INSTITUTE OF AERONAUTICAL ENGINEERING
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Dundigal, Hyderabad - 500 043

Lab Manual:Geotechnical Engineering Laboratory

LABORATORY NAME(ACEB20)

Prepared by

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Contents

INTRODUCTION

1.1 Introduction

The Geotechnical Engineering Laboratory intends to train the students in the field of testing of soils to determine their physical, index and engineering properties. This course enables the students to perform the most important tests including: soil classification, compaction, permeability, direct shear testing and cyclical triaxial testing; each experiment of soil testing is presented with brief introduction covering the important details of the experiment, the theory and the purpose for which it is to be performed, followed by the detailed explanation of apparatus required, procedure and specimen calculations.

1.1.1 Student Responsibilities

The student is expected to be prepared for each lab. Lab preparation includes reading the lab experiment from the lab manual.If you have questions or problems with the preparation,contact your lab assistant and faculty incharge but in a timely manner.Do not wait until an hour or two before the lab and then expect the lab assistant and faculty in charge to be immediately available.

Active participation by each student in lab activities is expected. The student is expected to askthe lab assistant and faculty incharge any questions they may have.

A large portion of the student's grade is determined in the comprehensive final exam, resulting in a requirement of understanding the concepts and procedure of each lab experiment for the successfulcompletion of the lab session. The student should remain alert and use common sense while performinga lab experiment. They are also responsible for keeping a professional and accurate record of the labexperiments in the lab manual wherever tables are provided. Students should report any errors in the lab manual to the faculty incharge or course coordinator.

1.1.2 Responsibilities of Faculty Teaching the Lab Course

The faculty shall be completely familiar with each labprior to the laboratory. He/She shall provide the students with details regarding the syllabus and safety review during the first week.Lab experiments should be checked in advance to make sure that everything is in working order.The faculty should demonstrate and explain the experiment and answer any questions posed by the students.Faculty have to supervise the students while they perform the lab experiments. The faculty is expected to evaluate the lab worksheets and grade them based on their practical skills and understanding of the experiment by taking viva voce. Evaluation of work sheets has to be done in a fair and timely manner to enable the students, for uploading them online through their CMS login within the stipulated time.

1.1.3 Laboratory In-charge Responsibilities

The laboratory in-charge should ensure that the laboratory is properly equipped, i.e., the faculty teaching the lab receive any equipment/components necessary to perform the experiments.He/She is responsible for ensuring that all the necessary equipment for the lab is available and in working condition. The laboratory in-charge is responsible for resolving any problems that are identified by the teaching faculty or the students.

1.1.4 Course Coordinator Responsibilities

The course coordinator is responsible fo rmaking any necessary corrections in course description and lab manual. He/She has to ensure that it is continually updated and available to the students in the CMS learning Portal.

1.2 Lab Policy and Grading

The student should understand the following policy:

ATTENDANCE: Attendance is mandatory as per the academic regulations.

LAB RECORD's: The student must:

1. Write the work sheets for the allotted experiment and keep them ready before the beginning of each lab.
2. Keep all work in preparation of and obtained during lab.
3. Perform the experiment and record the observations in the worksheets.
4. Analyze the results and get the work sheets evaluated by the faculty.
5. Upload the evaluated reports online from CMS LOGIN within the stipulated time.

Grading Policy:

The final grade of this course is awarded using the criterion detailed in the academic regulations. A large portion of the student's grade is determined in the comprehensive final exam of the laboratory course (SEE PRACTICALS),resulting in a requirement of understanding the concepts and procedure of each lab experiment for successful completion of the lab course.

Pre-Requistes and Co-Requisties:

The lab course is to be taken during the same semester as ACEB19, but receives a separate grade.

1.3 Course Goals and Objectives

The Geotechnical Engineering laboratory is designed to provide the student with the knowledge of soil properties and its behaviour under the different loading condition with and without water content. In addition, the student should learn how to record experimental results effectively and present these results in a written report. More explicitly, the class objectives are:

1. The concept behind the soil formation, type soil and the relationships between the soil mass and volume of voids and enables the students to perform moisture content, specific gravity and atterberg limits.
2. The procedure for soil classification through grain size distribution and classification of soil according to IS code.

3. The importance of determining the permeability and enables the students to perform permeability (constant head and variable head) test; so that students can estimate ground water flow, seepage through dams, rate of consolidation and settlement of structures.
4. IV. The behaviour of soil under different loading condition and enable the students derive the bearing capacity, design retaining walls, evaluate the stability of slopes and embankments, etc.

1.4 Use of Laboratory Instruments

One of the major goals of this lab is to familiarize the student with the proper equipment andtechniques for conducting experiments. Some understanding of the lab instruments is necessaryto avoid personal or equipment damage. By understanding the device's purpose and following a fewsimple rules, costly mistakes can be avoided.

The following rules provide a guideline for instrument protection.

1.5 Data Recording and Reports

1.5.1 The Laboratory Worksheets

Students must record their experimental values in the provided tables in this laboratory manual and reproduce the min the lab reports. Reports are integral to recording the methodology and results of an experiment. In engineering practice, the laboratory work sheets serve as an invaluable reference to the technique used in the lab and is essential when trying to duplicate a result or write a report. Note that the data collected will be an accurate and permanent record of the data obtained during the experiment and the analysis of the results. You will need this record when you are ready to prepare a lab report.

1.5.2 The Laboratory Files/Reports

Record is the primary means of communicating your experience and conclusions to other professionals. In this course you will use the lab report to inform your faculty incharge about what you did and what you have learned from the experience. Engineering results are meaningless unless they can be communicated to others. You will be directed by your faculty incharge to prepare a lab report on a few lab experiments during the semester.

Your laboratory record should be clear and concise. The lab record shall be typed on a word processor. As a guide, use the format on the next page. Use tables, diagrams , as necessary o show what you did, what was observed, and what conclusions you can draw from this.

Order of Lab Report Components

COVERPAGE- Cover page must include lab name and number, your name, your lab partner's name, and the date the lab was performed.

OBJECTIVE - Clearly state the experiment objective in your own words.

EQUIPMENT USED- Indicate which equipment was used in performing the experiment.
For each part of lab

- Write the lab's part number and title in bold font. Firstly, describe the problem that you studied in this part, give an introduction of the theory, and explain why you did this experiment. Do not lift the text from the lab manual; use your own words.

- Secondly, describe the experimental setup and procedures. Do not follow the lab manual in listing out individual pieces of equipment and assembly instructions. That is not relevant information in a lab report! Instead, describe the circuit as a whole and explain how it works. Your description should take the form of a narrative, and include information not present in the manual, such as descriptions of what happened during intermediate steps of the experiment.
- Thirdly, explain your findings. This is the most important part of your report, because here, you show that you understand the experiment beyond the simple level of completing it. Explain (compare expected results with those obtained). Analyze (analyze experimental error).
- Finally, provide a summary of what was learned from this part of the laboratory experiment. If the results seem unexpected or unreliable, discuss the mand give possible explanation

1.6 Conclusions

The conclusion section should provide a take home message summing up what has been learned from the experiment:

- Briefly restate the purpose of the experiment(the question it was seeking to answer)
- Identify the main findings (answer to the research question)
- Note the main limitations that are relevant to the interpretation of the results
- Summarise what the experiment has contributed to your understanding of the problem.

Further Probing Experiments- Advance experiments pertaining to this lab must be probed in further coming weeks

LAB 1–SPECIFIC GRAVITY OF SOIL SOLIDS BY PYCNOMETER METHOD

2.1 Introduction

Specific gravity is the ratio of the mass of unit volume of soil at a stated temperature to the mass of the same volume of gas-free distilled water at a stated temperature.

2.2 Objective

To determine the specific gravity of soil solids by Pycnometer bottle method.

2.3 Equipment Needed

1. Pycnometer of about 1 litre capacity
2. Weighing balance accurate to 1 g
3. Glass rod
4. De-aired distilled water etc

2.4 Specification

This test is specified in IS: 2720 (Part 4) – 1985. A soil's specific gravity largely depends on the density of the minerals making up the individual soil particles. However, as a general guide, some typical values for specific soil types are as follows:

• The specific gravity of the solid substance of most inorganic soils varies between 2.60 and 2.80. • Tropical iron-rich laterite, as well as some lateritic soils, usually have a specific gravity of between 2.75 and 3.0 but could be higher. • Sand particles composed of quartz have a specific gravity ranging from 2.65 to 2.67. • Inorganic clays generally range from 2.70 to 2.80. • Soils with large amounts of organic matter or porous particles (such as diatomaceous earth) have specific gravities below 2.60. Some range as low as 2.00.

2.5 Procedure

1. Clean and dry the Pycnometer and weigh it along with the conical cap (W1 in gm).
2. Select about 300 gm of dry soil free of clods and put the same into the Pycnometer. Weigh it (W2 in g) with cap and washer.
3. Fill the Pycnometer with de-aired water up-to half its height and stir the mix with a glass rod.

4. Add more water and stir it. Fit the screw cap and fill the Pycnometer flush with the hole in the conical cap and take the weight (W3 in g).
5. Remove all the contents from the Pycnometer, clean it thoroughly and fill it with distilled water. Weigh it (W4 in g).
6. Now use the above equation for determining G.
7. Repeat the same process for additional tests.

2.6 Theory:

Specific gravity of soil solids is defined as the weight of soil solids to weight of equal volume of water. In effect, it tells how much heavier (or lighter) the material is than water. This test method covers the determination of the specific gravity of soil solids that pass 4.75 mm sieve. Equation for specific gravity, G:
G= (W2-W1)/((W2-W1)-(W3-W4))

Where, W1=weight of Pycnometer in grams. W2=weight of Pycnometer + dry soil in grams. W3=weight of Pycnometer + soil+ water grams. W4=weight of Pycnometer + water grams.

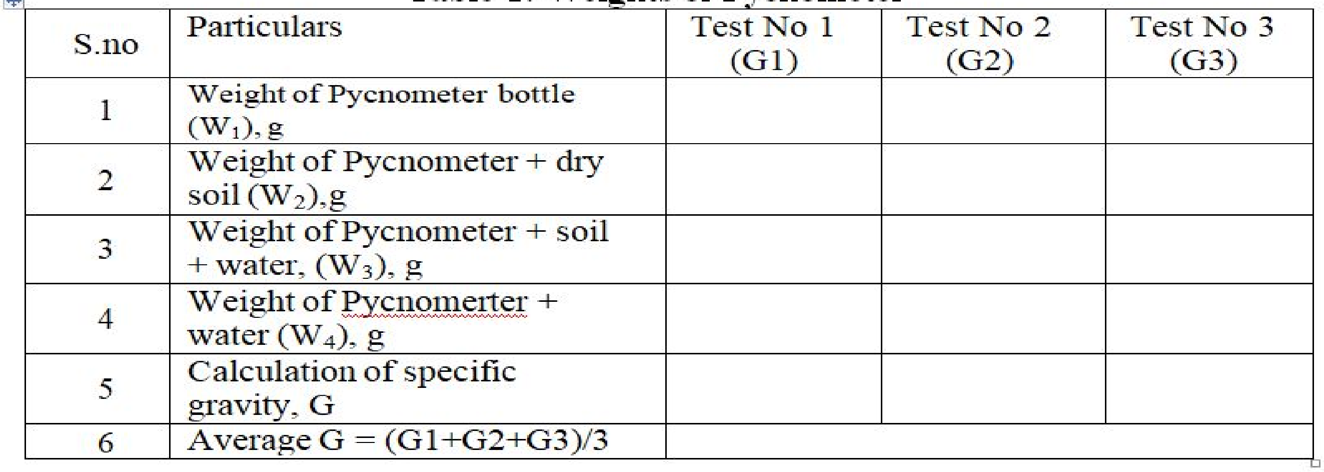
Note: This method is recommended for coarse and fine grained soils

2.7 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 glass jar, please be careful as there may be glass grains projecting out and it may tear the skin.
5. Make sure, you handle the glass jar and conical cap without falling on your legs or floor.
6. Hence, handle the equipment with care.

2.8 Table

Table 1: Weights of Pycnometer



S.no	Particulars	Test No 1 (G1)	Test No 2 (G2)	Test No 3 (G3)
1	Weight of Pycnometer bottle (W_1), g			
2	Weight of Pycnometer + dry soil (W_2),g			
3	Weight of Pycnometer + soil + water, (W_3), g			
4	Weight of Pycnomerter + water (W_4), g			
5	Calculation of specific gravity, G			
6	Average G = (G1+G2+G3)/3			

2.9 Specimen calculations:

G= (W2-W1)/((W2-W1)-(W3-W4))

2.10 Result:

AVERAGE G =

2.11 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.

2.12 Conclusion:

The experiment is conducted as per the procedure laid down. The specific gravity of soil solids obtained is————-This value falls in the range 2.6 to 2.75. Hence the type of soil is——

LAB 2 –SPECIFIC GRAVITY OF SOIL SOLIDS BY DENSITY BOTTLE METHOD

3.1 Introduction

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

3.2 Objective

To determine the specific gravity of soil solids by Density bottle method.

3.3 Specification

IS 2720 (Part III) – 1980 is the standard recommended to determine specific gravity of fine grained soils. The value ranges are same as the previous experiment. 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.

3.4 Equipment

1. 50 ml capacity density bottle with stopper
2. A constant temperature water bath (27°C)
3. Oven with a range of 105 to 110°C
4. Vacuum desiccators
5. Vacuum pump
6. Other accessories, such as, weighing balance accurate to 0.001 g, trays, wooden mallet, etc.

3.5 Theory:

Specific gravity of soil solids is defined as the weight of soil solids to weight of equal volume of water. Equation for specific gravity, G:

G= (W2-W1)/((W2-W1)-(W3-W4))

Where, W1= weight of empty bottle
W2= weight of bottle + dry soil
W3= weight of bottle + soil + water
W4= 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.

3.6 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.

3.7 Procedure

1. Clean and dry the density bottle and weigh it along with the stopper (W1 in g).
2. Select about 25 gm of dry soil free of clods and put the same into the density bottle. Weigh it with brass cap and washer (W2 in g).
3. Fill the density bottle with de-aired water upto half its height and stir the mix with a glass rod.
4. Add more water and stir it. Place the stopper on top and take the weight (W3 in g).
5. Remove all the contents from the density bottle, clean it thoroughly and fill it with distilled water. Weigh it (W4).
6. Use above equation for determining G.
7. Repeat the same process for additional tests.

3.8 Table:

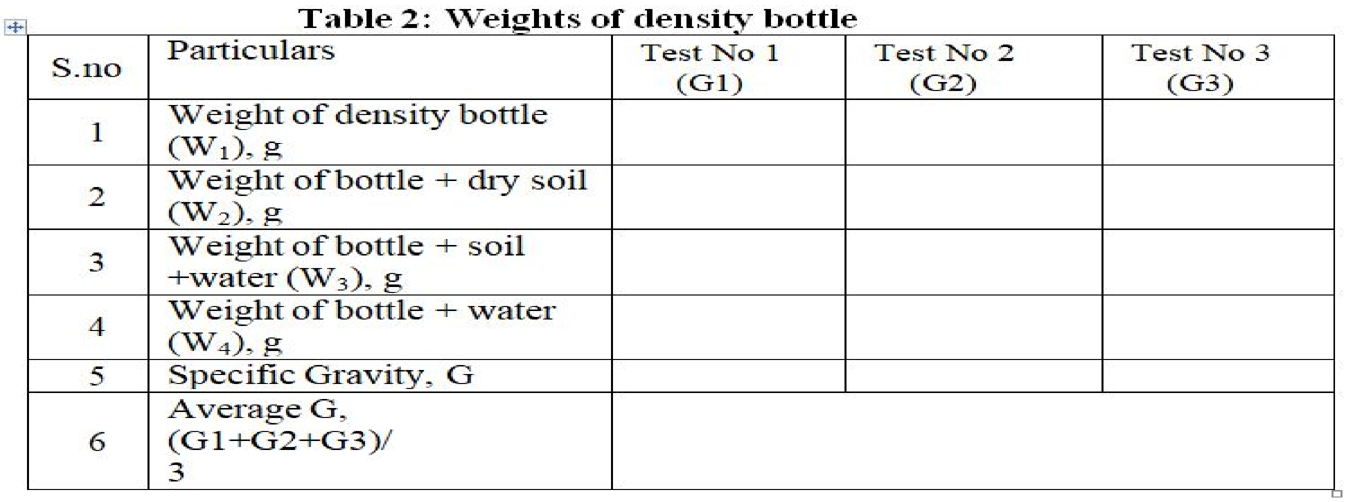


Table 2: Weights of density bottle

S.no	Particulars	Test No 1 (G1)	Test No 2 (G2)	Test No 3 (G3)
1	Weight of density bottle (W_1), g			
2	Weight of bottle + dry soil (W_2), g			
3	Weight of bottle + soil +water (W_3), g			
4	Weight of bottle + water (W_4), g			
5	Specific Gravity, G			
6	Average G, (G1+G2+G3)/ 3			

3.9 Specimen calculations:

G= (W2-W1)/((W2-W1)-(W3-W4))

3.10 Result:

AVERAGE G =

3.11 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.

3.12 Conclusion:

The experiment is conducted as per the procedure laid down. The specific gravity of soil solids obtained is————-This value falls in the range 2.6 to 2.75. Hence the type of soil is——

LAB 3–ATTERBERG'S LIMITS.

4.1 Introduction

This lab is performed to determine the plastic and liquid limits of a finegrained soil. The liquid limit (LL) is arbitrarily defined as the water content, in percent, at which a pat of soil in a standard cup and cut by a groove of standard dimensions will flow together at the base of the groove for a distance of 13 mm (1/2 in.) when subjected to 25 shocks from the cup being dropped 10 mm in a standard liquid limit apparatus operated at a rate of two shocks per second. The plastic limit (PL) is the water content, in percent, at which a soil can no longer be deformed by rolling into 3.2 mm (1/8 in.) diameter threads without crumbling.

4.1.1 Objectives

The purpose of the Atterberg Limit Lab was to calculate different properties of a certain soil type. The Atterberg limits are a basic measure of the critical water contents of a fine-grained soil: its shrinkage limit, plastic limit, and liquid limit.

4.2 Prelab

- Prior to coming to lab class, complete knowledge on how to write test cases for any application

4.3 Background

Karl Terzhagi and Arthur Casagrande recognized the value of characterizing soil plasticity for use in geotechnical engineering applications in the early 1930s. Casagrande refined and standardized the tests, and his methods still determine the liquid limit, plastic limit, and shrinkage limit of soils. This blog post will define the Atterberg limits, explain the test methods, and discuss the significance of the limit values and calculated indexes. We will also cover lab testing equipment used in the standard test methods.

4.4 Procedure:

Liquid Limit:

1. Take roughly 3/4 of the soil and place it into the porcelain dish. Assume that the soil was previously passed though a No. 40 sieve, air-dried, and then pulverized. Thoroughly mix the soil with a small amount of distilled water until it appears as a smooth uniform paste. Cover the dish with cellophane to prevent moisture from escaping.

2. Weigh four of the empty moisture cans with their lids, and record the respective weights and can numbers on the data sheet. .

3. Adjust the liquid limit apparatus by checking the height of drop of the cup. The point on the cup that comes in contact with the base should rise to a height of 10 mm. The block on the end of the grooving tool is 10 mm high and should be used as a gage. Practice using the cup and determine the correct rate to rotate the crank so that the cup drops approximately two times per second

4. Place a portion of the previously mixed soil into the cup of the liquid limit apparatus at the point where the cup rests on the base. Squeeze the soil down to eliminate air pockets and spread it into the cup to a depth of about 10 mm at its deepest point. The soil pat should form an approximately horizontal surface.

5. Use the grooving tool carefully cut a clean straight groove down the center of the cup. The tool should remain perpendicular to the surface of the cup as groove is being made. Use extreme care to prevent sliding the soil relative to the surface of the cup

6. Make sure that the base of the apparatus below the cup and the underside of the cup is clean of soil. Turn the crank of the apparatus at a rate of approximately two drops per second and count the number of drops, N, it takes to make the two halves of the soil pat come into contact at the bottom of the groove along a distance of 13 mm (1/2 in.) If the number of drops exceeds 50, then go directly to step eight and do not record the number of drops, otherwise, record the number of drops on the data sheet.

7. Take a sample, using the spatula, from edge to edge of the soil pat. The sample should include the soil on both sides of where the groove came into contact. Place the soil into a moisture can cover it. Immediately weigh the moisture can containing the soil, record its mass, remove the lid, and place the can into the oven. Leave the moisture can in the oven for at least 16 hours. Place the soil remaining in the cup into the porcelain dish. Clean and dry the cup on the apparatus and the grooving tool.

8. Remix the entire soil specimen in the porcelain dish. Add a small amount of distilled water to increase the water content so that the number of drops required to close the groove decrease.

9. Repeat steps six, seven, and eight for at least two additional trials producing successively lower numbers of drops to close the groove. One of the trials shall be for a closure requiring 25 to 35 drops, one for closure between 20 and 30 drops, and one trial for a closure requiring 15 to 25 drops. Determine the water content from each trial by using the same method used in the first laboratory. Remember to use the same balance for all weighing.

Plastic Limit:

1. Weigh the remaining empty moisture cans with their lids, and record the respective weights and can numbers on the data sheet.

2. Take the remaining 1/4 of the original soil sample and add distilled water until the soil is at a consistency where it can be rolled without sticking to the hands.

3. Form the soil into an ellipsoidal mass Roll the mass between the palm or the fingers and the glass plate Use sufficient pressure to roll the mass into a thread of uniform diameter by using about 90 strokes per minute. (A stroke is one complete motion of the hand forward and back to the starting position.) The thread shall be deformed so that its diameter reaches 3.2 mm (1/8 in.), taking no more than two minutes.

4. When the diameter of the thread reaches the correct diameter, break the thread into several pieces. Knead and reform the pieces into ellipsoidal masses and re-roll them. Continue this alternate rolling, gathering together, kneading and re-rolling until the thread crumbles

under the pressure required for rolling and can no longer be rolled into a 3.2 mm diameter thread.

5. Gather the portions of the crumbled thread together and place the soil into a moisture can, then cover it. If the can does not contain at least 6 grams of soil, add soil to the can from the next trial (See Step 6). Immediately weigh the moisture can containing the soil, record its mass, remove the lid, and place the can into the oven. Leave the moisture can in the oven for at least 16 hours.

6. Repeat steps three, four, and five at least two more times. Determine the water content from each trial by using the same method used in the first laboratory. Remember to use the same balance for all weighing.

Analysis:

Liquid Limit:

1. Calculate the water content of each of the liquid limit moisture cans after they have been in the oven for at least 16 hours.

2. Plot the number of drops, N, (on the log scale) versus the water content (w). Draw the best-fit straight line through the plotted points and determine the liquid limit (LL) as the water content at 25 drops.

Plastic Limit:

1. Calculate the water content of each of the plastic limit moisture cans after they have been in the oven for at least 16 hours.

2. Compute the average of the water contents to determine the plastic limit, PL. Check to see if the difference between the water contents is greater than the acceptable range of two results (2.6).

3. Calculate the plasticity index, PI=LL-PL. Report the liquid limit, plastic limit, and plasticity index to the nearest whole number, omitting the percent designation.

4.5 Probing further questions

1. The liquid limit and shrinkage limit of a soil sample are 46percent and 13 percent respectively. On over drying, the volume of soil specimen decreases from 35 cm3 at liquid limit to 21 cm3 at shrinkage limit. The specific gravity of soil particle is ?

2. The liquid limit and plastic limit of a soil are 36percent and 28 percent respectively. When the soil is dried from its state of liquid limit to dry state, the reduction in volume was found to be 35percent of its volume at liquid limit. The corresponding volume reduction from the state of plastic limit to dry state was 25 percent of its volume at Plastic limit. The shrinkage limit of soil is?

3. The Atterberg limits of a clay are 38 percent, 27 percent and 24.5 percent. Its natural water content is 30 percent. The clay is in. . . . . state?

4. The values of liquid limit and plasticity index for soils having common geological origin in a restricted locality usually define?

5. In a shrinkage limit test, the volume and mass of a dry soil pat are found to be 50 cm3 and 88 g, respectively. The specific gravity of the soil solids is 2.71 and the density of water is 1 g/cc. The shrinkage limit (in percentage, up to two decimal places) is. . . .?

4.6 Viva questions

1. What does an Atterberg limits test measure?
2. What is a toughness index?
3. What is the plastic limit?
4. What is the difference between liquid limit and plastic limit called?
5. Why is there 25 blows in liquid limit?

LAB 4– WATER CONTENT OF SOIL SOLIDS BY PYCNOMETER METHOD

5.1 Introduction

To determine water content by this method, the value of G should have bee determined prior.

5.2 Objectives

Determination of water content of soil solids by Pycnometer method.

5.3 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.

5.4 Equipment

1. Pycnometer of 1000 ml capacity with a brass conical cap.
2. Balance accurate to 1 g.
3. Glass rod other accessories.

5.5 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% = [((W2-W1)/(W3-W4))×(((G-1)/G)-1)]×100

Where, W1= Weight of empty Pycnometer in grams
W2 = Weight of Pycnometer + wet soil in grams
W3 = Weight of Pycnometer + dry soil in grams
W4 = Weight of Pycnometer + water in grams

5.6 Procedure:

1. Clean and dry the Pycnometer and weigh it (W1 in g).
2. Select a mass of wet soil of about 300 gm and place the same in Pycnometer and weigh it (W2 in g).
3. Fill the Pycnometer with distilled water up-to half its height and stir the mix with a glass rod.
4. Keep on adding more water till the mix is flush with the hole in the conical cap. Dry the Pycnometer outside and find the mass (W3 in g).
5. Remove the contents of PM and clean it. Fill with clean water up-to the top level of the hole in the cap weigh it (W4 in g).
6. Now use the above equation for determining water content, where, G value is taken from **Experiment No 1** (Determination of specific gravity by Pycnometer method) for the given soil.

5.7 Table

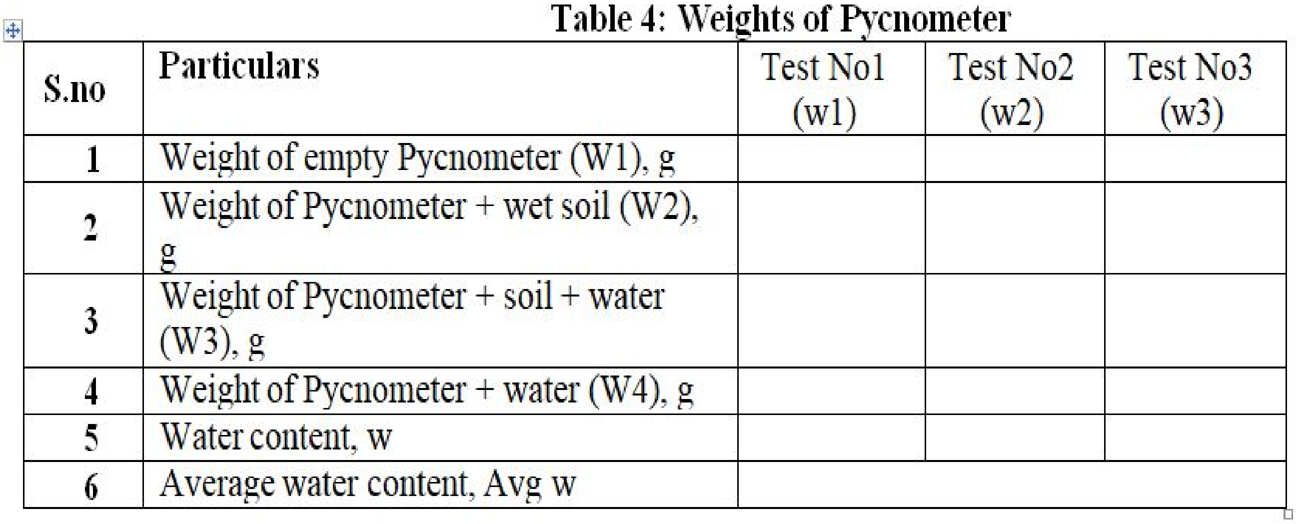


Table 4: Weights of Pycnometer

S.no	Particulars	Test No1 (w1)	Test No2 (w2)	Test No3 (w3)
1	Weight of empty Pycnometer (W1), g			
2	Weight of Pycnometer + wet soil (W2), g			
3	Weight of Pycnometer + soil + water (W3), g			
4	Weight of Pycnometer + water (W4), g			
5	Water content, w			
6	Average water content, Avg w			

5.8 Specimen calculations:

w % = [((W2-W1)/(W3-W4))×(((G-1)/G)-1)]×100
Average water content, w = (w1+w2+w3)/3

5.9 Result:

Average water content, w =———-%

5.10 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%.

5.11 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————

LAB 5–IN-SITU DENSITY BY CORE CUTTER METHOD

6.1 Introduction

Core cutter method is used for finding field density of cohesive/clayey soils placed as fill. It is rapid method conducted on field. It cannot be applied to coarse grained soil as the penetration of core cutter becomes difficult due to increased resistance at the tip of core cutter leading to damage to core cutter

6.2 Objectives

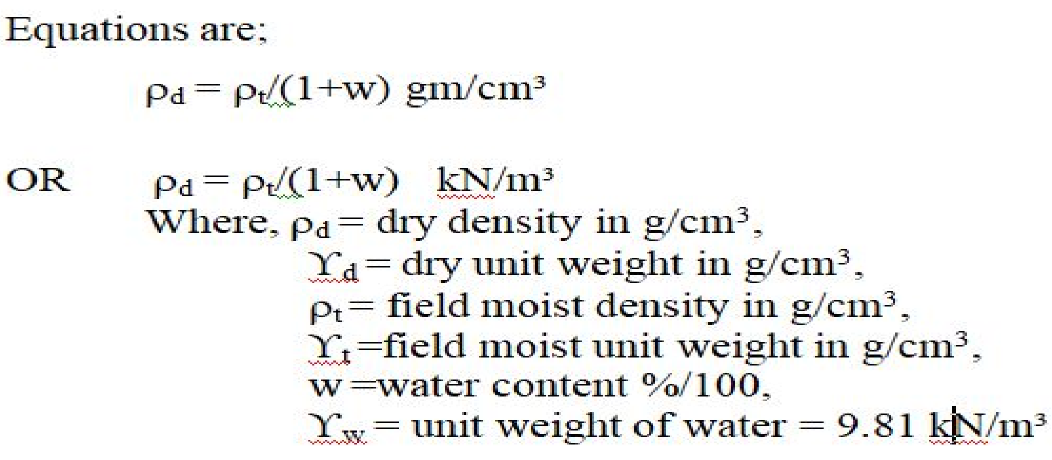
To determine the field density or unit weight of soil by Core cutter method.

6.3 Equipment

1. Cylindrical core cutter, 100mm internal diameter and 130mm long.
2. Steel dolley, 25mm high and 100mm internal diameter.
3. Steel rammer mass 9kg, overall length with the foot and staff about 900mm.
4. Balance, with an accuracy of 1g.
5. Palette knife, Straight edge, steel rule etc.
6. Square metal tray – 300mm x 300mm x 40mm.
7. Trowel.

6.4 Theory:

Field density is defined as weight per unit volume of soil mass in the field at in- situ 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;



Equations are;

$$\rho_d = \rho_t/(1+w) \text{ gm/cm}^3$$

OR $$\rho_d = \rho_t/(1+w) \text{ kN/m}^3$$

Where, ρ_d = dry density in g/cm^3,

Υ_d = dry unit weight in g/cm^3,

ρ_t = field moist density in g/cm^3,

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

w =water content %/100,

Υ_w = unit weight of water = 9.81 kN/m^3

6.5 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.

6.6 Procedure:

1. Measure the height and internal diameter of the core cutter to the nearest 0.25 mm.
2. Calculate the internal volume of the core-cutter Vc in cm^3.
3. Determine the weight of the clean cutter accurate to 1 g (W1 in g).
4. Select the area in the field where the density is required to be found out. Clean and level the ground where the density is to be determined.
5. Place the dolley over the top of the core cutter and press the core cutter into the soil mass using the rammer. Stop the pressing when about 15mm of the dolley protrudes above the soil surface.
6. Remove the soil surrounding the core cutter by digging using spade, up to the bottom level of the cutter. Lift up the cutter and remove the dolley and trim both sides of the cutter with knife and straight edge.
7. Clean the outside surface of the cutter and determine mass of the cutter with the soil (W2 in g).

8. Remove the soil core from the cutter and take the representative sample in the water content containers to determine the moisture content
9. The field test may be repeated at other places if required.
10. The water content of sample collected is determined in the laboratory as per Experiment no 3 (Determination of water content of soil solids by Oven Drying Method).

6.7 Observations:

Length of core cutter l=—- cm
Diameter of core cutter d=— cm
Volume of core cutter=Vc=—— cm

6.8 Table:

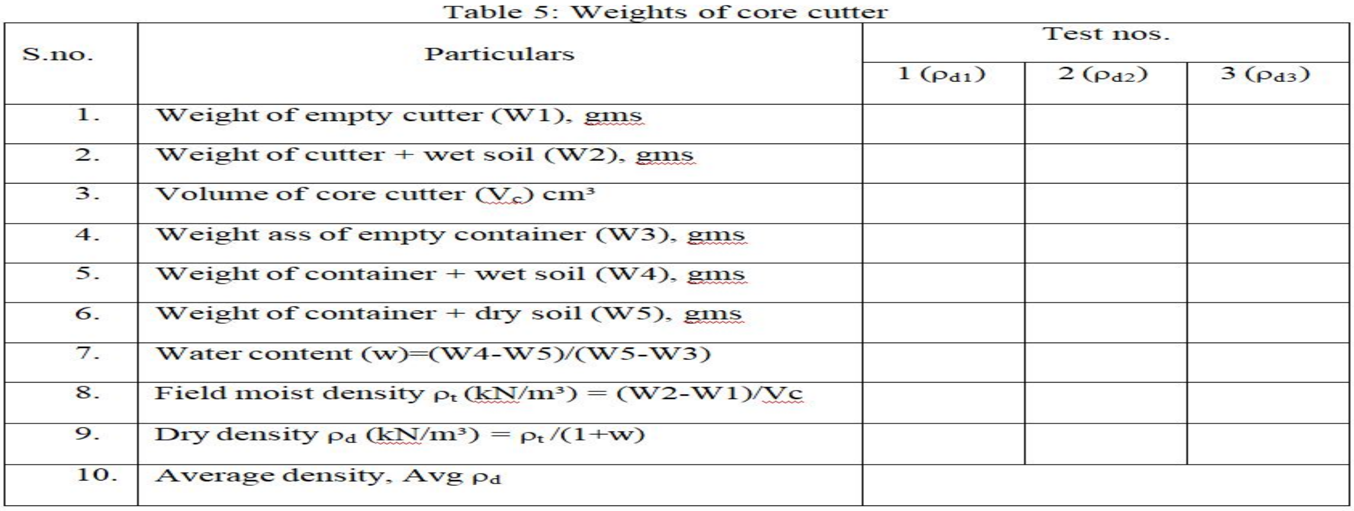


Table 5: Weights of core cutter

S.no.	Particulars	Test nos.		
		1 (ρ_{d1})	2 (ρ_{d2})	3 (ρ_{d3})
1.	Weight of empty cutter (W1), gms			
2.	Weight of cutter + wet soil (W2), gms			
3.	Volume of core cutter (V_c) cm³			
4.	Weight ass of empty container (W3), gms			
5.	Weight of container + wet soil (W4), gms			
6.	Weight of container + dry soil (W5), gms			
7.	Water content (w)=(W4-W5)/(W5-W3)			
8.	Field moist density ρ_t (kN/m³) = (W2-W1)/Vc			
9.	Dry density ρ_d (kN/m³) = ρ_t /(1+w)			
10.	Average density, Avg ρ_d			

6.9 Specimen calculations:

6.10 Result:

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

6.11 Verification/ Validation:

The dry density of most soils varies within the range of 1.1-1.6 g/cm3. In sandy soils, dry density can be as high as 1.6 g/cm3; in clayey soils and aggregated loams, it can be as low as 1.1 g/cm3.

6.12 Conclusion:

The value of dry density of the soil is——— The type of soil is ———

LAB 6– IN-SITU DENSITY BY SAND REPLACEMENT METHOD

7.1 Introduction

Sand replacement density (SRD) tests are used to measure the in-situ density of natural or compacted soils using sand pouring cylinders. The in-situ density is typically used for highway or pavement design purposes to estimate the relative density of base course or subgrade materials. 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. Moreover, dry density values are relevant both of embankment design as well as pavement design.

7.2 Objectives

To determine in-situ density of natural or compacted soil using Sand replacement method.

7.3 Specifications:

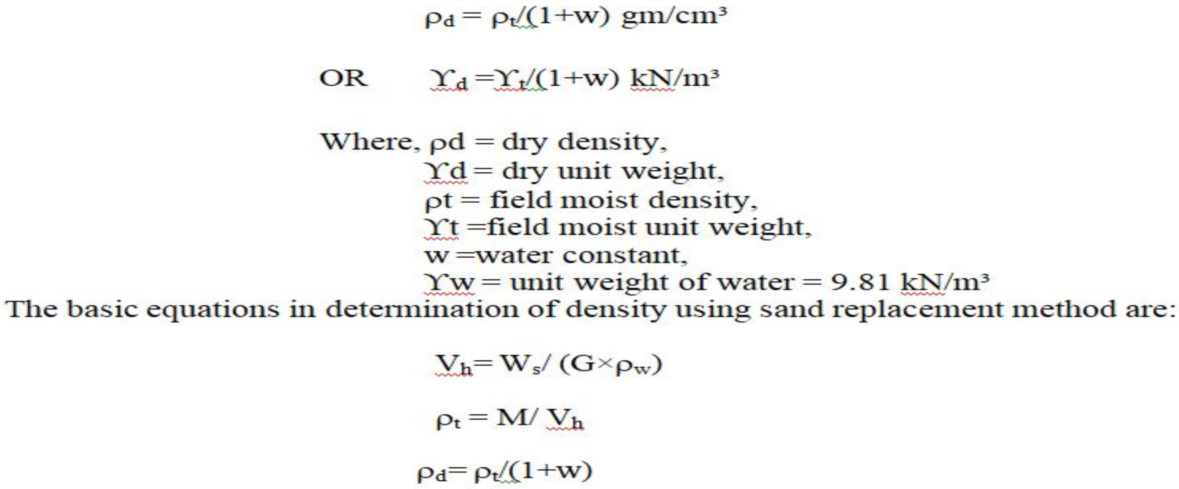
This test is done to determine the in-situ dry density of soil by core cutter method as per IS-2720-Part-28 (1975). In order to conduct the test, select uniformly graded clean sand passing through 600 micron IS sieve and retained on 300 micron IS sieve.

7.4 Equipment

1. Sand pouring cylinder of about 3 litre capacity (Small pouring cylinder as per IS 2720 Part 28)
2. Cylindrical calibrating container 10 cm internal diameter and 15 cm depth
3. Glass plate, trays, containers for determining water content
4. Tools for making of a hole of 10 cm diameter and 15 cm deep, knife and other accessories
5. Metal container to collect excavated soil
6. Metal tray, 300mm square and 40mm deep with a hole of 100mm in diameter at the centre
7. Weighing balance
8. Moisture content cans
9. Glass plate about 450 mm/600 mm square and 10mm thick
10. Oven
11. Dessicator

7.5 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:



$$\rho_d = \rho_t/(1+w) \text{ gm/cm}^3$$

OR $$\Upsilon_d = \Upsilon_t/(1+w) \text{ kN/m}^3$$

Where, ρd = dry density,
Υd = dry unit weight,
ρt = field moist density,
Υt =field moist unit weight,
w =water constant,
Υw = unit weight of water = 9.81 kN/m³

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

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

$$\rho_t = M/ V_h$$

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

7.6 Precautions:

1. If for any reason it is necessary to excavate the pit to a depth other than 12 cm, the standard calibrating can should be replaced by one with an internal height same as the depth of pit to be made in the ground.

2. Care should be taken in excavating the pit, so that it is not enlarged by levering, as this will result in lower density being recorded.

3. No loose material should be left in the pit.

4. There should be no vibrations during this test.

5. It should not be forgotten to remove the tray, before placing the SPC over the pit.

7.7 Procedures:

Stage1 –Determination of mass of sand that fills the cone

1. Measure the internal dimensions (diameter, d and height, h) of the calibrating can and compute its internal volume,

2. With the valve closed, fill the cylinder with sand (Weight of sand filled in the cylinder+cylinder W'=—— gms.)

3. Keep the cylinder on a glass plate, which is kept on a horizontal surface.
4. Open the valve and allow the sand to fill the cone completely. Close the valve. Weight of sand in the cylinder +cylinder W”=—— gms
5. Determine the mass of the sand left in the cylinder. Weight of sand fills the conical portion=W1=W’-W”
6. The difference between the mass of sand taken prior to opening of the valve and the weight of sand left in the cylinder after opening the valve gives the weight of sand that fills the cone. Let the mass be W1.

LAB 7–GRAIN SIZE ANALYSIS

8.1 Introduction

Grain size analysis is a typical laboratory test conducted in the soil mechanics field. The purpose of the analysis is to derive the particle size distribution of soils. Sieve Grain Size Analysis is capable of determining the particles' size ranging from 0.075 mm to 100 mm.

8.2 Objectives

This test is performed to determine the percentage of different grain sizes contained within a soil. The mechanical or sieve analysis is performed to determine the distribution of the coarser, larger-sized particles, and the hydrometer method is used to determine the distribution of the finer particles.

8.3 Equipment

1. Sieves of sizes: 4.75 mm, 2.0 mm, 1.0 mm, 600, 300, 150 and 75 micro meter. That is, I.S 460-1962 is used. The sieves for soil tests: 4.75 mm to 75 microns.
2. Thermostatically controlled oven.
3. Specimen rod
4. One hinged support & one fixed support

8.4 Background

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)×100 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.

Precautions

1. Clean the sieves set so that no soil particles were struck in them
2. While weighing put the sieve with soil sample on the balance in a concentric position.

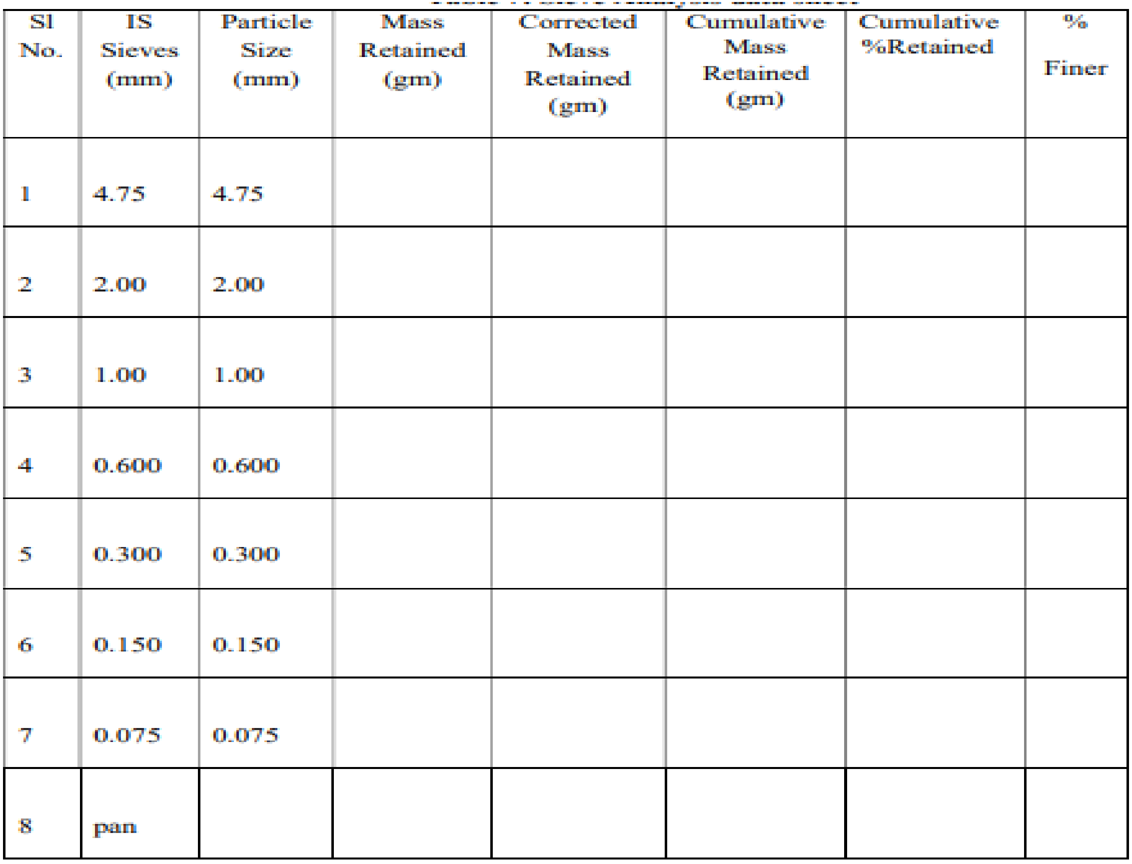
3. Check the electric connection of the sieve shaker before conducting the test.
4. No particle of soil sample shall be pushed through the sieves.

8.5 Procedure

1. Take a representative sample of soil received from the field and dry it in the oven.
2. Use a known mass of dried soil with all the grains properly separated out. The maximum mass of soil taken for analysis may not exceed 500 g.
3. Use a known mass of dried soil with all the grains properly separated out. The maximum mass of soil taken for analysis may not exceed 500 g.
4. Make sure sieves are clean. If many soil particles are stuck in the openings try to poke them out using brush.
5. The whole nest of sieves is given a horizontal shaking for 10 min in sieve shaker till the soil retained on each reaches a constant value.
6. Now the column just starts buckling.
7. Till the deflection of column occurs as shown in figure mean while applied load value approximately coincides with the theoretical value.Determine mass of soil retained on each sieve including that collected in the pan below.

TABULAR COLUMN

The test results obtained from a sample of soil are given below. Mass of soil taken for analysis W = gm



Sl No.	IS Sieves (mm)	Particle Size (mm)	Mass Retained (gm)	Corrected Mass Retained (gm)	Cumulative Mass Retained (gm)	Cumulative %Retained	% Finer
1	4.75	4.75					
2	2.00	2.00					
3	1.00	1.00					
4	0.600	0.600					
5	0.300	0.300					
6	0.150	0.150					
7	0.075	0.075					
8	pan						

8.6 Result

Uniformity coefficient, Cu=
Coefficient of curvature, Cc=

8.7 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 D10, D30 and D60 of soil using sieve analysis?

LAB 8– PERMEABILITY OF SOIL: CONSTANT AND VARIABLE HEAD TEST

9.1 Introduction

The constant head permeability test is a common laboratory testing method used to determine the permeability of granular soils like sands and gravels containing little or no silt. This testing method is made for testing reconstituted or disturbed granular soil samples.

9.2 Objective

The objective of constant head permeability test is to determine the coefficient of permeability of a soil. Coefficient of permeability helps in solving issues related to: Yield of water bearing strata. Stability of earthen dams.

9.3 PreLab

Study the Background section of this Laboratory exercise.

Constant head permeability

1. The constant head permeability test involves flow of water through a column of cylindrical soil sample under the constant pressure difference. The test is carried out in the permeability cell, or permeameter, which can vary in size depending on the grain size of the tested material.
2. The soil sample has a cylindrical form with its diameter being large enough in order to be representative of the tested soil. As a rule of thumb, the ratio of the cell diameter to the largest grain size diameter should be higher than 12 (Head 1982).
3. The usual size of the cell often used for testing common sands is 75 mm diamater and 260 mm height between perforated plates.
4. The testing apparatus is equipped with a adjustable constant head reservoir and an outlet reservoir which allows maintaining a constant head during the test. Water used for testing is de-aired water at constant temperature.
5. The permeability cell is also equipped with a loading piston that can be used to apply constant axial stress to the sample during the test. Before starting the flow measurements, however, the soil sample is saturated
6. During the test, the amount of water flowing through the soil column is measured for given time intervals

7. Knowing the height of the soil sample column L, the sample cross section A, and the constant pressure difference delta h, the volume of passing water Q, and the time interval delta T, one can calculate the permeability of the sample as
K=QL / (A*delta h.delta t)

Falling head permeability test The falling head permeability test is a common laboratory testing method used to determine the permeability of fine grained soils with intermediate and low permeability such as silts and clays. This testing method can be applied to an undisturbed sample.

9.4 Procedure

1. 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.
2. The diameter of the standpipe depends on the permeability of the tested soil.
3. . The test can be carried out in a Falling Head permeability cell or in an oedometer cell.
4. Before starting the flow measurements, the soil sample is saturated and the standpipes are filled with de-aired water to a given level.
5. The test then starts by allowing water to flow through the sample until the water in the standpipe reaches a given lower limit.
6. The time required for the water in the standpipe to to drop from the upper to the lower level is recorderd. Often, the standpipe is refilled and the test is repeated for couple of times.
7. The recorded time should be the same for each test within an allowable variation of about 10percent (Head 1982) otherwise the test is failed.

9.5 Result:

Coefficient of Permeability of soil k=

9.6 Viva questions:

1. Is code for soil permeability test?
2. How do you measure soil permeability?
3. What are the 3 types of permeability?
4. Which soil has the highest permeability?

LAB 9-COMPACTION TEST

10.1 Introduction

The Proctor compaction test is a laboratory method of experimentally determining the optimal moisture content at which a given soil type will become most dense and achieve its maximum dry density. This process is then repeated for various moisture contents and the dry densities are determined for each.

10.2 Equipment

1. Compaction mould 1000 ml capacity.
2. 6 kg rammer
3. Collar 60 mm hig
4. IS Sieve 4.75 mm
5. Oven
6. Weighing balance with accuracy of 1g
7. Mixing tools, spoons, trowels.

10.2.1 Background

Conduction of Proctor's compaction test is based on the assessment of water content and dry density relationship of a soil for a specified compactive effort. The mechanical process of densification through reduction of air voids in the soil mass is called compaction. The amount of mechanical energy which is applied to the soil mass is the compactive effort. There are many methods to compact soil in the field, and some examples include tamping, kneading, vibration and static load compaction. This test will employ the tamping or impact compaction method using the type of equipment and methodology developed by R. R. Proctor in 1933, hence, the test is also known as the Proctor test.
Usually, two types of test are performed:

1. The Standard Proctor test
2. The Modified Proctor tests.

In the Standard Proctor Test, the soil is compacted by a 2.6 kg rammer falling at a distance of 310 mm into a soil filled mould. The mould is filled with three layers of soil and each layer is subjected to 25 blows of rammer. The Modified Proctor Test is identical to the Standard Proctor Test except it employs a 4.89 kg rammer falling at a distance of 450 mm and uses five equals of soil instead of three.

The bulk density in g/ml of each compacted specimen shall be calculated from the equation:
Vm = (m2-m1)/Vm where, m1 = mass in g of mould and base
m2 = mass in g of mould, base and soil and,
Vm = Volume in ml of mould
The dry density in g/ml of each compacted specimen shall be calculated from the equation:
Vd = (100Ym)/(100+w)
where, w = moisture content of soil in percent.

10.3 Procedure

1. The mould with base plate is cleaned and dried and weighed it to measure the nearest 1 gm
2. Grease is applied on the mould along with base plate and collar completely.
3. About 16- 18 kg of air-dried pulverised soil is taken.
4. percent of water is added to the soil if the soil is sandy and about 8percent if the soil is clayey and mixed it thoroughly. The soil is kept in air tight container and allowed it to mature for about an hour
5. About 3 kg of the processed soil is taken and divided into approximately three equal portions.
6. One portion of the soil is put into the mould and compacted it by applying 25 number of uniformly distributed blows.
7. The top surface of the compacted soil is scratched using spatula before filling the mould with second layer of soil. The soil is compacted in the similar fashion as done in for the first layer and scratched it.
8. The same procedure for third layer is also repeated.
9. The collar is removed and trimmed off the excess soil projecting above the mould using straight edge.
10. The mould is cleaned and also the base plate from outside and weighed in to the nearest gram.
11. The soil is removed from the top, middle and bottom of the case and the average of water content is determined.
12. About 3 percent water or a fresh portion of the processed soil is added and the steps from 5 to 12 are repeated.Click Parameters at the bottom of the page.

10.4 Observations and calculations

1. Diameter of mould (D)= m
2. Height of mould (H)= cm
3. Mass of empty mould and base (in g)=
4. Mass of mould, base plate and . compacted soil (in g)=
5. Moisture content during compaction in percent=

6. Weight of soil (g)=
7. Volume
8. Bulk density
9. Dry density
10. Voide ratio
11. Degree of saturation

10.5 Viva questions

1. Which formula is used in constant head permeability test?
2. Why is constant head permeability test important?
3. In which type of soil constant head permeability is done?
4. What is soil permeability test?
5. What is the falling head test used for?

LAB 10– CALIFORNIA BEARING RATIO TEST

11.1 Introduction

This laboratory studies about The California bearing ratio (CBR) testing is an evaluation of the strength of a ground, base courses, and substrates.

11.2 Need and scope

The california bearing ratio test is penetration test meant for the evaluation of subgrade strength of roads and pavements. The results obtained by these tests are used with the empirical curves to determine the thickness of pavement and its component layers. This is the most widely used method for the design of flexible pavement.
This instruction sheet covers the laboratory method for the determination of C.B.R. of undisturbed and remoulded /compacted soil specimens, both in soaked as well as unsoaked state.

11.3 Equipment

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

11.4 Background:

The CBR test is performed by measuring the pressure required to penetrate a soil sample with a plunger of standard area. The measured pressure is then divided by the pressure required to achieve an equal penetration on a standard crushed rock material. The harder the surface, the higher the CBR value.

11.5 Preparation of test specimen

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

11.6 Procedure

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

11.7 Observations

1. Optimum water content (percentage)
2. Weight of mould + compacted specimen g
3. Weight of empty mould g
4. Weight of compacted specimen g
5. Volume of specimen cm3
6. Bulk density g/cc
7. Dry density g/cc

11.8 Viva questions

1. What is the purpose of CBR test
2. What is a good CBR test result?
3. What is CBR formula?
4. What is a good CBR?
5. What is the minimum CBR value for subgrade?

Lab 11– DIRECT SHEAR TEST

12.1 Introduction

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

12.2 Objective

To determine the shear strength of soil using the direct shear apparatus.

12.3 Specifications:

The test is conducted as per IS: 2720- 13 (1986), method of tests for soils. One kg of air dry sample passing through 4.75mm IS sieve is required for this test.

12.4 Equipments Required:

Shear box apparatus consisting of

1. Shear box 60 mm square and 50 mm deep,
2. Grid plates, porous stones, etc.
3. Loading device
4. Other accessories.

12.5 Theory:

Box shear tests can be used for the following tests.
1. Quick and consolidated quick tests on clay soil samples.
2. Slow test on any type of soil.
Only using box shear test apparatus may carry the drained or slow shear tests on sand. As undisturbed samples of sand is not practicable to obtain, the box is filled with the sand obtained from the field and compacted to the required density and water content to stimulate field conditions as far as possible.
So far clay soil is concerned the undisturbed samples may be obtained from the field. The sample is cut to the required size and thickness of box shear test apparatus and introduced into the apparatus. The end surfaces are properly trimmed and leveled. I9f tests on remolded

soils of clay samples are required; they are compacted in the mould to the required density and moisture content.

12.6 Equation:

Coulombs equation is used for computing the shear parameters.
For clay soils
S=c+ tan
For sand
S= tan
Where, S = shear strength of soil in kg/cm^2
c=unit cohesion in kg/cm^2
= normal load applied on the surface of the specimen in kg/cm^2
= angle of shearing resistance (degrees)
In a Direct Shear test, the sample is sheared along a horizontal plane. This indicates that the failure plane is horizontal. The normal stress (s) on this plane is the external vertical load divided by the area of the soil sample. The shear stress at failure is the external lateral load divided by the corrected area of soil sample. The main advantage of direct shear apparatus is its simplicity and smoothness of operation and the rapidity with which testing programmes can be carried out. But this test has the disadvantage that lateral pressure and stresses on planes other than the plane of shear are not known during the test.

12.7 Precautions:

1. The dimensions of the shear box should be measured accurately.
2. Before allowing the sample to shear, the screw joining the two halves of the box should be taken out.
3. Rate of strain or shear displacement rate should be constant throughout the test.
4. The spacing screws after creating required spacing between two halves of the shear box, should be turned back to make them clear of the lower part.
5. For drained test, the porous stones should be saturated by boiling in water.
6. Add the self weight of the loading yoke in the vertical load.
7. Failure of the soil specimen is assumed when the proving ring dial gauge reading begins to recede after reaching its maximum or at a 20% shear displacement of the specimen length.
8. One soil specimen should be tested with not more than three normal loading conditions as beyond this, the particle size of soil sample may change due to application of shear and normal load.

12.8 Procedure

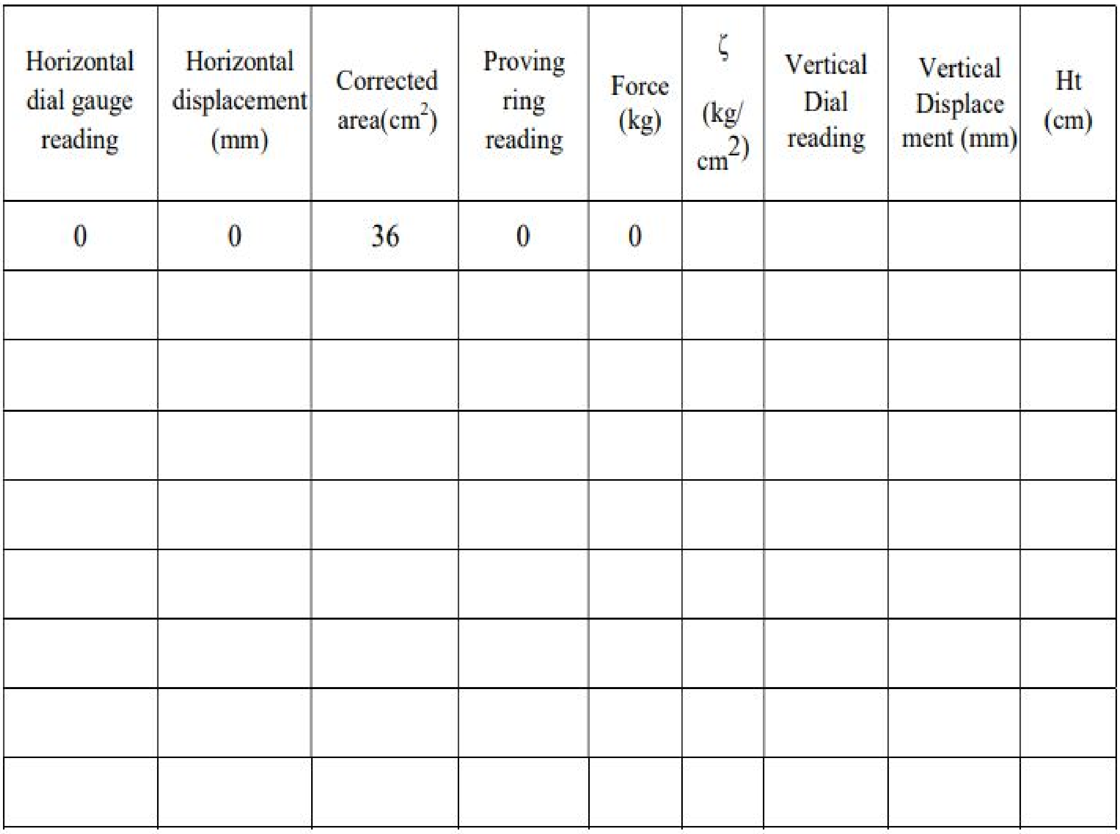
1. Place the sample of soil into the shear box, determine the water content and dry density of the soil compacted.
2. Make all the necessary adjustments for applying vertical load, for measuring vertical and lateral movements and measurement of shearing force, etc.

3. Apply a known load on the specimen and then keep it constant during the course of the test (for consolidation keep it for a long time without shearing, and quick tests apply the shearing without consolidation soon after placing the vertical load). Adjust the rate of strain as required of the specimen.
4. Shear the specimen till failure of the specimen is noticed or the shearing resistance decreases. Take the readings of the gauges during the shearing operation.
5. Remove the specimen from the box at the end of the test, and determine the final water content.
6. Repeat the tests on three or four identical specimens.

12.9 Table:

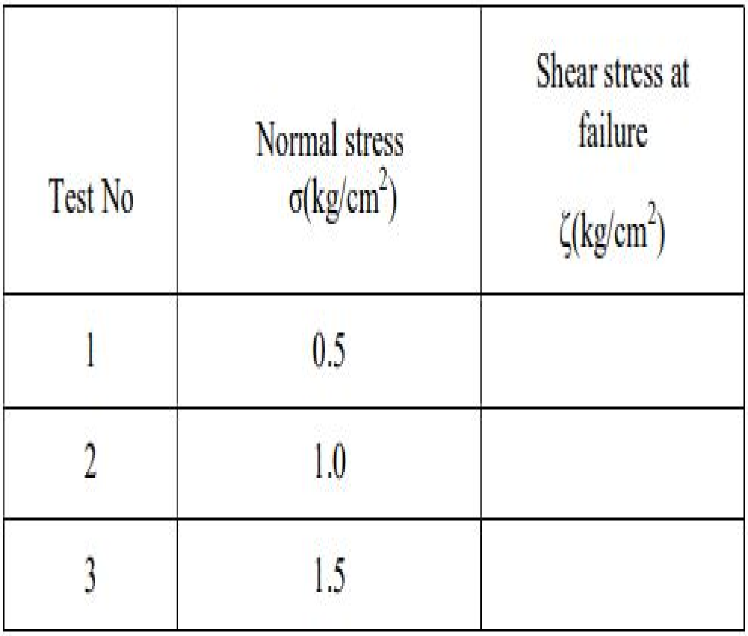
The test sample of cohesion less soil with a little cohesion is given in tabular form below.

1) Soil density d = 1.62 g/cm^3
Data sheet for sample 1: (for sample 2, 3, and 4 similar data sheets are to be prepared)
Initial area = Ao = 6×6 = 36 cm^2. Initial thickness = 2.4 cm. = 0.5 kg/cm^2



Horizontal dial gauge reading	Horizontal displacement (mm)	Corrected area(cm^2)	Proving ring reading	Force (kg)	ζ (kg/cm^2)	Vertical Dial reading	Vertical Displacement (mm)	Ht (cm)
0	0	36	0	0				

* Corrected area in cm^2 is given by b (b-horizontal displacement)
b = width of shear box=6cm
From three samples the following results are obtained



Test No	Normal stress σ(kg/cm^2)	Shear stress at failure ζ(kg/cm^2)
1	0.5	
2	1.0	
3	1.5	

From the results a graph of Horizontal displacement VS Shear stress is drawn
Mohr’s circles are also plotted.
From Mohr’s circle the following details are obtained;
Major principal stress sigma1= ———– kg/cm^2
Minor principal stress sigma2= ————kg/cm^2
Inclination to major principal stress 1= ——— degrees
Inclination to minor principal stress 2= ——— degrees

12.10 Result:

Angle of internal friction =——
Unit cohesion C =——kg/cm^2

12.11 Verification and Validation

The angle of shearing resistance of sands depends on state of compaction, coarseness of grains, particle shape and roughness of grain surface and grading. It varies between 28o (uniformly graded sands with round grains in very loose state) to 46o (well graded sand with angular grains in dense state). The friction between sand particles is due to sliding and rolling friction and interlocking action.

12.12 Conclusion:

The given soil has angle of friction as , showing the type of sand as densely coarse.

12.13 Viva Questions:

1. What are the initial adjustments required for the equipment?

2. What is the proving ring capacity in direct shear test?
3. What are the steps taken to get accurate result?

Lab 12 – VANE SHEAR TEST

13.1 Introduction

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.

13.2 Objective

To determine Cohesion or Shear Strength of Soil.

13.3 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.

13.4 Equipment Required:

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

13.5 Theory:

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

13.6 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.

13.7 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

13.8 Calculations:

Undrained Shear strength of Clay Cu=———-

13.9 Result:

Undrained Shear strength of Clay Cu = ————— kg/cm^2

13.10 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.

13.11 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. Is it possible to determine the sensitivity of clay suing this method?
4. What are the advantages of vane shear test?
5. What are the disadvantages of vane shear test?