Department of

CIVIL ENGINEERING

Zakura Campus

GEOTECHNICAL ENGINEERING I LABORATORY MANUAL

NAME: ____

ROLL NO: ____

BRANCH: ____

Institute of Technology, University of Kashmir
Srinagar, Jammu and Kashmir
190006

FOREWORD

About Institute of technology Zakura campus, University of Kashmir

The University of Jammu and Kashmir was founded in the year 1948. In the year 1969 it was bifurcated into two full-fledged Universities: University of Kashmir at Srinagar and University of Jammu at Jammu. The University of Kashmir is situated at Hazratbal in Srinagar. It is flanked by the world famous Dal Lake on its eastern side and Nigeen Lake on the western side. The Main Campus of the University spread over 247 acres of land is divided into three parts – Hazratbal Campus, Naseem Bagh Campus and Mirza Bagh Campus (serving residential purpose). Additional land has been acquired at Zakura near the main campus for further expansion of the University. The tranquil ambience of the Campus provides the right kind of atmosphere for serious study and research.

About the civil engineering Department:

The Department of Civil Engineering at the Institute of Technology, Zakura Campus, received official approval from the University of Kashmir Council on April 22, 2017. This approval represents a significant milestone in the department's establishment, designed to meet the increasing demand for skilled civil engineers in this region of India. The first cohort of students was admitted in the academic session 2020-2021, setting the foundation for an educational environment that emphasizes innovation and excellence.

Dedicated to delivering high-quality engineering education, the department ensures that students acquire both theoretical knowledge and practical skills essential for success. This comprehensive approach prepares graduates for fulfilling careers at national and international levels.

In addition to a well-rounded curriculum, the department boasts state-of-the-art laboratories, including specialized facilities for Concrete Technology, Surveying, and Structural Engineering. These labs provide students with invaluable hands-on experience, enabling them to apply theoretical concepts to real-world challenges. Furthermore, the department is actively expanding its laboratory offerings to ensure that students have access to the latest tools and technologies in civil engineering. This commitment empowers students to make meaningful contributions to society and excel in their careers.

Vision of the department:

To provide high-quality technical education that is socially and industrially relevant, aiming to develop civil engineers and professionals who can enhance their creativity, critical thinking, and problem-solving skills

FOREWORD

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 instruction manual guides the students to conduct the test as per Bureau of Indian Standard procedures. The students shall follow the guidelines indicated for conducting the tests for more effective, for better understanding and for logically interpreting the results.

- Before conducting any test, students shall come prepared with theoretical background of the corresponding test (indicated under the section 'theory' in each test).
- Students shall make sure to have the knowledge of measuring instruments like slide calipers, screw gauge, and other gauges.
- Students shall give importance to accuracy and precision while conducting the test and interpreting the results.
- Students shall acquaint themselves with the safe and correct usage of instruments / equipment under the guidance of teaching / supporting staff of the laboratory.

It is hoped that this instruction manual will serve to orient the students in the right direction of soil testing. The Author would like to express my sincere gratitude to Dr. Junaid Hassan Masoodi, Coordinator of the Civil Engineering Department, for their invaluable guidance and continuous support throughout the preparation of this lab manual. Their insightful suggestions and encouragement have greatly contributed to improving the quality and clarity of this work. Their leadership and expertise have been instrumental in shaping this manual to serve as a useful resource for students. I truly appreciate their time, effort, and unwavering support.

Contents

General instructions on safety and Do's and Don'ts

- Before starting laboratory work follow all written and verbal instructions carefully. If you do not understand a direction or part of a procedure, ASK YOUR CONCERN TEACHER BEFORE PROCEEDING WITH THE ACTIVITY.
- Before use equipment must be read carefully Labels and instructions. Set up and use the equipment as directed by your teacher.
- Any failure / break-down of equipment must be reported to the teacher.
- Observe good housekeeping practices. Replace the materials in proper place after work to keep the lab area tidy.
- Maintain silence and clean environment in the lab
- Protect yourself from getting electric shock.

GENERAL NOTES ON WRITING LABORATORY RECORD

All civil engineering projects require some soil exploration work at the very early stages, where soil tests are carried out in the laboratory and in situ. There are several commercial soil testing laboratories, and they have their own reporting styles. The report may be read by engineers who may not have the opportunity to see the soils being tested. Therefore, it is necessary to provide complete information in a simple and concise manner.

Notes on Plotting:

The following items should be looked into when presenting experimental data in graphical form:

1. **Scale:**

   Choose convenient scales; avoid odd, fractional, or decimal numbers per division. Even if preprinted graph paper is used, it is generally a good idea to put small tic marks at major divisions and indicate numerical values of these divisions. The scales should be chosen to adequately show the range of data i.e., the curves, data, notes, legend etc. should fill the graph.

2. **Axes:**

   Provide arrowheads at the ends. All axes need to be labelled (preferably in words) along with the units. Symbols are acceptable provided they are widely recognised or they are defined in the text. A modern approach is to enclose the graphs in a rectangular box, showing grid lines as necessary. The grid lines should be thinner than the curves or the axes.

3. **Experimental & theoretical curves:**

   If the curve is based on experimental data, show the data points clearly. If more than one set of data is included (e.g., std. proctor & modified Proctor compaction test data), differentiate between them by using different symbols and define them in a legend and/or clearly label the curves.

   It is a good idea to use different types of curves (e.g., -----, ..., ———) to distinguish the graphs.

   Smooth curves should be drawn with french curve through experimental data points - rarely should individual points be connected by straight lines. When showing variation of field water contents and blow counts with depth, in a bore log, connect the points by straight line segments.

Do not show the data points on theoretical curves, such as those plotted from calculations based on a mathematical formulae (e.g., zero air void curve).

4. **Title & figure number:**

   All plots, figures and tables need to be numbered and titled so that they can be referred to in the report.

5. **Data from other sources:**

   When you include data from other literature, clearly show them in the figure and give proper references.

The common software such as Excel, Origin, etc. have all the facilities you would need for a professional look. A good quality plot can be made within 30 minutes, with the axes, scales, etc. fixed up nicely. It is worth learning one of them.

EXPERIMENT - 1

DETERMINATION OF CONSISTENCY LIMITS OF SOIL

1(a) LIQUID LIMIT TEST

Objective:

To determine the liquid limit of given soil sample by mechanical method.

Standards:

1. Indian Standards : IS: 2720 (Part-5)
2. ASTM: D-4318
3. AASHTO: T-89

Need and scope:

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

Definition (As per Casagrande):

The liquid limit is the moisture content at which the groove, formed by a standard tool into the sample of soil taken in the standard cup, closes for 12 mm on being given 25 blows in a standard manner. At this limit the soil possess low shear strength.

Apparatus:

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

Figure 1: Casagrande's liquid limit device

Procedure:

1. About 120 g of air-dried soil from thoroughly mixed portion of material passing 425-micron I.S sieve is to be obtained.
2. Distilled water is mixed to the soil thus obtained in a mixing dish to form uniform paste. The paste shall have a consistency that would require 30 to 35 drops of cup to cause required closer of standard groove for sufficient length.
3. A portion of the paste is placed in the cup of liquid limit device where cup rest on the base and spread into portion with few strokes of spatula.
4. Trim it to a depth of 1 cm at the point of maximum thickness and return excess of soil to the dish.
5. The soil in the cup shall be divided by the firm strokes of the grooving tool along the diameter through the center line of the follower so that clean sharp groove of proper dimension is formed.
6. Lift and drop the cup by turning crank at the rate of two revolutions per second until the two halves of soil cake come in contact with each other for a length of about 12 mm by flow only (should not slip).
7. The number of blows required to cause the groove close for about 12 mm shall be recorded.

8. A representative portion of soil is taken from the cup for water content determination.
9. Repeat the test with different moisture contents at least three more times for blows between 10 and 40.

Observations:

Details of the sample: ....

Natural moisture content: .... Room temperature: ....

Observation Table:

Determination Number	**1**	**2**	**3**		**4**
Container number					
Mass of container , M_1 (g)					
Mass of container + wet soil, M_2 (g)					
Mass of container + dry soil, M_3 (g)					
Mass of water, $M_2 - M_3$ (g)					
Mass of dry soil, M_3-M_1 (g)					
Moisture content (%) = $\frac{M_2 - M_3}{M_3 - M_1} \times 100$					
No. of blows					

Calculation:

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

Interpretation and recording:

Result:

Flow index, $I_f = \frac{(W_2 - W_1)}{(log\frac{N1}{N2})}$ = slope of the flow curve = ______.

Questionnaire:

1. If natural water content of the soil is greater than the liquid limit and consistency index is negative, what is the consistency/ state of the soil?
2. What is the difference in consistency of soil and consistency of cement?

1(b) PLASTIC LIMIT TEST

Objective:

Determination of the plastic limit of soil

Standards:

1. Indian Standards : IS: 2720 (Part-5)
2. ASTM: D-4318
3. AASHTO: T-90

Need and scope:

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

Apparatus:

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

Figure 1: Equipment for Plastic Limit

Procedure:

1. Take about 20 g of thoroughly mixed portion of the material passing through 425 micron I.S. sieve obtained in accordance with I.S. 2720 (Part 1).
2. Mix it thoroughly with distilled water in the evaporating dish till the soil mass becomes plastic enough to be easily molded with fingers.
3. Allow it to season for sufficient time (for 24 hrs.) to allow water to permeate throughout the soil mass.
4. Take about 8 g of this plastic soil mass and roll it between fingers and glass plate with just sufficient pressure to roll the mass into a thread of uniform diameter throughout its length. The rate of rolling shall be between 80 and 90 strokes per minute.
5. Continue rolling till you get a thread of 3 mm diameter.
6. Kneed the soil together to a uniform mass and re-roll.
7. Continue the process until the thread crumbles when the diameter is 3 mm.
8. Collect the pieces of the crumbled thread in air tight container for moisture content determination.
9. Repeat the test atleast 3 times and take the average of the results calculated to the nearest whole number.

Observation:

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

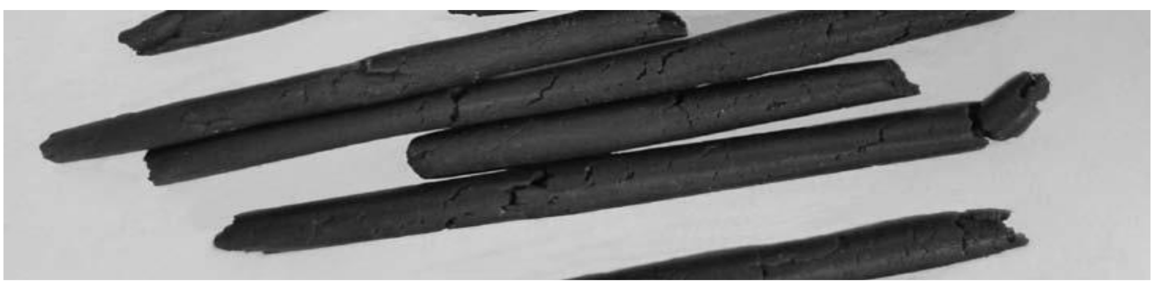

Figure 3: 3 mm thread of soil with cracks

Observation Table:

Determination Number	**1**	**2**	**3**
Container No.			
Mass of container + lid, W_1 (g)			
Mass of container + lid + wet sample, W_2 (g)			
Mass of container + lid + dry sample, W_3 (g)			
Mass of dry sample (soil solids) = $W_3 - W_1$ (g)			
Mass of water in the soil = $W_2 - W_3$ (g)			
Water content, w (%) = $\frac{W_2 - W_3}{W_3 - W_1} \times 100$			

Results:

Flow index, $I_f = \frac{(W_2 - W_1)}{(log\frac{N1}{N2})}$ = slope of the flow curve = _______.

Plasticity Index, $I_p = w_l - w_p$ = _______.

Toughness Index, $I_T = \frac{I_p}{I_f}$ = _______.

Liquidity Index, $I_L = \frac{w_o - w_p}{I_p}$ = ________.

Consistency Index, $I_c = \frac{w_l - w_o}{I_p}$ = ________.

Where, w_o = Natural Moisture content of soil

Result Summary						
Liquid limit (w_l)	Plastic limit (w_P)	Flow Index (I_f)	Plasticity Index (I_p)	Toughness Index (I_T)	Liquidity Index (I_L)	Consistency Index (I_c)

1(c) SHRINKAGE LIMIT TEST

Objective:

To determine the shrinkage limit and calculate the shrinkage ratio for the given soil

Standards:

1. Indian Standards : IS: 2720 (Part-6)
2. ASTM: D-427
3. AASHTO: T-92

Theory:

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

Need and scope:

Soils which undergo large volume changes with change in water content may be troublesome. Volume changes may not and usually will not be equal.

A shrinkage limit test should be performed on a soil.

1. To obtain a quantitative indication of how much change in moisture can occur before any appreciable volume changes occurs.
2. To obtain an indication of change in volume.

The shrinkage limit is useful in areas where soils undergo large volume changes when going through wet and dry cycles (as in case of earth dams).

Apparatus:

1. Evaporating Dish- Porcelain, about 12cm diameter with flat bottom.
2. Spatula
3. Shrinkage Dish- Circular, porcelain or non-corroding metal dish (3 nos) having a flat bottom and 45 mm in diameter and 15 mm in height internally.
4. Straight Edge- Steel, 15 cm in length.

5. Glass cup- 50 to 55 mm in diameter and 25 mm in height, the top rim of which is ground smooth and level.
6. Glass plates- Two, each 75 x 75 mm one plate shall be of plain glass and the other shall have prongs.
7. Sieves- 2mm and 425- micron IS sieves.
8. Oven- thermostatically controlled.
9. Graduate- Glass, having a capacity of 25 ml and graduated to 0.2 ml and 100 cc one –mark flask.
10. Balance- Sensitive to 0.01 g minimum.
11. Mercury- Clean, sufficient to fill the glass cup to over flowing.
12. Wash bottle containing distilled water.
13. Desiccator

Caution:

Do not touch the mercury with gold rings.

Procedure:

Preparation of soil paste:

1. Take about 100 g of soil sample from a thoroughly mixed portion of the material passing through 425-micron I.S. sieve.
2. Place about 30 g the above soil sample in the evaporating dish and thoroughly mix with distilled water and make a creamy paste.

Use water content somewhere around the liquid limit.

Filling the shrinkage dish:

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

6. Air- dry the wet soil cake for 6 to 8hrs, until the colour of the pat turns from dark to light. Then oven-dry up to a constant weight at 105^0 C to 110^0 C (say about 12 to 16 hrs).
7. Remove the dried disk of the soil from oven. Cool it in a desiccator. Then obtain the weight of the dish with dry sample.
8. Determine the weight of the empty dish and record.
9. Determine the volume of shrinkage dish which is evidently equal to volume of the wet soil as follows. Place the shrinkage dish in an evaporating dish and fill the dish with mercury till it overflows slightly. Press it with plain glass plate firmly on its top to remove excess mercury. Pour the mercury from the shrinkage dish into a measuring jar and find the volume of the shrinkage dish directly. Record this volume as the volume of the wet soil pat.

Volume of the Dry Soil Pat:

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

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

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

Calculation:

Tabulation and results:

S.No	Determination	1	2	3
1.	Shrinkage dish No.			
2.	Mass of shrinkage dish, g			
3.	Mass of shrinkage dish + wet soil pat, g			
4.	Mass of shrinkage dish + dry soil pat, g			
5.	Mass of oven-dry soil pat (W_o), g			
6.	Mass of water, g			
7.	Moisture content (w) of soil pat, %			
8.	Mass of mercury filling shrinkage dish + Mass of evaporating dish			
9.	Mass of evaporating dish			
10.	Mass of mercury filling shrinkage dish, g			
11.	Volume of wet soil pat (V), ml			
12.	Mass of mercury displaced by the dry soil pat, g			
13.	Mass of evaporating dish, g			
14.	Mass of mercury displaced by the dry soil pat, g			
15.	Volume of dry soil pat (V_o), g			
16.	Shrinkage limit $= \left(\mathrm{w} - \frac{\mathrm{V} - \mathrm{V_o}}{\mathrm{W_o}}\right) \times 100$			
17.	Shrinkage ratio, $\mathrm{R} = \frac{W_o}{V_o}$			

NOTE: This test will not be conducted due to use of hazardous metal, mercury.

1(d) FREE SWELL INDEX

Objective:

To determine the free swell index of soil as per IS: 2720 (Part XL) – 1977.

Standard:

1. IS: 2720 (Part XL) -1977

Need and scope:

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

Swelling soils, which are clayey soils, are also called expansive soils. When these soils are partially saturated, they increase in volume with the addition of water. They shrink greatly on drying and develop cracks on the surface. These soils possess a high plasticity index. Black cotton soils found in many parts of India belong to this category. Expansive soils contain minerals like montmorillonite, which due to large specific surface are capable of absorbing large amount of water. When they absorb water, they increase in volume. The more water they absorb the more their volume increases. Expansions of ten percent or more are not uncommon. This change in volume can exert large force on a building or other structure to cause damage. Cracked foundations, floors and basement walls are typical types of damage done by swelling soils.

Expansive soils will also shrink when they dry out. This shrinkage can remove support from buildings or other structures and result in damaging subsidence. Fissures in the soil can also develop. These fissures can facilitate the deep penetration of water when moist conditions or runoff occurs. This produces a cycle of shrinkage and swelling that places repetitive stress on structures.

Apparatus:

1. 425 micron IS sieve
2. Oven
3. Balance, with an accuracy of 0.01g
4. Graduated glass cylinder - 2 nos., each of 100ml capacity
5. Glass rod for stirring

Procedure:

1. Take two oven dried specimens of 10g each passing through 425micron IS Sieve.
2. Pour each soil specimen into a graduated glass cylinder of 100ml capacity.
3. Pour distilled water in one and kerosene oil in the other cylinder up to 100ml mark.
4. Remove entrapped air by gently shaking or stirring with a glass rod.
5. Allow the suspension to attain the state of equilibrium (for not less than 24hour).

6. Final volume of soil in each of the cylinder should be read out.

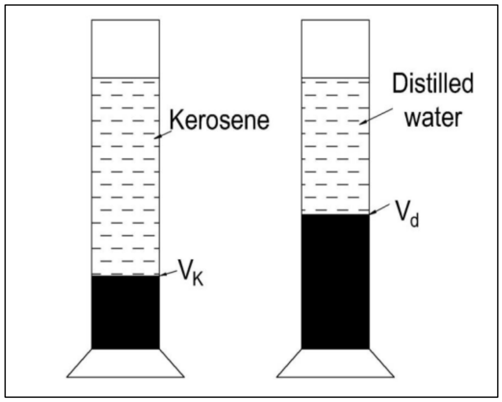

Figure 1: Schematic representation of experimental procedure

Calculation:

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

where,

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

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

FSI in %	Expansiveness
<20	Low
20-35	Moderate
35-50	High
>50	Very high

Observation Table:

Trial No.	**1**	**2**
Mass of dry soil passing 425micron IS Sieve (g)		
Volume of soil specimen in distilled water after 24h (V_d) ml		
Volume of soil specimen in kerosene after 24h (V_k) ml		
Free Swell Index (%) = $\frac{V_d - V_k}{V_k} \times 100$		
Average (%)		

Result:

The differential free swell index (DFS) of the given soil is **_________.**

Safety and precautions:

1. In the case of highly expansive soils such as sodium bentonites the sample size may be 5 g or alternatively a cylinder of 250 ml capacity for 10 g of sample may be used.
2. Switch off the oven and use hand gloves while removing the soil sample from oven.

Questionnaire:

1. Under what condition DFS value be negative and for what type of soil?

EXPERIMENT - 2

FIELD DENSITY TEST
2(a) CORE CUTTER METHOD

Objective:

To determine the in-situ dry density of soil by core cutter method

Standard:

IS: 2720 (Part XXIX) – 1975

Theory:

The Core-cutter method consists of driving a core-cutter of known volume into the soil after placing it on the cleaned soil surface. The cutter filled with soil is removed and excess soil is trimmed off. The cutter with the soil is weighed. The volume of the cutter is calculated from the dimensions of the cutter and the in-situ weight is determined by dividing the weight of the soil in the cutter by the volume of the cutter. By determining the water content of the soil in the laboratory, the dry unit weight of the soil can be computed.

The in-situ density of the soil is needed for stability analysis, for the determination of the degree of compaction of compacted soil, etc. The core-cutter method is suitable for fine-grained soils free from aggregations. It is less accurate than the sand-replacement method and is not recommended, unless speed is essential or unless the soil is well compacted.

Apparatus:

1. Cylindrical core cutter - seamless steel tube, 130 mm long and 10 cm internal diameter, with a wall thickness of 3 mm and beveled at one end.
2. Steel rammer - With solid mild steel foot 140 mm diameter and 75 mm height with a concentrically screwed 25 mm diameter solid mild steel staff. The overall length of the rammer including the foot as well as the staff should be approximately 900 mm. The rammer (foot and staff together) should weigh approximately 9 kg.
3. Steel dolly – 2.5 cm high and 10 cm internal diameter with a wall thickness of 7.5 mm and with a lip to enable it to be fitted on top of the core-cutter
4. Electronic balance with an accuracy of 1 gm.
5. Steel rule
6. Spade or pickaxe
7. Straight edge - A steel strip about 30 cm long, 2.5 cm wide and 3 to 5 mm thick with one bevelled edge.

8. Knife
9. Sample extruder

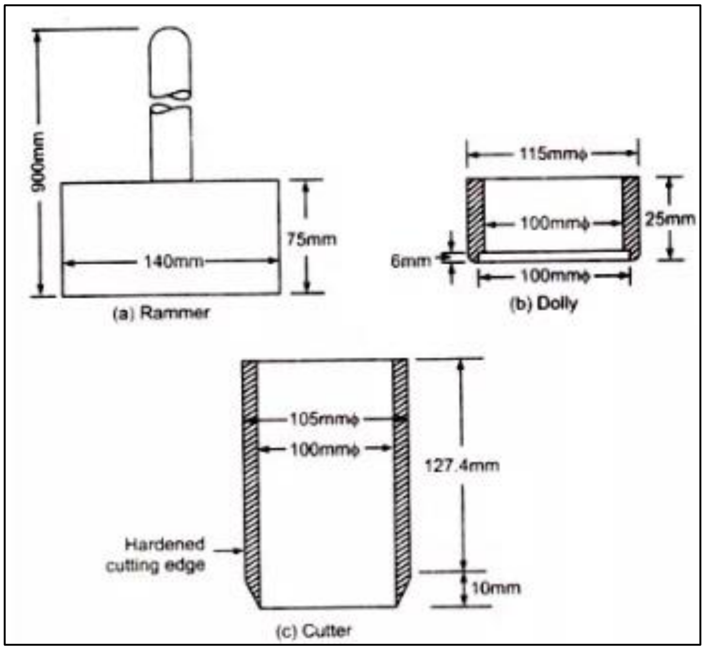

Figure 1: Core cutter setup

Site preparation:

Clear a small area, approximately 30 cm square and level it. The area should be free from vegetation and should not contain tree roots, rocks and boulders. The ideal site would be cohesive soil.

Test procedure:

1. Measure the height (h) and internal diameter (d) of the core cutter. Determine the inner volume of the core-cutter (V_c)
2. Apply grease to the inside of the core cutter and weigh the empty core cutter (W_1)
3. Clean and level the place where density is to be determined.
4. Attach the steel dolly on the top of the core cutter. With the help of the steel rammer drive the core cutter vertically into the soil until only about 15 mm of the dolly protrudes above the surface.
5. Excavate the soil around the cutter with a crow bar and gently lift the cutter without disturbing the soil in it.
6. Trim the top and bottom surfaces of the sample and clean the outside surface of the cutter.
7. Weigh the core cutter with soil (W_2)

8. Remove the soil from the core cutter using a sample ejector and take representative soil sample from it to determine the moisture content.
9. Report the dry density of the soil to second place of decimal in g/cm^3 and water content of the soil to two decimal figures.

CALCULATIONS:

1. Bulk unit weight:

$$\gamma_b = \frac{W_2 - W_1}{V_c}$$

where,

Υ_b = Bulk unit weight in g/cc

W_1 = empty weight of the core cutter in grams

W_2 = weight of the core cutter with soil in grams

V_c = Volume of the cutter in cc.

2. Dry unit weight:

$$\gamma_d = \frac{100\,\gamma_b}{100 + w}$$

where,

Υ_d = Dry unit weight in g/cc

Υ_b = Bulk unit weight in g/cc

w = moisture content in percentage

3. In-situ void ratio:

$$e = \frac{G_s - \gamma_w}{\gamma_d}$$

where,

e = in-situ void ratio

Gs = Specific gravity of soil solids

Υ_w = Unit weight of of water in g/cc

Υ_d = Dry unit weight of soil in g/cc

Result:

The in-situ dry density of the soil is ________.

The in-situ void ratio of soil is _________.

Safety and precautions:

1. 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.
2. No loose material should be left in the pit.
3. There should be no vibrations during this test.

2(b) SAND REPLACEMENT METHOD

Objective:

To determine the in-situ dry density of soil by sand replacement method.

Standards:

1. IS: 2720 (Part-XXVIII)
2. ASTM: D-1556
3. AASHTO: T-19

Need and scope:

Determination of field density of cohesionless soil is not possible by core cutter method, because it is not possible to obtain a core sample. In such situation, the sand replacement method is employed to determine the unit weight.

The in-situ density of natural soil is needed for the determination of bearing capacity of soils, for the purpose of stability analysis of natural soils, for the determination of pressures on underlying strata, for calculation of settlement, etc. In compacted soils, the in-situ density is needed to check the amount of compaction that the soil has undergone for comparing with design data. The correct estimation of the in-situ density of both natural and compacted soils is therefore of great importance.

By conducting this test it is possible to determine the bulk density of the soil. The moisture content is likely to vary from time to time and hence the bulk density also. So it is required to report the test result in terms of dry density. It is a quality control test, where compaction is required.

Apparatus:

1. Sand pouring cylinder of 3L capacity mounted above a pouring cone and separated by a shutter cover plate.
2. Calibrating container: With an internal diameter of 100 mm and an internal depth of 150 mm. Fitted with a flange approximately 50 mm wide and about 5 mm thick surrounding the open end. The volume of the container should be given to an accuracy of 0.25 percent.
3. Metal tray with a central hole: 300 mm square and 40 mm deep with 100 mm hole in the centre.
4. **Dry sand:** Clean, uniformly graded natural sand passing the 1 mm IS Sieve and retained on the 600 micron IS Sieve. It shall be free from organic matter and should be oven dried and

stored for a suitable period to allow its water content to reach equilibrium with atmospheric humidity.

5. Tools for excavating holes; suitable tools such as scraper tool to make a level surface.
6. Balance to weigh unto an accuracy of 1g.
7. Glass plate about 450 mm/600 mm square and 9mm thick.
8. Suitable non-corrodible airtight containers.
9. Thermostatically controlled oven with interior on non-corroding material to maintain the temperature between 105^0C to 110^0C.
10. A dessicator with any desiccating agent other than sulphuric acid.

Figure1: Apparatus for sand replacement method

Procedure:

Bulk density of sand:

1. The volume of calibrating container is found.
2. The sand pouring cylinder is filled with sand within about 10mm from top.
3. The sand pouring cylinder with sand is weighed as W_1.
4. The sand pouring cylinder is kept over the calibrating cylinder. The shutter is opened and sand is allowed to run out into the calibrating container till no further movement of sand is observed.
5. The shutter is closed and again the sand pouring cylinder containing the remaining sand is weighed as W_2.

6. The sand pouring cylinder is kept on a glass plate.
7. The shutter is opened and the sand is allowed to run out until no further movement of the sand took place in the cylinder. The shutter is closed and the sand pouring cylinder is removed carefully.
8. The sand left on the glass plate is weighed as W_3.
9. The weight of sand to fill the calibrating container is found.
10. The bulk density of sand is found.
11. The same operations are repeated twice ensuring the same weight of the cylinder with sand before pouring.

Dry density of soil:

1. An area of about $450mm^2$ is exposed on the soil surface where test is to be performed.
2. The surface is trimmed and levelled.
3. The metal tray with the central hole is kept on the prepared surface.
4. A hole is excavated in the soil using an excavating tool.
5. The hole in the metal tray is used as a pattern while excavating.
6. The excavation is done upto a depth of 150 mm.
7. The excavated soil is weighed as W_W.
8. The sand pouring cylinder is filled with standard sand to the weight as recorded earlier.
9. The sand pouring cylinder is placed concentrically over the excavated hole.
10. The shutter is opened and sand is allowed to run out into the hole until no further movement of sand took place in the cylinder. Then, the shutter is closed.
11. The cylinder is removed from the excavated hole. Then, the pouring cylinder is weighed with the remaining sand as W_4.
12. The weight of the sand in the hole is found as W_1-W_4-W_2.
13. The volume of the hole is found.
14. The bulk density is found.
15. A small soil specimen is taken for moisture content determination.
16. The dry density is found.
17. The field operations are repeated in the same area at different locations to get average results.
18. The average dry density of the field soil is found.

Observation Table:

Table 1: Bulk density of sand.

Sl. No.	**Sample Details Calibration**	**1**	**2**	**3**
1.	Volume of calibrating container (V) in cc			
2.	Weight of cylinder + sand (before pouring), W_1 g			
3.	Mean weight of cylinder + sand (after pouring), W_2 g			
4.	Mean weight of sand in cone (of pouring cylinder), W_3 g			
5.	Weight of sand to fill calibrating container $W_a = (W_1 - W_2 - W_3)$ g			
6.	Bulk density of sand $\gamma_s = \frac{W_a}{V}$ g/cc			

Table 2: Dry density of soil.

Sl. No.	**Measurement of soil density**	**1**	**2**	**3**
1.	Weight of wet soil from hole, W_w g			
2.	Weight of cylinder + sand (before pouring), W_1 g			
3.	Weight of cylinder + sand (after pouring), W_4 g			
4.	Weight of sand in hole, $W_b = (W_1 - W_4 - W_3)$ g			
5.	Volume of hole, $V_b = \frac{W_b}{\Upsilon_s}$ cc			
6.	Bulk density $\Upsilon_b = \frac{W_w}{W_b} \times \Upsilon_s$ g/cc			
7.	Water content (%)			
8.	Dry density $\Upsilon_d = \frac{\Upsilon_b}{1+w}$ g/cc			
9.	Average dry density of soil			

Result:

The dry density of soil is ________.

General remarks:

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

Questionnaire:

1. How to decide the type of test if you have a mixture of fine and coarse grained soil?

EXPERIMENT - 3

COMPACTION TEST
3(a) LIGHT COMPACTION TEST

Objective:

To determine the maximum dry density (M.D.D.) and optimum moisture content (O.M.C.) of a given soil sample using light compaction test.

Standards:

1 Indian Standards : IS: 2720 (Part-7)

2 ASTM: D-698 - 12e2

3 AASHTO: T-99

Need and scope:

Compaction can be defined as a simple ground improvement technique, where the soil is densified through external compactive effort.

This method covers the determination of the relationship between the moisture content and density of soils compacted in a mould of a given size with a 2.6 kg rammer dropped from a height of 310 mm.

Apparatus:

1. Proctor mould having a capacity of 944 cc with an internal diameter of 10.2 cm and a height of 11.6 cm. The mould shall have a detachable collar assembly and a detachable base plate.
2. Rammer: A mechanically operated metal rammer having a 5.08 cm diameter face and a weight of 2.6 kg. The rammer shall be equipped with a suitable arrangement to control the height of drop to a free fall of 310 mm.
3. Sample extruder.
4. A balance of 15 kg capacity.
5. Sensitive balance.
6. Straight edge.
7. Graduated cylinder.

8. Mixing tools such as mixing pan, spoon, towel, spatula etc.

9. Containers.

Figure 1: Rammer and mould for compaction test

Procedure:

1. Take a representative oven-dried sample, approximately 5 kg in the given pan. Thoroughly mix the sample with sufficient water to dampen it to approximately four to six percent below optimum moisture content.
2. Weigh the proctor mould without base plate and collar. Fix the collar and base plate. Place the soil in the Proctor mould and compact it in 3 layers giving 25 blows per layer with the 2.6 kg rammer falling through 310 mm height.
3. Remove the collar, trim the compacted soil even with the top of the mould by means of the straight edge and weigh.
4. Divide the weight of the compacted specimen by 944 cc and record the result as the bulk weight in gram per cubic centimeter of the compacted soil.
5. Remove the sample from the mould and slice vertically through and obtain a small sample for moisture determination.
6. Thoroughly break the remaining material until it passes through 4.75mm sieve as per eye judgment. Add water in sufficient amount to increase the moisture content of the soil sample by one or two percent and repeat the above procedure for each increment of water added. Continue this series of determination until there is either a decrease or no change in the bulk unit weight of the compacted soil.

Calculation:

$$Bulk\ density\ = \frac{weight\ of\ compacted\ soil}{Volume\ of\ Mould}$$

$$Dry\ density\ = \frac{bulk\ density}{(1+w)}$$

where,

'w' is the moisture content of the soil.

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

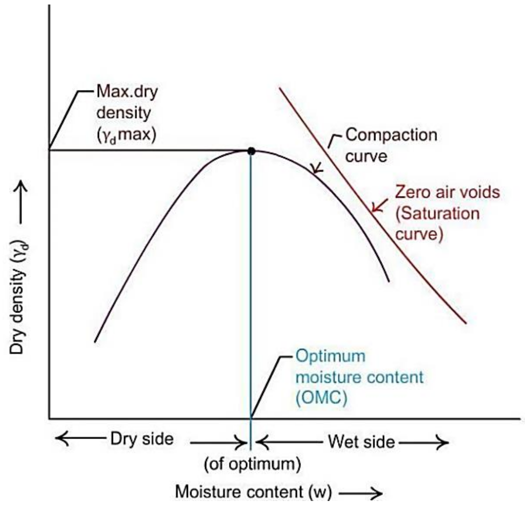

Figure 2: Compaction Curve

Observations:

Cylinder (mould)

a) height = cm
b) dia = cm
c) volume = cc

Observation Table:

Test No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Mass of empty mould, W_m g							
Assumed water content, w%							
Mass of mould + compacted soil, W_1 g							
Mass of compacted soil, g							
Bulk density, Υ_t (g/cc)							
Container No.							
Mass of container (empty), X_1 g							
Mass of container + wet soil, X_2 g							
Mass of container + dry soil, X_3 g							
Mass of water, (X_2-X_3) g							
Mass of dry soil, (X_3-X_1) g.							
Actual water content, w (%)							

Dry density = Υ_t / (1+w) g/cc							
Υ_d (ZAV), g/cc							

Calculation of Zero Air Void Line:

Zero air void line gives the relationship between dry density and moisture content when the degree of saturation is assumed to be 100%. It can be calculated by using the following formula

$$\gamma_{d(100\%\ sat)} = \frac{G\gamma_w}{1 + wG}$$

where,

$\gamma_{d(100\%\ sat)}$ = dry density corresponding to 100% saturation (g/cc).

G = specific gravity of soil solids.

w = water content of soil

γ_w = unit weight of water (g/cc)

3(b) HEAVY COMPACTION TEST

Objective:

To determine the maximum dry density (M.D.D.) and optimum moisture content (O.M.C.) of a given soil sample using heavy compaction test.

Standards:

1. Indian Standards : IS: 2720 (Part-8)
2. ASTM: D-1557 - 12e1
3. AASHTO: T-180

Need and scope:

Compaction can be defined as a simple ground improvement technique, where the soil is densified through external compactive effort.

This method covers the determination of the relationship between the moisture content and density of soils compacted in a mould of a given size with a 4.9 kg rammer dropped from a height of 450 mm.

Apparatus:

1. Proctor mould having a capacity of 944 cc with an internal diameter of 10.2 cm and a height of 11.6 cm. The mould shall have a detachable collar assembly and a detachable base plate.
2. Rammer: A mechanical operated metal rammer having a 5.08 cm diameter face and a weight of 4.9 kg. The rammer shall be equipped with a suitable arrangement to control the height of drop to a free fall of 450 mm.
3. Sample extruder.
4. A balance of 15 kg capacity.
5. Sensitive balance.
6. Straight edge.
7. Graduated cylinder.
8. Mixing tools such as mixing pan, spoon, towel, spatula etc.

9. Containers.

Procedure:

1. Take a representative oven-dried sample, approximately 5 kg in the given pan. Thoroughly mix the sample with sufficient water to dampen it to approximately four to six percentage points below optimum moisture content.
2. Weigh the proctor mould without base plate and collar. Fix the collar and base plate. Place the soil in the Proctor mould and compact it in 5 layers giving 25 blows per layer with the 4.9 kg rammer falling through 450 mm height.
3. Remove the collar, trim the compacted soil even with the top of the mould by means of the straight edge and weigh.
4. Divide the weight of the compacted specimen by 944 cc and record the result as the bulk weight in gram per cubic centimeter of the compacted soil.
5. Remove the sample from the mould and slice vertically through and obtain a small sample for moisture determination.
6. Thoroughly break the remaining material until it passes through 4.75mm sieve as per eye judgment. Add water in sufficient amount to increase the moisture content of the soil sample by one or two percent and repeat the above procedure for each increment of water added. Continue this series of determination until there is either a decrease or no change in the bulk unit weight of the compacted soil.

Calculation:

$$Bulk\ density\ = \frac{weight\ of\ compacted\ soil}{Volume\ of\ Mould}$$

$$Dry\ density\ = \frac{bulk\ density}{(1 + w)}$$

where,

w is the moisture content of the soil.

Observations:

Cylinder (mould)

a) height = cm
b) dia = cm
c) volume = cc

Test No.	1	2	3	4	5	6	7
Mass of empty mould, W_m g							
Mass of cylinder + compacted soil, W_1 g							
Mass of compacted soil, g							
Bulk density, γ_t (g/cc)							
Container No.							
Mass of container (empty), X_1 g							
Mass of container + wet soil, X_2 g							
Mass of container + dry soil, X_3 g							
Mass of water, (X_2-X_3) g							
Mass of dry soil, (X_3-X_1) g.							
Water content, w (%)							
Dry density = Υ_t / (1+w), g/cc							
Υ_d (ZAV), g/cc							

Calculation of Zero Air Void Line:

Zero air void line gives the relationship between dry density and moisture content when the degree of saturation is assumed to be 100%. It can be calculated by using the following formula

$$\gamma_{d(100\%\,sat)} = \frac{G\gamma_w}{1+wG}$$

where,

$\gamma_{d(100\%\ sat)}$ = Dry density corresponding to 100% saturation (g/cc).

G = Specific gravity of soil solids.

w = Water content of soil

γ_w = Unit weight of water (g/cc)

Questionnaire:

1. For a particular soil what will happen to OMC and MDD with increase in compactive effort.

2. What type of structure of soil at dry of optimum and wet of optimum?
3. Will above compaction tests will be effective for clayey soil?

EXPERIMENT - 4

PERMEABILITY TEST

4(a) CONSTANT HEAD METHOD

Objective:

To determine the coefficient of permeability of a soil using constant head method.

Standards:

1. Indian Standards : IS: 2720 (Part-36)
2. ASTM: D-2434
3. AASHTO: T-215

Need and scope:

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

Planning and organization:

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

Definition of coefficient of permeability:

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

Equipment:

1. Permeameter of non-corrodible material having a capacity of 1000 ml, with an internal diameter of 100 ± 0.1 mm and internal effective height of 127.3 ± 0.1 mm.
2. The mould shall be fitted with a detachable base plate and removable extension counter.
3. **Compacting equipment:** 50 mm diameter circular face, weight 2.6 kg and height of fall 310 mm as specified in I.S 2720 part VII 1980.
4. **Drainage bade:** A bade with a porous disc, 12 mm thick which has the permeability 10 times the expected permeability of soil.
5. **Drainage cap:** A porous disc of 12 mm thick having a fitting for connection to water inlet or outlet.

6. **Constant head tank:** A suitable water reservoir capable of supplying water to the permeameter under constant head.
7. Graduated glass cylinder to receive the discharge.
8. Stop watch to note the time.
9. A meter scale to measure the head differences and length of specimen.

Figure 1: Experimental setup for constant head permeability test

Preparation of specimen for testing:

- **Undisturbed soil sample**

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

- **Disturbed soil sample:**

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

Test procedure:

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

Observation and recording:

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

Calculation:

The test is based Darcy's law for laminar flow. q = kiA

where,

q = Discharge per unit time.
A = Total area of c/s of soil perpendicular to the direction of flow.
i = hydraulic gradient.
k = Darcy's coefficient of permeability

Coefficient of permeability for a constant head test is given by

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

where,

k = coefficient of permeability in cm/sec
Q = volume of discharge in cm^3
L = Length of specimen in cm
A = Cross-sectional area of specimen in cm^2
h = Head causing flow in cm

The viscosity of the water changes with temperature. As temperature increases viscosity decreases and the permeability increases. The coefficient of permeability is standardized at 27°C, and the permeability at any temperature T is related to K_{27} by the following ratio:

$$K_{27} = K_T \frac{\eta_T}{\eta_{27}}$$

where,

η_T *and* η_{27} are the viscosities at the temperature T of the test and at 27° C, respectively.

Table 1: Properties of Distilled Water (η = absolute)

Temperature °C	Density (g/cc)	Viscosity (Poise)
4	1.0000	0.01567
16	0.99897	0.01111
17	0.99880	0.01083
18	0.99862	0.01056
19	0.99844	0.01030
20	0.99823	0.01005
21	0.99802	0.00981
22	0.99780	0.00958
23	0.99757	0.00936
24	0.99733	0.00914
25	0.99708	0.00994
26	0.99682	0.00874
27	0.99655	0.00855
28	0.99627	0.00836
29	0.99598	0.00818
30	0.99568	0.00801

Presentation of data:

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

Observation:

Permeability Test Record:

Project: ……… Tested By: ……..

Location: …….. Boring No. : ....

Depth: ………

Details of sample

Diameter of specimen …...cm Length of specimen(L) …...cm

Area of specimen (A) …...cm^2 Specific gravity of soil G_s …….

Volume of specimen (V) ……cm^3 Weight of dry specimen (W_s) …..g

Moisture content ……. %

Observation Table:

Experiment No.		1	2	3	4
Length of specimen	L(cm)				
Area of specimen	A(cm^2)				
Height of water (head)	h(cm)				
Volume	V(cm^3)				
Time	t(sec)				
Temperature	T(°C)				
Permeability K_T	K_T (cm/sec)				
Permeability K_{20}	K_{20} (cm/sec)				

Interpretation and Reporting:

Compare the results with the empirical relationships

$K= CD_{10}^2$ and compare the constants

Questionnaire:

1. The flow inside the soil sample is laminar or turbulent?
2. What type of head loss you expect in the soil sampler?

4(b) FALLING HEAD METHOD

Objective:

To determine the coefficient of permeability of the given soil sample using falling head method

Standards:

1. Indian Standards : IS: 2720 (Part-17)
2. ASTM: D- D5084
3. AASHTO: T-215
4. BS: 1377-5

Need and scope:

The test results of the permeability experiments are used:

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

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

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

Principle of the experiment:

The passage of water through porous material is called seepage. A material with continuous voids is called a permeable material. Hence, permeability is a property of a porous material which permits passage of fluids through inter connecting voids.

Hence, permeability is defined as the rate of flow of water under laminar conditions through a unit cross-sectional area perpendicular to the direction of flow through a porous medium under unit hydraulic gradient and under standard temperature conditions.

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

$$q = kiA$$

where,

q = discharge per unit time.

A = total area of c/s of soil perpendicular to the direction of flow.

i = hydraulic gradient.

k = Darcy's coefficient of permeability = the mean velocity of flow that will occur through the cross-sectional area under unit hydraulic gradient.

The coefficient of permeability, k,

$$k = \frac{2.303aL}{A(t_1 - t_o)} \log_{10}\left(\frac{h_o}{h_1}\right)$$

where,

a = area of cross-section of standpipe

L and *A* = length and area of cross-section of the soil sample

Planning and organization:

The tools and accessories needed for the test are:

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

12. Trimming knife etc.

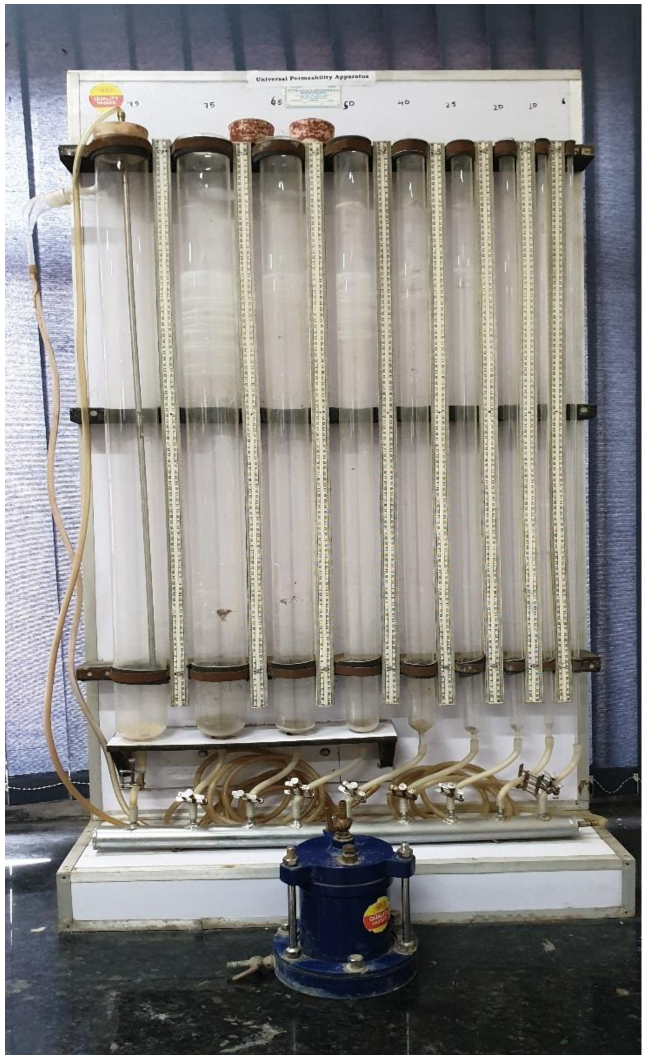

Figure1: Experimental setup for falling head permeability test

Knowledge of equipment:

1. The permeameter is made of non-corrodible material with a capacity of 1000 ml, with an internal diameter of 100±0.1 mm and effective height of 127.3± 0.1 mm.
2. The mould has a detachable base plate and a removable exterior collar.
3. The compacting equipment has a circular face with 50 mm diameter and a length of 310 mm with a weight of 2.6 kg.
4. The drainage base is a porous disc, 12 mm thick with a permeability 10 times that of soil.
5. The drainage cap is also a porous disc of 12 mm thickness with an inlet/outlet fitting.
6. The container tank has an overflow valve. There is also a graduated jar to collect discharge.

7. The stand pipe arrangements are done on a board with 2 or 3 glass pipes of different diameters.

Preparation of the specimen:

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

A. Undisturbed soil specimen:

It is prepared as follows:

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

B. Disturbed specimen:

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

(a) Preparation of statically compacted (disturbed) specimen.

1. Take 800 to 1000 g of representative soil and mix with water to O.M.C determined by I.S Light Compaction test. Then leave the mix for 24 hours in an airtight container.
2. Find weight ‘W’ of soil mix for the given volume of the mould and hence find the dry density.

3. Now, assemble the permeameter for static compaction. Attach the 3 cm collar to the bottom end of 0.3 litre mould and the 2 cm collar to the top end. Support the mould assembly over 2.5 cm end plug with 2.5 cm collar resting on the split collar kept around the 2.5 cm end plug. The inside of the 0.3 litre mould is lightly greased.
4. Put the weighed soil into the mould. Insert the top 3 cm end plug into the top collar, tamping the soil with hand.
5. Keep now the entire assembly on a compressive machine and remove the split collar. Apply the compressive force till the flange of both end plugs touch the corresponding collars. Maintain this load for 1 minute and then release it.
6. Then, remove the top 3 cm plug and collar. Place a filter paper on fine wire mesh on the top of the specimen and fix the perforated base plate.
7. Turn the mould assembly upside down and remove the 2.5 cm end plug and collar. Place the top perforated plate on the top of the soil specimen and fix the top cap on it, after inserting the seating gasket.
8. Now the specimen is ready for test.

(B) Preparation of dynamically compacted disturbed sample:

1. Take 800 to 1000 g of representative soil and mix it with water to get the optimum moisture content (desired density). Leave the mix in airtight container for 24 hours.
2. Assemble the permeameter for dynamic compaction. Grease the inside of the mould and place it upside down on the dynamic compaction base. Weigh the assembly correct to 0.1 g (W_1). Put the 3 cm collar to the other end.
3. Now, compact the wet soil in 2 layers with 15 blows to each layer with a 2.5 kg dynamic tool. Remove the collar and then trim off the excess. Weigh the mould assembly with the soil (W_2).
4. Place the filter paper or fine wire mesh on the top of the soil specimen and fix the perforated base plate on it.
5. Turn the assembly upside down and remove the compaction plate. Insert the sealing gasket and place the top perforated plate on the top of soil specimen and fix the top cap.
6. Now, the specimen is ready for test.

Experimental procedure:

1. Prepare the soil specimen as specified.
2. Saturate it. De-aired water is preferred.
3. Assemble the permeameter in the bottom tank and fill the tank with water.
4. Inlet nozzle of the mould is connected to the stand pipe. Allow some water to flow until steady flow is obtained.
5. Note down the time interval 't' for a fall of head in the stand pipe 'h'.
6. Repeat step 5 three times to determine 't' for the same head.
7. Find 'a' by collecting 'q' for the stand pipe. weigh it correct to 1 g and find 'a' from q/h=a.

Therefore, the coefficient of permeability is ________ cm/s

Observation Table:

		1st set	**2nd set**	**3rd set**
Area of stand pipe	a (cm^2)			
Cross sectional area of soil specimen	A (cm^2)			
Length of soil specimen	L (cm)			
Initial reading of stand pipe	h_0 (cm)			
Final reading of stand pipe	h_1 (cm)			
Time	t (sec)			
Test temperature	T (^oC)			
Coefficient of permeability at T	k_T (cm/sec)			
Coefficient of permeability at 27^o C	k_{27} (cm/sec)			

General remarks:

1. During test there should be no volume change in the soil, there should be no compressible air present in the voids of soil i.e. soil should be completely saturated. The flow should be laminar and in a steady state condition.
2. Coefficient of permeability is used to assess drainage characteristics of soil, to predict rate of settlement founded on soil bed etc.

Questionnaire:

1. Is there any effect of capillarity on the reading of stand pipe?
2. What is the type of flow inside the soil sample?

EXPERIMENT - 5

CONSOLIDATION TEST

Objective:

To determine the settlements due to primary consolidation of soil by conducting one dimensional test

Standards:

1. Indian Standards : IS: 2720 (Part-15)
2. ASTM: D-2435
3. AASHTO: T-216

Need and scope:

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

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

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

Planning and organization:

1. Consolidometer consisting essentially of
    a) A ring of diameter 60mm and height 20mm
    b) Two porous plates or stones of silicon carbide, aluminum oxide or porous metal.
    c) Guide ring.
    d) Outer ring.
    e) Water jacket with base.
    f) Pressure pad.
    g) Rubber basket.

2. Loading device consisting of frame, lever system, loading yoke dial gauge fixing device and weights.
3. Dial gauge to read to an accuracy of at least 0.01mm.
4. Thermostatically controlled oven.
5. Stopwatch to read seconds.
6. Sample extractor.
7. Miscellaneous items like balance, soil trimming tools, spatula, filter papers, sample containers.

Figure 1: Consolidation test setup

Principle involved:

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

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

1. **Undisturbed sample:**

   From the sample tube, eject the sample into the consolidation ring. The sample should project about one cm from outer ring. Trim the sample smooth and flush with top and bottom of the ring by using a knife. Clean the ring from outside and keep it ready from weighing.

2. **Remoulded sample :**

a. Choose the density and water content at which sample has to be compacted from the moisture density relationship.
b. Calculate the quantity of soil and water required to mix and compact.
c. Compact the specimen in compaction mould in three layers using the standard rammers.
d. Eject the specimen from the mould using the sample extractor.

Procedure:

1. Saturate two porous stones either by boiling in distilled water about 15 minute or by keeping them submerged in the distilled water for 4 to 8 hrs. Wipe away excess water. Fittings of the consolidometer, which is to be enclosed.
2. Assemble the consolidometer with the soil specimen and porous stones at top and bottom of specimen, providing a filter paper between the soil specimen and porous stone. Position the pressure pad centrally on the top porous stone.

3. Mount the mould assembly on the loading frame, and center it such that the load applied is axial.
4. Position the dial gauge to measure the vertical compression of the specimen. The dial gauge holder should be set so that the dial gauge is in the begging of its releases run, allowing sufficient margin for the swelling of the soil, if any.
5. Connect the mould assembly to the water reservoir and the sample is allowed to saturate. The level of the water in the reservoir should be at about the same level as the soil specimen.
6. Apply an initial load to the assembly. The magnitude of this load should be chosen by trial, such that there is no swelling. It should be not less than 50 g/cm^2 for ordinary soils & 25 g/cm^2 for very soft soils. The load should be allowed to stand until there is no change in dial gauge readings for two consecutive hours or for a maximum of 24 hours.
7. Note the final dial reading under the initial load. Apply first load of intensity 0.1 kgf/cm^2 start the stopwatch simultaneously. Record the dial gauge readings at various time intervals. The dial gauge readings are taken until 90% consolidation is reached. Primary consolidation is gradually reached within 24 hrs.
8. At the end of the period, specified above take the dial reading and time reading. Double the load intensity and take the dial readings at various time intervals. Repeat this procedure for successive load increments. The usual loading intensity are as follows :
   0.1, 0.2, 0.5, 1, 2, 4, 8 kgf/cm^2.
9. After the last loading is completed, reduce the load to ¼ of the value of the last load and allow it to stand for 24 hrs. Reduce the load further in steps of ¼ the previous intensity till an intensity of 0.1 kg/cm^2 is reached. Take the final reading of the dial gauge.
10. Reduce the load to the initial load, keep it for 24 hrs and note the final readings of the dial gauge.
11. Quickly dismantle the specimen assembly and remove the excess water on the soil specimen in oven, note the dry weight of it.

Observation and reading:

Name of the project

Borehole no.: 1

Depth of the sample :

Description of soil :

Empty weight of ring :

Area of ring :

Diameter of ring :

Volume of ring :

Height of ring :

Specific gravity of soil sample No:

Dial Gauge = mm (least count)

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

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

Observation Sheet for Consolidation Test : Pressure and voids ratio:

Applied pressure	Final dial reading	Dial change	Specimen height	Height solids	Height of voids	Void ratio
0						
0.1						
0.2						
0.5						
1.0						
2.0						
4.0						
8.0						
4.0						
2.0						
1.0						
0.5						
0.2						
0.1						

Calculations:

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

$$H_s = \frac{W_s}{(G \times A)}$$

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

$$e = \frac{(H - H_S)}{H_S}$$

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

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

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

In the log fitting method, a plot is made between dial readings and logarithmic of time, the time corresponding to 50% consolidation is determined.

In the square root fitting method, a plot is made between dial readings and square root of time and the time corresponding to 90% consolidation is determined.

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

5. Coefficient of compressibility: It is calculated as follows

$$a_v = \frac{0.435 \times C_c}{\text{Average pressure for the increment}}$$

where,

C_c = Coefficient of compressibility

6. **Coefficient of permeability:** It is calculated as follows

$$k = \frac{c_v \times m_v \times \gamma_w}{(1+e)}$$

Graphs:

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

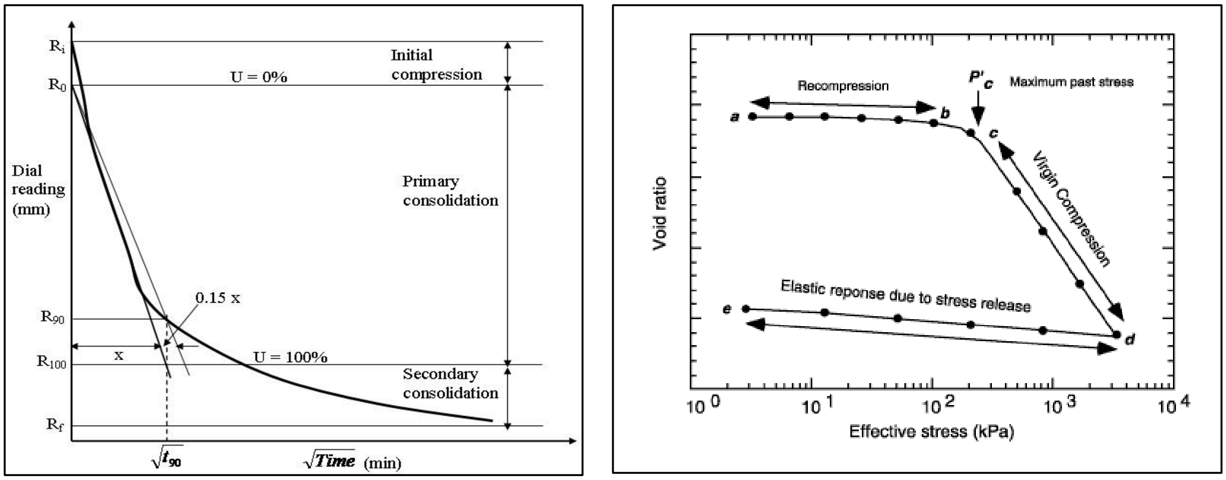

Figure 2: Sample graphs

General remarks:

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

Questionnaire:

1. What will happen if the sample height or diameter is changed in the oedometer test?
2. The soil with higher over consolidation ratio is good or bad for an engineering back fill?
3. For what type of soil, oedometer tests is preferred to determine the coefficient of permeability?