) cm^3	1021.01		
4	Field moist density, $\frac{W_2 - W_1}{V_0}$	2.05g/m^3		

Precautions

1. Core cutter method of determining the field density of soil is only suitable for fine grained soil (Silts and clay). That is, core cutter should not be used for gravels, boulders or any hard surface. This is because collection of undisturbed soil sample from a coarse-grained soil is difficult and hence the field properties, including unit weight, cannot be maintained in a core sample.
2. Core cutter should be driven into the ground till the steel dolly penetrates into the ground half way only so as to avoid compaction of the soil in the core.
3. Before lifting the core cutter, soil around the cutter should be removed to minimize the disturbances.
4. While lifting the cutter, no soil should drop down.

Figures

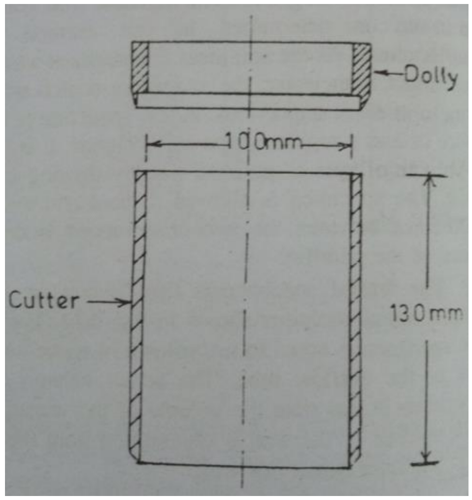

Figure: Core Cutter with Dolly

Result: Average in-situ field dry density: = --------------

Conclusion: The value of dry density of the soil is ____.
The type of soil is ____.

Verification/ Validation: The dry density of most soils varies within the range of 1.1-1.6 g/cm^3. In sandy soils, dry density can be as high as 1.6 g/cm^3; in clayey soils and aggregated loams, it can be as low as 1.1 g/cm^3.

Viva Questions

1. Out of wet density, dry density, and saturated density, which one of them is maximum and minimum? Explain.
2. What are the main factors which affect in-situ density of soil? Explain.
3. Beside the density, what other properties do you need to calculate the void ratio a degree of saturation of soils?
4. What are the other methods to calculate the field density of soil?
5. Which is the most accurate method to determine the field density?

Experiment – 9

Determination of Optimum Moisture Content and Maximum Dry Density of Soil by Standard Proctor Test

Aim: To determine the optimum moisture content and maximum dry density of a soil by standard proctor test.

Apparatus Required

1. Cylindrical mould of capacity 1000 ml having internal diameter 100 mm and height 127.3 mm or cylindrical mould of capacity 2250 ml having internal diameter 150 mm and height 127.3 mm. The cylindrical mould is having base plate and removable extension collar.
2. Rammer for light compaction, weight 2.6 kg and free drop 310 mm.
3. Balance 10 kg capacity with 1g accuracy.
4. Balance 200g capacity with accuracy 0.01 g.
5. Spatula.
6. Steel straight edge.

Specifications: The experiment is conducted as per IS 2720-7(1980).

Theory: Compaction is the application of mechanical energy to a soil so as to rearrange its particles and reduce the void ratio. It is applied to improve the properties of an existing soil or in the process of placing fill such as in the construction of embankments, road bases, runways, earth dams, and reinforced earth walls. Compaction is also used to prepare a level surface during construction of buildings. There is usually no change in the water content and in the size of the individual soil particles.

The objectives of compaction are:

a) To increase soil shear strength and therefore its bearing capacity.
b) To reduce subsequent settlement under working loads.
c) To reduce soil permeability making it more difficult for water to flow through

To assess the degree of compaction, it is necessary to use the dry unit weight, which is an indicator of compactness of solid soil particles in a given volume. The laboratory testing is meant to establish the maximum dry density that can be attained for a given soil with a standard amount of compactive effort.

1. Bulk density $\rho_t = (M_2\text{-}M_1)/V$
2. Dry density $\rho_d = \rho t/(1 + w)$
3. Dry density ρ_d for zero air voids line.

$$\rho_d = GP_w/(1 + (wG/S))$$

Where, M_1 = mass of mould used for proctor test

M_2 = mass of mould + compacted soil.

M = mass of wet soil.

V = volume of mould.

ρ_w = density of water.

G = Specific gravity of soils.

W = water content.

S = degree of saturation.

Procedure

1. Take about 3 kg air dried soil sample for 1000 ml mould. Sieve the soil through 20 mm and 4.75 mm IS sieve. If the percentage of soil retained on 4.75 mm sieve is less than 20, take 1000 ml mould.
2. Take about 2.5 kg of soil for 1000 ml mould for light compaction.
3. Add water about 4 percent for coarse grained soil and 8 percent for fine grained soil. Keep this soil water mix in an airtight container for about 5 to 30 minutes.
4. Find the weight of mould with base plate. Let it be W_1.
5. Fix the collar on the mould and apply grease inside of the mould and collar.
6. For light compaction, use 2.6 kg rammer with height of fall 310 mm with 25 number of blows for a layer of soil. Scratch the compacted soil on top and put the second layer and compact it as the first layer. Similarly scratch the top of second layer and put the soil on it and compact it as the first layer.
7. Remove the collar carefully and level off the top of the mould by means of straight edge. Find the weight of mould plus base plate plus wet soil. Let it be W_2.
8. Repeat steps 4 to 5 times, using a fresh part of soil specimen each time. Add water to the specimen such that the water content increases each time.

Observations and Model Calculations

Volume of mould = 1000cc
Weight of rammer =2.5kg
Number of blows=25

Table 1: Standard Proctor Test

Observations	1	2	3
Weight of mould + base plate, W_1(g)	4512		
Weight of mould+ base plate + compacted soil, W_2(g)	6128		
Weight of compacted soil (w)=$(W_2 - W_1)$ (g)	1616		
Bulk density, $\gamma_b = \frac{W}{V}\ g/cm^3$	1.616		
Dry density, $\gamma_d = \frac{\gamma_b}{1+w}\ g/cm^3$	1.496		

Result: Optimum Moisture Content (OMC) =

$\gamma_{dry} =$

Conclusions: The maximum density of the soil is ______ with an OMC of _______. This indicates, after w%, any additional water addition, there is no gain in strength of soil.

Precautions

1. During compaction, the mould should be placed on a solid base.
2. During the compaction, blows should be uniformly distributed over the surface of each layer.
3. Scratch each layer of compacted soil and then put the next layer and compact.
4. After compacting the last layer, the soil should project about 5mm above the top rim of the mould which is to be trimmed with a cutting edge.

Figures

Figure: Compaction Test

Verification and Validations: The peak point of the compaction curve - The peak point of the compaction curve is the point with the maximum dry density dry density. Corresponding to the maximum dry density ρ_{dmax} is the water content known as the optimum water content. The optimum water content is the water content that results in the greatest density for a specified compactive effort. Compacting at water contents higher than the optimum water content results in a relatively dispersed soil structure (parallel particle orientations) that is weaker, more ductile, less pervious, softer, more susceptible to shrinking, and less susceptible to swelling than soil compacted dry of optimum to the same density.

Viva Questions

1. What is the difference between standard proctor test and modified proctor test?
2. What is relative density of soil?
3. What is voids ratio? What is zero air voids line?
4. What is the practical implication of conducting standard proctor test?
5. How to determine OMC of soil? Explain.
6. How is compaction different from consolidation?
7. Did you watch any civil engineering construction compaction is carried out? Explain.
8. Is there any other method other than standard proctor test to determine maximum Dry density?

Experiment – 10

a) Determination of Coefficient of Permeability of Soil by Constant Head Method

Aim: To determine coefficient of permeability of soil by constant head method.

Apparatus Required

1. Permeameter mould - 1000cc capacity, 100 mm diameter and 127.3 mm height.
2. Compaction equipment- suitable static or dynamic equipment.
3. Drainage base - with porous disc of 12 mm thickness and dummy plate of 12 mm, provision with water inlet/outlet connection.
4. Drainage cap - with porous disc 12 mm thick with water inlet outlet connection.
5. Constant head tank.
6. Set of stand pipes- glass stand pipes of diameter 5 to 20 mm suitably mounted on stand or fixed with the wall.
7. IS sieves
8. Mixing tray
9. Graduated cylinder
10. Metric scale
11. Stop watch
12. Thermometer
13. Source of water
14. Balance
15. Filter papers (10 cm diameter)
16. Grease
17. Spatula

Specifications: IS 2720-17 (1986): Methods of test for soils, Part 17. This test is used to determine the permeability of granular soils like sands and gravels containing little or no silt

Theory: The rate of flow under laminar flow conditions through a unit cross sectional are of porous medium under unit hydraulic gradient is defined as coefficient of permeability. Water flowing through soil exerts considerable seepage force which has direct effect on the safety of hydraulic structures. The rate of settlement of compressible clay layer under load depends on its permeability.

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

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. Permeability of soil can be determined from Darcy's Law. The equation to determine the permeability of soil using constant head permeability test is given by:

$k = (Q \times L)/(A \times h \times t)$ Where, k = coefficient of permeability

Q = volume of water collected in time t

h = head causing flow

A = cross sectional area of sample

L = length of sample

Preparation of Sample

Undisturbed Sample

A sample of diameter 8.5 cm and height 12.73 cm is obtained by trimming off the undisturbed specimen. Filter paper is put at both the ends of the soil sample.

The sample with filter paper is placed over the bottom saturated porous stone of the drainage base. The annular space between the mould and soil sample is filled with cement slurry or mixture of 10% bentonite with 90% fine sand by weight to avoid any leakage from sides. Drainage cap is fixed over the top of the mould.

Saturation of Sample

The outlet of the bottom drainage base plate the mould is connected to the water storage and the water is allowed to flow in until the sample gets saturated. Then the water reservoir is disconnected from the outlet at the bottom.

Procedure

Constant Head Test

1. Connect the inlet at the top of plate to constant head water reservoir.
2. Open the bottom outlet and ascertain stead state of flow.
3. Collect the quantity of water (Q) for a time interval (t).
4. Repeat step 3 for same time interval 4 more times.
5. Dismantle the permeability apparatus.
6. Find the weight of wet soil in mould.
7. Take soil from the sample and put it for water content determination.

Observations and Calculations

Length of specimen (L)= 12.7cm
Diameter of specimen (d) = 10cm
Area of specimen (A) = ….cm^2
Volume of specimen (V) = …. cm^3
Coefficient of Permeability k,

$$k = \frac{Q}{Ai}$$

$$then, i = \frac{h}{L}$$

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

Table: Constant Head Permeability test (Model Calculations)

S.No	Time, t (sec)	Constant head (cm)	Quantity, Q (cm^3)	q=Q/t (cm^3/sec)	k_T (cm/sec)
1	15	182	390	26	0.023
2					
3					
4					
5					
6					

Result: Coefficient of Permeability of soil k=----------------------cm/sec

Conclusions: The type of soil tested is ___ as the permeability falls in the range as shown in the above table.

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

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

Precautions

1. Grease must be applied liberally between mould, base plate and collar.
2. The porous stones used in permeability test must be saturated just before placing.
3. Before taking the observations, soil sample must be completely saturated.
4. The water is allowed to flow out of outlet upto the time when steady flow established and then observations are taken.

Figures

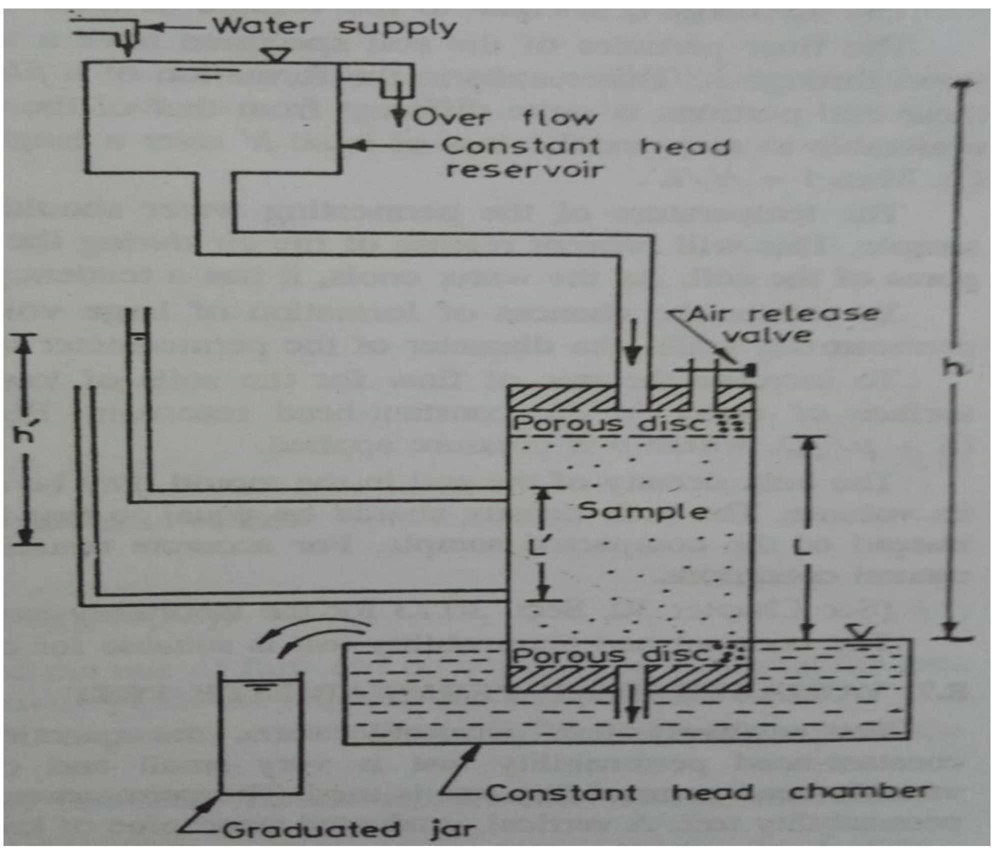

Figure: Constant Head Permeameter

Viva Questions

1. What is Darcy's law of flow velocity through soils? What are its Limitations?
2. What are the steady and unsteady flows of water? What type of flow is assumed to occur in soils?
3. What are the laboratory methods of determination of coefficient of permeability of soil? State their suitability.
4. What is the effect of entrapped air on the coefficient of permeability of soil?
5. Constant head method is suitable for what type of soils?
6. Soil with largest void ratio has lesser or more permeability?
7. Coefficient of permeability is also called as?

Experiment – 10

b) <u>Determination of Coefficient of Permeability of Soil by Variable Head Method</u>

Aim: To determine the coefficient of permeability of soil by falling head method.

Apparatus Required

1. Permeameter mould - 1000cc capacity, 100 mm diameter and 127.3 mm height.
2. Compaction equipment - suitable static or dynamic equipment.
3. Drainage base - with porous disc of 12 mm thickness and dummy plate of 12 mm, provision with water inlet/outlet connection.
4. Drainage cap - with porous disc 12 mm thick with water inlet outlet connection.
5. Constant head tank.
6. Set of stand pipes- glass stand pipes of diameter 5 to 20 mm suitably mounted on stand or fixed with the wall.
7. IS sieves
8. Mixing tray
9. Graduated cylinder
10. Metric scale
11. Stop watch
12. Thermometer
13. Source of water
14. Balance
15. Filter papers (10 cm diameter)
16. Grease
17. Spatula

Specifications: IS 2720-17 (1986): Methods of test for soils, Part 17. This test is used for fine grained soils with intermediate and low permeability such as silts and clays. This testing method can be applied to an undisturbed sample.

Theory: The falling head permeability test involves flow of water through a relatively short soil sample connected to a standpipe which provides the water head and also allows measuring the volume of water passing through the sample. The diameter of the standpipe depends on the permeability of the tested soil. The test is carried out in falling head permeameter cell.

Before starting the flow measurements, the soil sample is saturated and the standpipes are filled with de-aired water to a given level. The test then starts by allowing water to flow through the sample until the water in the standpipe reaches a given lower limit. The time required for the water in the standpipe to drop from the upper to the lower level is recorded. Often, the standpipe is refilled and the test is repeated for couple of times.

The recorded time should be the same for each test within an allowable variation of about 10% otherwise the test is failed.

The below equation can be used:

$$k = ((2.3\times a \times L)/(A\times(t_2-t_1)))\times \log10(h_1/h_2)$$

Where, L = length of soil sample column

A = Sample cross-section

a = the cross-section of the standpipe

(t_2-t_1) = the recorded time for the water column to flow though the sample
h_1 and h_2 = the upper and lower water level in the standpipe measured using the same water head reference

Procedure

Falling Head Test

1. Connect the specimen through top inlet to a selected stand pipe.
2. Open the bottom outlet when steady state condition is reached then note down the time interval (t) required for the water level to fall from a known initial height (head) h_1 to a known final head h_2. Measure the heads h_1 and h_2 from the centre of outlet.
3. Repeat test for four more times.

Observations and Calculations

Length of specimen (L)= 12.7cm
Diameter of specimen (d) = 10cm
Area of specimen (A) = $\pi/4\times(10)^2$=78.5398cm^2
Volume of specimen (V) = $\pi/4\times(10)^2\times12.7$=999.02cm^3
Area of stand pipe (a) = = $\pi/4\times(1)^2$=0.785cm^2
Initial head of water in stand pipe (h_1) = ….cm
Final head of water in stand pipe (h_2) = ….cm

Table: Falling head Permeability test (Model Calculations)

S.No	Time, t (sec)	Falling Head (cm)		$\log_{10}\left(\frac{h_1}{h_2}\right)$	Coefficient of permeability K (cm/sec)
		h_1	h_2		
1	**11.84**	**88**	**78**	**0.0523**	**1.293×10^{-3}m/s**
2					
3					
4					
5					

$$k = \frac{2.303\,aL}{At}\log_{10}\left(\frac{h_1}{h_2}\right)\ \text{cm/sec}$$

Result: Coefficient of Permeability of soil k=----------------------cm/sec

Conclusions: As per the value of coefficient of permeability ______________, type of soil from the above table is ____________.

Precautions

1. All possible leakage of joints must be eliminated.

2. Porous stones must be saturated before being put to use.
3. De-aired and distilled water should be used to prevent choking of flowing water.
4. Soil sample must be carefully saturated before taking the observations.
5. Use of high heads, which result in turbulent flows, should be avoided.

Figures

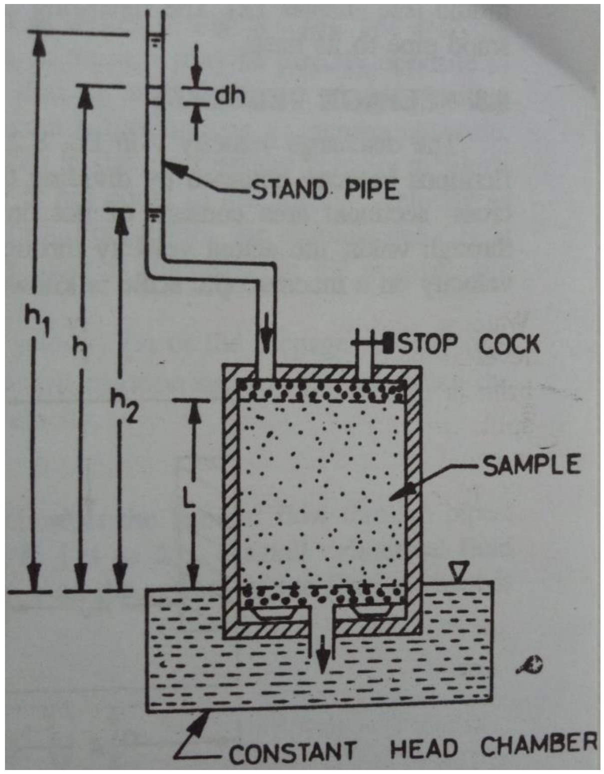

Figure: Variable Head Permeameter

Verification/Validations: The coefficient of permeability of a soil describes how easily a liquid will move through a soil. It is also commonly referred to as the hydraulic conductivity of a soil. This factor can be affected by the viscosity, or thickness (fluidity) of a liquid and its density. The number can also be affected by the void size, or region of non-soil, void continuity, and soil particle shape and surface roughness. It is an important factor when determining the rate at which a fluid will actually flow through a particular type of soil.

Viva Questions

1. A fully saturated soil is said to be in which phase?
2. Valid range of degree of saturation of soil in percentage is?
3. If the voids of a soil mass are full of air only, the soil is termed as?
4. Which method is the most suitable to determine the permeability of the clayey soil?
5. Is there any connection between permeability of soil and temperature? If
6. temperature increases, will permeability increase?
7. In the case of natural deposits, permeability is higher parallel to stratification or perpendicular to stratification?

Experiment – 11
Determination of Shear Strength of Soil by Direct Shear Test

Aim: To determine shear strength of soil sample using the direct shear test.

Apparatus Required

1. Shear box (60 mm x 60 mm x 50 mm)
2. Box Container to hold the shear box
3. Base plate having cross grooves on its top surface
4. Grid plates 2 no's
5. Porous stone, 6mm thick, 2 no's
6. Loading pad
7. Loading frame
8. Loading yoke
9. Proving ring capacity 2kN
10. Dial gauges, accuracy 0.001mm, 2 no's
11. Static or dynamic compaction devices
12. Spatula

Theory: Shear strength of a soil is its maximum resistance to shearing stresses. The shear strength is expressed as

$$s = c' + \overline{\sigma} \tan\phi'$$

Where c' = effective cohesion,

$\overline{\sigma}$ = effective stress

ϕ' = effective angle of shearing resistance

The shear test can be conducted under three different drainage conditions. The direct shear test is generally conducted on sandy soils as a consolidated drain test.

Procedure

1.Measure the internal dimensions of the shear box. Also determine the average thickness of the grid plates.

2. Fix the upper part of the box to the lower part using the locking screws. Attach base plate to the lower part.

3. place the grid plate in the shear box keeping the serrations of the grid at right angles to the direction of shear. Place a porous stone over the grid plate.

4. Weigh the shear box with base plate, grid plate and porous stone.

5. Place the soil specimen in the box. tamp it directly in the shear box at the required density. When the soil on the top half of the shear box is filled up to 10 to 15mm depth. Level the soils surface.

6. Weigh the box with the soil specimen.

7. Place the box inside the container, and fix the loading pad on the box. Mount the box container on the loading surface.

8. Bring the upper half of the box in contact with the proving ring. Check the contact by giving a slight movement. Fill the container with water if the soil is to be saturated. Otherwise omit this step.

9. Mount the loading yoke on the ball placed on the loading pad.
10. Mount one dial gauge on the loading yoke to record the vertical displacement and another dial gauge on the container to record the horizontal displacement.
11. Place the weights on the loading yoke to apply a normal stress of 25kN/m^2.
Allow the sample to consolidate under the applied normal stress. Note the reading of the vertical displacement dial gauge.
12. remove locking screws. Using the spacing screws, raise the upper part slightly above the lower part such that the gap is slightly larger than the maximum particle size.
Remove the spacing screws.

13. Adjust all the dial gauges to read zero. The proving ring should also read zero.
14. Apply all the horizontal shear load at a constant rate of strain of 0.2mm/ minute.
15. Record the readings of the proving ring, the vertical displacement dial gauge and the horizontal displacement dial gauge at the regular intervals. Take the first few reading at closer intervals.
16. Continue the test till the specimen fails or till a strain of 20% is reached.
17. At the end of the test, remove the specimens from the box, and take a representative sample for the water content determination.
18. Repeat the test on identical specimens under the normal stresses of 50,100,200,400kN/m^2 etc.

Observations and Calculations

Size of Shear box= Area of box=
Thickness of specimen= Volume of specimen=
Mass of soil specimen= Bulk density=
Water content= Bulk density=
Void ratio= Dry density=
Mass on hanger= Tare mass of hanger=
Normal Stress= Total Mass=
Mass of box+ base plate + porous stone + grid plate =
Mass of box+ base plate + porous stone + grid plate + Soil specimen =

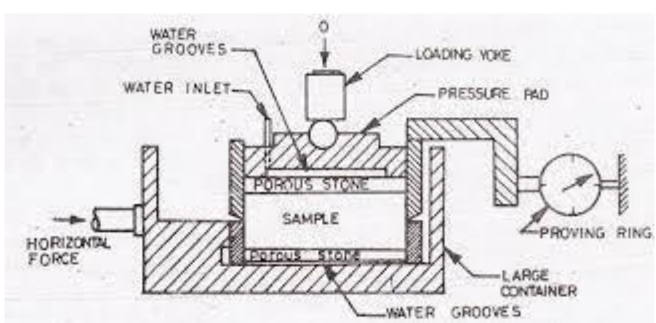

Figure: Shear Box

Table: Direct Shear Test (Table1: Normal stress 1kg/cm^2)

Least count of the dial: Proving ring Constant:

Horizontal Gauge reading (1	Vertical dial gauge reading (2)	Proving ring reading (3)	Hor. Dial gauge reading Initial reading div. Gauge (4)	Shear deformation col. (4) X Least count of dial (5)	Vertical gauge reading Initial reading (6)	Vertical deformation = div. In col. (6) X L.C of dial gauge (7)	Proving reading Initial reading (8)	Proving reading Initial reading (8)
0								
25								
50								
75								
100								
125								
150								
175								
200								
250								
300								
400								
500								
600								
700								
800								
900								

Calculations:

Sample Size =

Area of sample, Ao =

Volume of sample, V =

Weight of sample, w =

Density of sample =

Table: Direct Shear Test

S. No	Proving Ring Reading		Shear Force, Pn, kg	Applied Load, Kg	Normal Force, Pv	Normal Stress	Shear Stress, T= Pn/A
	Initial Div	Final Div					
1							
2							
3							

Result: The shear strength parameters of the given soil sample τ =

Viva Questions

1. Why is shear strength of soil required?
2. Could we use direct shear test for sand and clay?
3. Is it at the predetermined plane the failure is happening in the direct shear test or naturally?
4. Is there any other apparatus using which we can determine the shear strength of soil? Name those.
5. Will this test give reliable undrained strength?

Experiment No 12
Unconfined Compression Test

Aim: To determine the unconfined compression test of soil.

Apparatus Required

1. Loading frame of capacity of 2 t, with constant rate of movement. What is 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. What is the range of the temperature used for drying the soil
10. Sample extractor and split sampler.
11. Dial gauge (sensitivity 0.01mm).

Theory: 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 remoulded soil sample

The test is performed on a cylindrical sample with a height to diameter ratio of 2: 1. The sample is placed between the plates of a mechanical load frame without any covering or lateral support. Load and deformation readings are noted until the failure of the sample or a strain of 20%, whichever is smaller.

The unconfined compression test is by far the most popular method of soil shear testing because it is one of the fastest and cheapest methods of measuring shear strength. The method is used primarily for saturated, cohesive soils recovered from thin-walled sampling tubes. The unconfined compression test is in appropriate for dry sands or crumbly clays because the materials would fall apart without some land of lateral confinement. In the unconfined compression test, we assume that no pore water is lost from the sample during set-up or during the shearing process.

A saturated sample will thus remain saturated during the test with no change in the sample volume, water content, or void ratio. More significantly, the sample is held together by an effective confining stress that results from negative pore water pressures. Pore pressures are not measured in an unconfined compression test; consequently, the effective stress is unknown. Hence, the undrained shear strength measured in an unconfined test is expressed in terms of the total stress.

Procedure

1. The sample is prepared in the same way as for a triaxial test. Its natural water content and dry density are determined prior to the testing. The length (Lo) and diameter (do) are also measured.
2. Set the sample on the pedestal of the equipment and complete all the necessary adjustments for applying on axial loads.
3. Apply the axial load at a strain of about 0.5 to 2 % per minute and continue the load till the sample fails OR the deformation reaches 20 % of axial strain.

4. Sketch the failure pattern and measure the angle of failure if possible.
5. Take a small sample of soil from the failure zone for water content determination.

Calculations

The axial strain, $\varepsilon\% = (\Delta L/Lo)\times 100$

Where, ΔL = change in length of specimen.

L_o = Initial length of specimen.

b) Corrected area A, $A = A_o/(1-\varepsilon)$

Where,

A_o = initial sectional area op the specimen.

Compressive stress, $\sigma 1$, (which is the principal stress) is $\Delta\sigma 1 = P/A$ where P = axial load.

A plot of $\sigma 1$ versus ε gives the maximum stress, which is the unconfined compressive strength of the soil specimen.

Observations and Tabulation

Initial data available

a) Do = cm, L = cm, Ao = cm^2

b) Initial bulk density, ρt = gm/cm^3

c) Initial water content, w = %

Table: Data Sheet for Sample 1

Strain dial reading	**ΔL(mm)**	**Axial Strain %**	**Corrected area, A(cm^2)**	**Proving ring reading (PR)**	**Axial Load P(kg)**	**Stress σ=P/A (kg/cm^2)**

Note: Plot a graph of Compressive stress as ordinate and Axial Strain as abscissa.

Result: Average unconfined compressive stress qu=______kg/cm^2

Angle of internal friction_______

Undrained cohesive strength_________kg/cm^2

Figure

Figure: Unconfined compression test

Verification/Validations: Minimum three samples should be tested, correlation can be made between unconfined strength and field SPT value N practically. Upto 6% strain the readings may be taken at every min (30 sec).

Conclusion: Unconfined compressive strength, qu = ______.

Shear strength, S = qu/2 = ______.

Precautions

1. Both the ends of the sample are shaped so that it should sit properly on the bottom plate of the loading frame.
2. Rate of loading of the sample should be constant

Viva Questions

1. Why we need Mohr's circle for this experiment?
2. Is there any stress which cannot be determined in the case of UCC?
3. Could the drainage condition be handled in UCC?
4. What is the difference between unconfined compression test and triaxial test?
5. What is meant by unconfined compression strength of soil?
6. Plot roughly the Mohr circle for Unconfined Compressive Strength of soil.
7. Explain the procedure to determine the Unconfined compressive strength of soil.

Experiment -13
Vane Shear Test

Aim: To determine Cohesion or Shear Strength of Soil.

Apparatus Required

1. Vane shear test apparatus with accessories
2. The soil samples

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

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

The vane shear test apparatus consists of four stainless steel blades fixed at right angle to each other and firmly attached to a high tensile steel rod. The length of the vane is usually kept equal to twice its overall width. The diameters and length of the stainless steel rod were limited to 2.5mm and 60mm respectively. At this time, the soil fails in shear on a cylindrical surface around the vane. The rotation is usually continued after shearing and the torque is measured to estimate the remoulded shear strength. Vane shear test can be used as a reliable in-situ test for determining the shear strength of soft-sensitive clays. The vane may be regarded as a method to be used under the following conditions.

1. Where the clay is deep, normally consolidated and sensitive.
2. Where only the undrained shear strength is required.

It has been found that the vane gives results similar to that as obtained from unconfined compression tests on undisturbed samples.

Procedure

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

Observations

Force observed P = _______kg

Eccentricity (lever arm), x =_______cm

Turning moment P_x =_________kg-cm

Length of the vane, L =________cm

Radius of the vane blades, r =________cm

Calculations: Undrained Shear strength of Clay

$$Cu= (Px)/(2\times\Pi\times r^2 (L+(2/3)\times r))$$

Figure

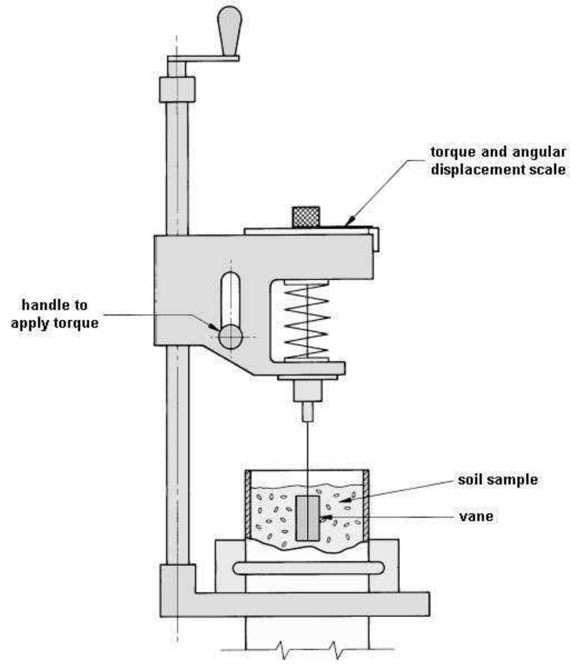

Figure: Vane Shear test

Result: Undrained Shear strength of Clay, C_u=------------kg/cm^2

Verification/Validations: Where the strength is greater than that able to be measured by the vane, i.e., the pointer reaches the maximum value on the dial without the soil shearing, the result shall be reported in either of the following two ways e.g 195 + kPa or > 195 kPa.

Conclusions: The vane shear strength of soil is ____________.

Viva Questions

1. Is this method the direct method to determine the shear strength of soil?
2. Is it possible to determine the sensitivity of clay suing this method?
3. What is meant by sensitivity of clay?
4. What are the advantages of vane shear test?
5. What are the disadvantages of vane shear test?
6. Is this experiment an easy one?
7. What is the equation used to find the shear strength?
8. How is the torque applied to the sample?