BABU BANARASI DAS
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Vision of the Institute	Mission of the Institute
"To become a leading institute of providing professionally competent and socially responsive technocrats with high moral values."	⇨ To create an eco-system for the dissemination of technical knowledge, to achieve academic excellence. ⇨ To develop technocrats with creative skills and leadership qualities, to solve local and global challenges. ⇨ To impart human values and ethics in students, to make them socially and Eco-friendly responsible.

LAB MANUAL
OF
GEOTECHNICAL ENGG.

[BCE 552]

B.TECH, 3rd.Year, 5th.Semester -

Dr. A.P.J. Abdul Kalam Tech. University
Uttar Pradesh

2025-26

Department of Civil Engineering

Faculty Name: Mr. Ashish

Verma

(Assistant Professor)

Approved by: (Head of the Department)

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MANUAL CONTENTS

This manual is intended for the 3rd year students of Civil Engineering in the subject of Geotechnical Engineering Lab. This manual typically contains practical/lab sessions related to Geotechnical Engineering, covering various aspects to enhance understanding of soil behavior, foundation systems, and field applications.

Students are advised to thoroughly go through this manual rather than only the topics mentioned in the syllabus, as practical exposure is essential for understanding and visualizing the theoretical concepts related to soil mechanics, site investigation, and foundation engineering.

Good luck, and we wish you an engaging and insightful laboratory experience.

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PREFACE

This practical manual will be helpful for students of Civil Engineering for understanding the course from the point of view of applied aspects. Though all the efforts hav been made to make this manual error free, yet some errors might have crept in inadvertently. Suggestions from the readers for the improvement of the manual are most welcomed.

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VISION OF THE DEPARTMENT

To impart academic excellence in civil engineering field with emphasis on holistic development of the professional, while inculcating ethics, socially and professionally responsive technocrats.

MISSION OF THE DEPARTMENT

M1: To provide a comprehensive platform for academic expertise and proficiency
M2: To develop civil engineering professionals with creative skills and leadership qualities in order to face regional and global challenges.
M3: To develop ethics in students in order to promote socially responsible environmental awareness with innovative thinking.

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Program Educational Objectives(PEOs) of Department

PEO 1: To enhance skill and expertise in field of civil engineering with aim of boosting employability and entrepreneurship.
PEO 2: To develop multidisciplinary approach of civil engineering system with lifelong learning solutions.
PEO 3: To develop the potential to pursue higher education and research in field of civil engineering

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Program Outcomes:(PO)

Graduates will be able to achieve

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PO 1.Engineering knowledge: Apply the knowledge of mathematics, science, engineering Fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO 2.Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO 3.Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO 4.Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO 5.Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO 6.The engineer and society: Apply reasoning informed by the contextual knowledge to assess `societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO 7.Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO 8.Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO 9.Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO 10.Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear

PO 11.Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO 12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change

Program Specific Outcomes(PSOs) of the Department

PSO 1: Graduates shall be able to apply critical thinking in research ,design ,analysis and implementation of civil engineering problems

PSO 2: Graduates shall be able to inculcate the idea of sustainability in engineering solution to meet real world challenges.

Course Evaluation Scheme

Sr No	Subject Code	Subject Name	Periods			Evauation Scheme				Total	Credit
						Sessional Assessment			PE		
			L	T	P	CT	TA	PS			
1.	BCE552	Geotechnical Engineering Lab	0	0	2	-	-	50	50	100	1

Course Objectives:

The teacher will explain:

1.	Calculate and explain the water content and specific gravity of soil.
2.	Measure and analyze the in-situ density and relative density of soil.
3.	Analyze and evaluate the grain size distribution and consistency limits of soil.
4.	Determine and evaluate the dry density of soil through compaction processes and assess the permeability of soil.
5.	Perform and evaluate shear strength tests (direct shear and triaxial) to assess soil stability under various conditions.

Pre- requisite: Fundamentals of Geotechnical engineering.

Course Outcomes (COs)

Course Outcomes: The students should be able to:		**Bloom's Level**
CO1	Calculate and explain the water content and specific gravity of soil.	L3
CO2	Measure and analyze the in-situ density and relative density of soil.	L4
CO3	Analyze and evaluate the grain size distribution and consistency limits of soil.	L5
CO4	Determine and evaluate the dry density of soil through compaction processes and assess the permeability of soil.	L5
CO5	Perform and evaluate shear strength tests (direct shear and triaxial) to assess soil stability under various conditions.	L5

CO-PO-PSO Mapping

COs \ POs	**PO 1**	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO 8**	**PO 9**	**PO1 0**	**PO1 1**	**PO1 2**	**PSO 1**	**PSO 2**
CO 1	3	2	1	2	2	-	-	-	-	-	-	1	2	1
CO 2	3	3	1	3	2	-	-	-	1	-	-	1	3	1
CO 3	3	3	2	3	2	-	-	-	1	-	-	1	3	2
CO 4	3	3	2	3	2	-	-	-	1	-	-	1	3	2
CO 5	3	3	2	3	2	-	-	-	2	-	-	1	3	2

The extent of mapping is as follows: 1 for low, 2 for moderate, 3 for high &"-" for No correlation between CO & PO.

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List of Experiments

S. No.	Experiment
1	Determination of water content of a given moist soil sample by (i) oven drying method, (ii) pycnometer method.
2	Determination of specific gravity of a given soil sample by (i) density bottle, (ii) pycnometer method.
3	Determination of in situ dry density of soil mass by (i) core-cutter method, (ii) sand replacement method.
4	Determination of relative density of a given soil sample.
5	Determination of complete grain size distribution of a given soil sample by sieve analysis and sedimentation (hydrometer) analysis.
6	Determination of consistency limits (liquid, plastic and shrinkage limits) of the soil sample used in experiment no. 5 (grain-size analysis).
7	Determination of shear strength of soil by Direct shear test.
8	Determination of compaction characteristics (OMC & MDD) of a given soil sample.
9	Determination of permeability of a remoulded soil sample by constant head &/or falling head method.
10	Determination of consolidation characteristics of a remoulded soil sample by an odometer test.
11	Determination of shear strength characteristics of a given soil sample by U/U test from Triaxial Compression Machine.
12	Retrieving soil samples and conducting SPT tests by advancing boreholes through hand-held auger.

Beyond Syllabus:

S.No.	Experiment
1	Computation of CBR value

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S.No.	Name of the Experiment	CO	BTL	Lab Conduction Date	Remark/ Grade/ Marks	Faculty Signature with Date

Softwares & Hardwares Required:

Hardware:

- **Peripherals/Lab Equipment:**
  - Oven, weighing balance, pycnometer
  - Sieve shaker, hydrometer setup
  - Core cutter, sand replacement apparatus
  - Direct shear test apparatus, triaxial testing machine .
  - Compaction test setup, permeability apparatus, consolidation (oedometer) apparatus.
  - Cassagrande apparatus.

- Follow all lab safety instructions and wear proper PPE (lab coat, gloves, safety shoes if required).
- Read the experiment procedure carefully before starting.
- Ensure all equipment is clean, calibrated, and in working condition before use.
- Handle soil samples carefully to avoid contamination or moisture loss.
- Take accurate measurements and record observations neatly in the lab record.
- Maintain proper labeling of samples and test data.
- Use equipment like oven, sieve shaker, and testing machines as per guidelines.
- Work in coordination with your lab partners/team members.
- Switch off equipment after use and maintain cleanliness of the workspace.
- Report any faulty equipment or unusual results to the lab instructor immediately.

Don'ts

- Do not operate any equipment without proper instruction or supervision.
- Do not disturb soil samples during preparation or testing.
- Avoid guessing or fabricating readings—always use actual observations.
- Do not overload or misuse testing machines (e.g., triaxial, shear apparatus).
- Do not leave equipment running unattended.
- Avoid spilling water or soil near electrical equipment.
- Do not mix up different soil samples or test results.
- Do not ignore safety precautions, especially with hot ovens and heavy equipment.
- Avoid careless handling of delicate instruments like balances and glassware.
- Do not leave the lab untidy after completing experiments.

EXPERIMENT NO. 1

Object:

To determine the water content of a given moist soil sample by:
(i) Oven Drying Method
(ii) Pycnometer Method

Theory:

Water content (w) is defined as the ratio of the weight of water present in the soil to the weight of dry soil, expressed as a percentage.

$w = (W_w / W_s) \times 100$

Where:
Ww = Weight of water
Ws = Weight of dry soil

Water content influences soil strength, compressibility, and permeability.

Apparatus:

Oven Drying Method:
- Oven (105–110°C)
- Weighing balance
- Moisture containers
- Desiccator

Pycnometer Method:
- Pycnometer
- Weighing balance
- Water
- Dry soil sample

Procedure:

Oven Drying Method:
1. Weigh empty container (W1)
2. Add moist soil and weigh (W2)
3. Dry in oven for 24 hrs
4. Cool in desiccator
5. Weigh dry soil (W3)

Pycnometer Method:
1. Take dry soil (Ws)
2. Weigh pycnometer + soil (W1)
3. Add water and remove air
4. Weigh (W2)
5. Weigh pycnometer with water only (W3)

Observations:

Oven Method:
W1 = _______
W2 = _______
W3 = _______

Pycnometer Method:
Ws = _______
W1 = _______
W2 = _______
W3 = _______

Calculations:

Oven Method:
w = ((W2 - W3) / (W3 - W1)) × 100

Pycnometer Method:
w = [(W2 - W1) - (W3 - Ws)] / Ws × 100

Result:

Water Content:
Oven Method = _______%
Pycnometer Method = ______%

Precautions:

1. Maintain oven temperature at 105–110°C
2. Avoid loss of soil
3. Ensure complete drying
4. Remove air bubbles in pycnometer

Experiment 2

Objective-

Determination of specific gravity of a given soil sample by (i) density bottle, (ii) pycnometer method.

THEORY:

The specific gravity of a soil is the ratio of the mass of a given volume of the soil solids at a stated temperature to the mass of an equal volume of de-aired water at the same temperature.

NEED AND SCOPE:

The specific gravity is used in the computations of the laboratory tests such as hydrometer test and oedometer test (1-D consolidation test). It can be used in relating the weight of soil to its volume and in calculation of phase relationship, i.e., the relative volume of solids to water and air in a given volume of soil. The value of specific gravity can give rough idea of presence of organic matters or any metal present in soil. Lower specific gravity values around 2 or below indicates the presence of high organic content in soil. Higher specific gravity values in range of 2.75-2.85 indicates the presence of iron or any other metal in the soil.

APPARATUS REQUIRED:

1. Specific gravity bottles of glass with 50 ml/100 ml capacity with a fitted glass stopper
2. Glass-stopper with small hole through center to permit emission of air and water
3. Balance - 0.001 g sensitivity
4. Oven - capable of 105^0C ± 1^0C
5. Thermometer
6. Funnel
7. Sand bath for heating

PROCEDURE:

1. Take the weight of the empty specific gravity bottle, 'W1'.

2. Transfer the oven dried soil sample to the specific gravity bottle (about *10 gm when 50 cc stoppered bottle is used and about 20gm when 100cc stoppered bottle* is used).
3. Take the weight of bottle filled with soil, 'W2'.
4. Add water to fill the bottle about three fourth of its volume.
5. Remove the entrapped air either by subjecting the contents to a partial vacuum or by boiling gently in a sand-bath till the air bubbles cease to appear while occasionally rolling the bottle to assist in removal of air
6. Then cool to room temperature and fill the bottle with water up to the mark and clean and dry the outside surface with a clean, dry cloth and note down the temperature.
7. Determine the weight of the bottle with water and soil, 'W3'.
8. Then remove the soil and water from the bottle and clean it.
9. Fill the bottle completely with water up to the mark and take the weight of bottle filled with water, 'W4'.
10. From data obtained determine specific gravity of the soil.

11. TABULATION AND RESULTS:

Test no.	1	2	3
Temperature ºc			
Bottle no.			
Weight of specific gravity bottle (W1) (g)			
Weight of specific gravity bottle + soil (W2) (g)			
Weight of specific gravity bottle + soil + water (W3) (g)			
Weight of specific gravity bottle + water (W4) (g)			
Specific gravity of soil at temperature ºc G's = $\frac{(W2 - W1)}{(W4 - W1) - (W3 - W2)}$			

Temperature correction, k27			
Specific gravity of soil at temperature, 27 ºc $G_s = K_{27} \times G'_s$ (see K27 from Table I)			
Average			

The specific gravity of the given sol is = (No unit)
Determine the type of soil according to your interpretations from

specific gravity of the soil For any temperature T, correction factor

can be given as,

12. K_{27}= □□□□□□□□□ □□□□□□□□ □□ □□□□□ □□ □° □ □□□□□□□□□□□□

13. K 1 4 5 . ______________________________
2 □□□□□□□□□ □□□□□□□□ □□ □□□□□ □□ 27° □ □□□□□□□□□□□□
7
=

=

Correction factors for different temperatures are given in Table I.

Table-I: Correction Factor for Variation in Specific Gravity of water due to Temperature

Temperature °C	K27
15	1.0026
16	1.0024
17	1.0023
18	1.0021
19	1.0019
20	1.0017
21	1.0015
22	1.0013
23	1.0010
24	1.0008
25	1.0005
26	1.0003
27	1
28	0.9997
29	0.9994
30	0.9991
31	0.9988
32	0.9985
33	0.9982
34	0.9979
35	0.9975
36	0.9972
37	0.9968
38	0.9964
39	0.9961
40	0.9957

EXPERIMENT 3

Aim: To determine the mass density of soils by

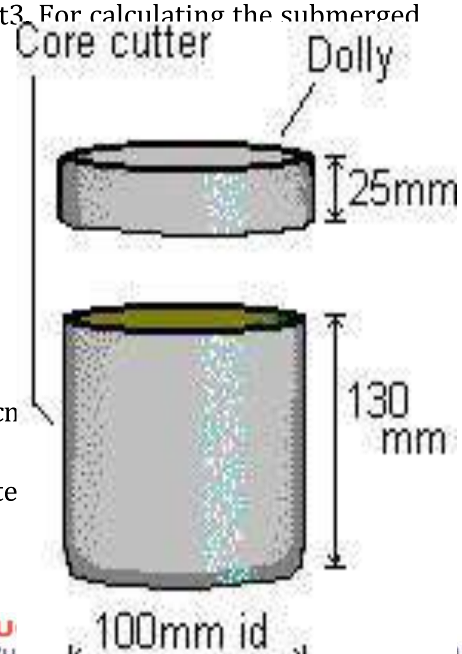
(a) Core cutter method
(b) Sand replacement method

Theory

Density is defined as the mass per unit volume of soil γ= W/V

Where γ= mass density of soil w = total mass of soil
v = total volume of soil

Here mass and volume of soil comprise the whole soil mass. In the above figure, voids may be filled with both water and air or only air or only water, consequently the soil may be wet or dry or saturated. In soil the mass of air is consider negligible and therefore the saturated density is maximum , dry density is minimum and wet density is in between the two if soils are found below water table submerged density is also estimated. The density can be expressed in g/cm3, or t/m3 or kg/m3 or 1b/t3. For calculating the submerged density the density of water is taken as 1 g/c3 = 1 t/m3 Dry density of the soil is calculated by using some equation.



(A) Core cutter method :-

Apparatus

Special

1. Cylindrical core cutter (height = 12.74 cm, dia 10 cm
2. Steel rammer
3. Steel dolly (2.5 cm high and 10 cm internal diamete

General

1. Balance (accuracy 1gm2. Balance (accuracy 0.01g m)
3. Steel rule
4. Spade of pickaxe
5. Straight edge
6. Knife
7. Water content crucibles
8. Desiccator
9. Oven
10. Tongs

Precautions

1. Steel dolly should be placed on the top of the cutter before ramming it dow
2. Core cutter should not be used in gravels and boulders.
3. Before lifting the cutter, soil should be removed round the cutter, to minimize the disturbances.
4. While lifting the cutter, no soil should drop down,
5. During pressing and lifting the cutter care should be taken that some soil is projected at both the ends of the cutter.
6. Values should be reported to second place of decimal

Observations and calculation

1. Ether all observation in table 1.
2. Calculate wet density of soil γt

Internal Diameter of
Cutter (cm) = Height of
Cutter (cm) =
Cross-sectional Area of cutter
(cm2) = Volume of Cutter
(cm3) =
Specific Gravity of soil =

Core Cutter Method

Sr.No.	Determination No.	1	2	3
1	Mass of Core Cutter W1(gm)			
2	Mass of Core + Soil, W2(gm)			
3	Mass of wet soil (W2-W1)			
4	Mass of Crucible(gm)			
5	Mass of Crucible + wet soil (gm)			
6	Mass of Crucible + dry soil (gm)			
7	Mass of Water = (6-7)			

`

Observations and Calculation

1. Enter all the readings in table 2, 3 and 4
2. Bulk density of sand is calculated as shown in table (2.) This density is used in determining the volume of the hole made in the soil.
3. Table 4 show the calculations of wet density, dry density, void ratio and degree of saturation of the soil.
4. Above Equations are used to calculate the dry density, void and degree of saturation

Determination:

01. Container No.
02. Mass of container with lid. W1 (gm)
03. Mass of container with lid + wet soil, W2 (gm)
04. Mass of container with lid + dry soil, W2 (gm)
05. Mass of water, Ww = W2 - W3 (gm)
06. Mass of dry soil, Ws = W3 - W1 (gm)
07. Moisture content, W = [W2 - W3 / W3-W1] x 100, (%)

Calibration of Apparatus Date

1. Volume of Calibrating Container, V (gm)
2 .Mass of Pouring Cylinder+ Sand, W'1(gm) (Before Pouring in the Calibration Cylinder)
3 Mass of Pouring Cylinder +Sand W'2 (gm) (After Pouring In the Calibration Cylinder)
4 Mass of Pouring Cylinder +Sand W'3 (gm) (After Making the sand cone on flat surface)
5 Mass of sand for filling the calibrating cylinder and cone (gm) W'4 = (W'1-W'2)
6 Mass of sand for making the cone only (gm) W'5 = (W'2-W'3)
7 Mass of sand in the calibrating cylinder only (gm) W'6 = (W'4-W'5)
8 Bulk Density of Sand, g_d = W'6 /V (gm/cc)

Sand Replacement Method

1. Mass of Pouring Cylinder+ Sand, W'1(gm) (Before Pouring In the Calibration Cylinder)
2 Mass of Pouring Cylinder +Sand W'2 (gm) (After Pouring In the Calibration Cylinder)
3 Mass of Pouring Cylinder +Sand W'3 (gm) (After Making the sand cone on flat surface)
4 Mass of sand used in the hole and cone (gm) W4 = (W1-W2)
5 Mass of sand in the Cone only (gm) W5 = (W2-W3)
6 Mass of sand in the hole only (gm) W6 = (W4-W5)
7 Volume of Sand, V= W6/ ρ_d
8 Mass of Tray + Excavated Soil, W7 (gm)
9 Mass of Tray Only, W8 (gm)
10 Mass of Excavated Soil, (W= W7-W8) (gm)

Result
1 Wet Density (ρ_b) = (10/7) (gm/cc)
2 Dry Density (ρ_d) = ρ_b / (1+w) (gm/cc)
3 Void Ratio, e = [(Gs ρ_w)/ρ_d]-1
4 Degree of Saturation, S = (w.Gs/e) x 100 (%)

Result:

In-situ density of soil by
1. Core cutter =--------------gm/cc

Experiment 4

Aim: To determine the relative density of cohesion less soil.

Theory: Relative density and percent compaction are commonly used for evaluating the state of compactness of a given soil mass. The engineering properties,such as shear strength, compressibility, and permeability, of a givensoil depends on the level of compaction.

Test Procedure:

(1) Fill the mold with the soil (approximately 0.5 inch to 1 inch above the top of the mold) as loosely as possible by pouring the soil using a scoop or pouring device (funnel). Spiraling motion should be just sufficient to minimize particle segregation.

(2) Trim off the excess soil level with the top by carefully trimming the soil surface with a straightedge.

(3) Determine and record the mass of the mold and soil. Then empty the mold (M1). See Photograph on Page 35.

(4) Again fill the mold with soil (do not use the same soil used in step 1) and level the surface of the soil by using a scoop or pouring device (funnel) in order to minimize the soil segregation. The sides of the mold may be struck a few times using a metal bar or rubber hammer to settle the soil so that the surcharge base-plate can be easily placed into position and there is no surge of air from the mold when vibration is initiated.

(5) Place the surcharge base plate on the surface of the soil and twist it slightly several times so that it is placed firmly and uniformly in contact with the surface of the soil. Remove the surcharge base-plate handle.

(6) Attach the mold to the vibrating table.

(7) Determine the initial dial reading by inserting the dial indicator gauge holder in each of the guide brackets with the dial gage stem in contact with the rim of the mold (at its center) on the both sides of the guide brackets. Obtain six sets of dial indicator readings, three on each side of each guide bracket. The average of these twelve readings is the initial dial gage reading, Ri. Record Ri to the nearest 0.001 in. (0.025 mm). See Photograph on Page 35.

(8) Firmly attach the guide sleeve to the mold and lower the appropriate surcharge weight onto the surcharge base plate.

(9) Vibrate the mold assembly and soil specimen for 8 min.

(10) Determine and record the dial indicator gage readings as in step (7). The average

of these readings is the final dial gage reading.

(11) Remove the surcharge base-plate from the mold and detach the mold from the vibrating table.

(12) Determine and record the mass of the mold and soil (M2)

(13) Empty the mold and determine the weight of the mold.

(14) Determine and record the dimensions of the mold (i.e., diameter and height) in order to calculate the calibrated volume of the mold, Vc. Also, determine the thickness of the surcharge base-plate, Tp **Analysis:**

(1) Calculate the minimum index density (ρ_d min) as follows: $\frac{M_{s1}}{V_C}$

Where, Ms1= mass of tested-dry soil = Mass of mold with soil placed loose – mass of mold Vc= Calibrated volume of the mold

(2) Calculate the maximum index density (ρ_d max) as follows: $= \frac{M_{s2}}{V_C}$

Ms2 = mass of tested-dry soil = Mass of mold with soil after vibration – Mass of mold

V = Volume of tested-dry soil = Vc – (Ac*H)

Where, Ac = the calibrated cross sectional area of the mold H = [Rf −Ri]+Tp

Observation and Calculation

Sample Description:

Mass of empty mold: ___ ______________

Diameter of empty mold: ___ ______________

Height of empty mold: ___ ______________

Mass of mold and soil (M1): ___ ______________

Average initial dial gauge reading (Ri): ___ ______________

Average final dial gauge reading (Rf): ___ ______________

Thickness of surcharge base plate (TP): ___ ______________

Mass of mold and soil (M2): ___ ______________

Result:

Object: Determination of complete grain size distribution of a given soil sample by sedimentation analysis

(1) Take the fine soil from the bottom pan of the sieve set, place it into a beaker, and add 125 mL of the dispersing agent (sodium hexametaphosphate (40 g/L)) solution. Stir the mixture until the soil is thoroughly wet. Let the soil soak for at least ten minutes.

(2) While the soil is soaking, add 125mL of dispersing agent into the control cylinder and fill it with distilled water to the mark. Take the reading at the top of the meniscus formed by the hydrometer stem and the control solution. A reading less than zero is recorded as a negative (-) correction and a reading between zero and sixty is recorded as a positive (+) correction. This reading is called the zero correction. The meniscus correction is the difference between the top of the meniscus and the level of the solution in the control jar (Usually about +1).Shake the control cylinder in such a way that the contents are mixed thoroughly. Insert the hydrometer and thermometer into the control cylinder and note the zero correction and temperature respectively.

(3) Transfer the soil slurry into a mixer by adding more distilled water, if necessary, until mixing cup is at least half full. Then mix the solution for a period of two minutes.

(4) Immediately transfer the soil slurry into the empty sedimentation cylinder. Add distilled water up to the mark.

(5) Cover the open end of the cylinder with a stopper and secure it with the palm of your hand. Then turn the cylinder upside down and back upright for a period of one minute. (The cylinder should be inverted approximately 30 times during the minute.)

(6) Set the cylinder down and record the time. Remove the stopper from the cylinder. After an elapsed time of one minute and forty seconds, very slowly and carefully insert the hydrometer for the first reading.

(**Note:** It should take about ten seconds to insert or remove the hydrometer to minimize any disturbance, and the release of the hydrometer should be made as close to the reading depth as possible to avoid excessive bobbing).

(7) The reading is taken by observing the top of the meniscus formed by the suspension and the hydrometer stem. The hydrometer is removed slowly and placed back into the
Control cylinder. Very gently spin it in control cylinder to remove any particles that may have adhered.

(8) Take hydrometer readings after elapsed time of 2 and 5, 8, 15, 30, 60 minutes and 24 hours

Data Analysis:

Hydrometer Analysis:

(1) Apply meniscus correction to the actual hydrometer reading.

(2) From Table 1, obtain the effective hydrometer depth L in cm (for meniscus corrected reading).

(3) For known Gs of the soil (if not known, assume 2.65 for this lab purpose), obtain the value of K from Table 2.

(4) Calculate the equivalent particle diameter by using the

following formula: D = K x Sq. root Of (L/T)
Where t is in minutes, and D is given in mm.

(5) Determine the temperature correction *CT* from Table 3.

(6) Determine correction factor "*a*" from Table 4 using Gs..

(7) Calculate corrected hydrometer reading as follows:
Rc = RACTUAL - zero correction + CT

(8) Calculate percent finer as follows:
P = (Rc ×a ×100)/ WS

Where, WS is the weight of the soil sample in grams.

(9) Adjusted percent fines as follows: = P xF200/100.
F200 = % finer of #200 sieve as a percent

(10) Plot the grain size curve D versus the adjusted percent finer on the semi logarithmic sheet.

Experiment 5

Object: To determine the liquid limit and plastic limit of the soil.

Theory: Liquid limit is the water content at which soil passes from zero strength to an Infinitesimal strength, hence the true value of liquid limit cannot be determined. For determination purpose liquid limit is that water content at which a part of soil, cut by a groove of standard dimensions, will flow together for a distance of 1.25cm under an impact of 25 blows in a standard liquid limit apparatus. The soil at the water content liquid limit apparatus. The soil at the water content has some strength which is about 0.17 N/cm2 (17.6 gm/cm2). At this water content soil just passes from liquid state to plastic state. The moisture content at which soil has the smallest plasticity is called as the plastic limit. Just after the plastic limit the soil displays the properties of a semi- solid. Change in state at these limits.

Apparatus

Special

1. Cassagrande's liquid limit device
2. A.S.T.M. and B.S. grooving tool (Cassagrande's type)
3. Glass plate 20X15cm
4. 425 micron I.S. sieve
5. 3 mm diameter rod

General

Spatula, Basin (300c.c. capacity), Balance (0.01 gm sensitivity), Water content tins or crucibles, Drying oven, Distilled water, Measuring cylinder, Desiccator,

Procedure

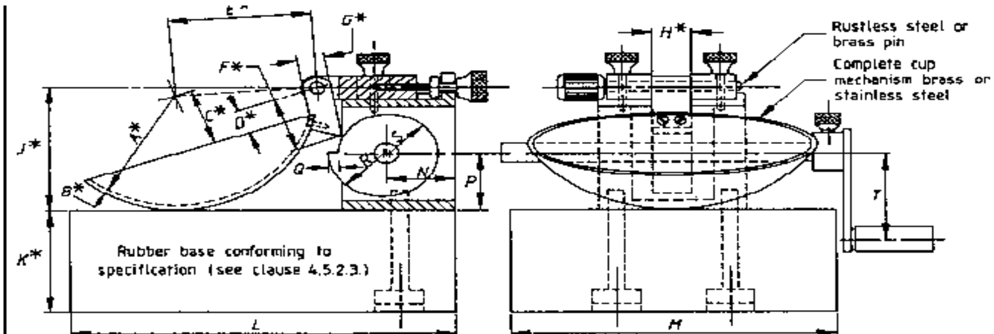
(a) Liquid Limit

1. Adjust the cup of the liquid limit apparatus with the help of grooving tool gauge & the adjustment plate to give a drop of exactly 1 cm on the point of contact on base.
2. Take about 120gm of an air dried sample passing 425 µ sieves.
3. Mix it thoroughly with some distilled water to from a uniform paste.
4. Place a portion of the paste in the cup of the liquid limit device, smooth the surface with spatula to a maximum depth of 1cm. Draw the grooving tool through the sample along the symmetrical axis of the cup, holding the tool perpendicular to the cup.
5. Turn the handle at a rate of 2 revolutions per second and count blows until two

parts of the soil sample come into contact at the bottom of the soil sample come into contact at the bottom of the groove along a distance of 10mm.

6. Transfer about 15gm of the soil forming the edges of the groove that flowed together to a water content tin and determine the water content by oven drying.
7. Transfer the remaining soil in the cup to the main soil sample in the basin and mix thoroughly after adding a small amount of water

8. Repeat steps 4, 5 and 6. Obtain at least four sets of readings in the range of 10 to 40 blows.



NOTE. This design has been found satisfactory, but alternative designs may be used provided that the essential requirements are fulfilled.

Figure 2. Casagrande liquid limit apparatus

* See 4.1.3.1.1 of BS 1377 : Part 1 : 1990.

Observation and Calculations

(a) Liquid Limit (L.L. or WL.L)

1. Use table 1 for recording the number of blows and calculating the moisture contents.
2. Use semi log graph paper, take number of blows on semi log scale (x-axis) and water contents on ordinary scale (y-axis). Plot all the points and draw a straight line (flow curve) passing through these points.
3. Read the water content at 25 blows which is the value of liquid limit

Sr. No.	Determination No.	1	2	3
1	No. of blows			
2	Container No.			
3	Mass of container + wet soil (gm)			
4	Mass of container + dry soil ,(gm)			
5	Mass of water (3)-(4) (gm)			
6	Mass of container, (gm)			
7	Mass of dry soil (4)-(6)			

8	Moisture content (5)/ (7) x 100, (%)			

Liquid limit:

(b) Plastic Limit

1. Take about 30gm of air dried sample passing 425 micron sieve.
2. Mix thoroughly with distilled water on the glass plate until it is plastic enough to be shaped into a small ball.
3. Take about 10gm of the plastic soil mass and roll it between the hand and the glass plate to from the soil mass into a thread. If diameter of thread becomes less than 3mm without cracks, it shows that water added in the soil is more than its plastic limit; hence the soil is kneaded further and rolled into thread again.
4. Repeat this rolling and remolding process until the thread starts just crumpling at a diameter of 3mm.
5. If crumpling starts before 3mm diameter thread in step 3, it show the water added in step 2 is less than the plastic limit of the soil, hence some more water should be added and mixed to a uniform mass and rolled again, until the thread starts just crumbling at a diameter of 3mm.
6. Collect the pieces of crumbled soil thread at 3mm diameter in an air tight container and determine moisture content.
7. Repeat this procedure twice more with fresh samples of 10gm each.

Precaution

1. Use distilled water in order to minimize the possibility of iron exchange between the soil and any impurities in the water.
2. Soil used for liquid and plastic limit determinations should not be oven dried prior to testing.
3. In liquid limit test, the groove should be closed by a flow of the soil and not by slippage between soil and the cup.
4. After mixing distilled water to the soil sample, sufficient time should be given to permeate the water throughout the soil mass.
5. Wet soil taken in the container for moisture content determination should not be left open in the air even for some time, the containers with soil samples should either be placed in desiccators or immediately be weighed,

6. For each test, cup and grooving tool, should be clean.

Classification of soil

1. Calculating plasticity index (P.I. or Ip) Ip = **WL.L - WP.L.**
2. Use plasticity chart for classification of given soil. Or

Calculate the plasticity the plasticity index of 'A' line

(P.I.) A = **0.73 (WL.L-- 20)**

Where WL.L is in percentage If P.I. > (P.I.) A the soil is clay If P.I. < (P.I.) A the soil is silt

L.L. = 0-35 low Compressibility

35-50 medium Compressibility

> 50 High Compressibility

Toughness Index =Plasticity Index/Flow Index.

Flow index=w1---w2 /Log10 (N1/N2) w1 = water content in % at N1 Blows w2 = water content in % at N2 Blows

Observation and Calculations

Sr. No.	Determination No.	1	2	3
1	Container No.			
2	Mass of container + wet soil (gm)			

3	Mass of container + dry soil ,(gm)			
4	Mass of water, (2)-(3) (gm			
5	Mass of container (gm)			
6	Mass of dry soil (3)-(5) ,(gm)			
7	Plastic Limit (4)/ (6) x 100,(%)			

Average plastic limit:

RESULT

Liquid limit L.L (%) =
Plastic limit P.L (%) =
Plasticity Index P.I =
Classification =
Flow Index IF =
Toughness Index IT =

Experiment 6

DIRECT SHEAR TEST

Aim: To determine shear strength parameters of the given soil sample at known density and moisture content by direct shear test.

Theory

Shear strength of a soil has its maximum resistance to shearing stress at failure on the failure plane.
Shear strength is composed of

(i) Internal friction which is the resistance due to friction between individual particles at their contact points and interlocking of particles.

(ii) Cohesion which is resistance due to inter particles forces which tend to hold the particles together in a soil mass. Coulomb has represented the shear strength of soil by the equation:

$$\tau = c + \sigma \tan\varphi$$

Where t = shear strength of soil = shear stress at failure C = Cohesion
sn = Total normal stress on the failure plane f = Angle of internal (shearing) friction

The parameters c and f are not constant for type of soil but depend on it degree of saturation and the condition of laboratory testing. There are three types of laboratory test.

(a) Undrained Test –water is not allowed to drain out during the entire test, hence there is nodissipation of pressure.

(b) Consolidate under the initially applied normal stress only, hence drainage is permitted. But no drainage is allowed during shear.

(c) Drained Test— Drainage is slowed throughout the test during the application of normal and shear stresses, No pore pressure is set-up at any stage of the test. Coulomb's shear strength equation has been modified on the concept of pore pressure development. Modified equation is

$$\tau' = c' + \sigma \tan\varphi$$

Where c' = effective

cohesion s' =
effective normal
stress
u = pore pressure
s = total normal stress
f = effective angle of shearing resistance

Apparatus

Special

1. Shear box (Non- corrosive meal, size 60 mm X 60mm X 50mm)
2. Container for shear box.
3. Grid plates (two plain and two perforated, depth of serrations 1.5mm)
4. Base plate (non-corrosive metal with cross-grooves on its top face)
5. Porous stone (two, 6 mm thick).
6. Loading pad.
7. Loading frame.
8. Loading yoke.
9. Proving ring with dial gauge (capacity 1.5-2.0M accuracy of dial gauge 0.002mm).
10. Other accessories (two fixing screws, two spacing screws)
11. Static/ dynamic compaction device (for remolded samples)

General:

1. Sample trimmer
2. Stop clock
3. Balance (capacity 1kg sensitivity 0.1 gm capacity 160 gm sensitivity 0.01)
4. Spatula and straight edge.
5. Drying crucibles.
6. Drying oven
7. Scale.
8. Desired water (for saturated samples).
9. Dial gauges (two, sensitivity 0.01 mm)
10. Weights
11. Oven

Procedure

1. Prepare a soil specimen of size 6 cm X 6cm X 2 cm either from undisturbed soil sample or from compacted and remoulded sample
2. Fix the upper part of the box to the lower part by the fixing screws. Attach the base plate to the lower part.
3. Place a porous stone in the box.
4. For undrained test, place the grid on the stone, keeping the serrations of the grid at right angle to the direction of shear. For consolidated undrained and drained tests use
5. the perforated grid in place of plain grid.
6. Weigh the box with base plate, porous stone and grid
7. Transfer the soil specimen prepared in step in the box.
8. Weigh the box with soil specimen
9. Place the upper grid, porous stone and loading pad in the order on soil specimen.
10. Place the box inside the container and mount it on loading frame.
11. Bring the upper half of the box in contact with proving ring assembly. Contact is observed with proving ring assembly. Contact is observed by a slight movement of proving ring dial gauge.
12. Fill the container with if soil is to be saturated.
13. Mount the loading yoke on the ball placed on the loading pad.
14. Mount one dial gauge on the yoke to record the vertical movement and other dial gauge on the container to record the shear movement.
15. Put the weights on the loading yoke to apply the normal stress of intensity 2.5N/cm2 .Add the weight of yoke also in estimating the normal stress intensity.
16. For consolidated undrained fully under this normal load. This step is avoided for undrained test.
17. Remove the fixing screws from the box and raise slightly the upper half box with the help of spacing screws. Remove the spacing screws also.
18. Adjust all the three dial gauges to read zero.
19. Shear load is applied at a constant rate of strain
20. Record readings of proving ring dial gauge and vertical and shear movement dial gauges at every half minute.
21. Continue the test until the specimen fails
22. Repeat the test on identical specimen under increasing normal stress 0.5,1,2 and 4 kg/cm2

23. Determine the moisture contents of the specimen before and after the test.

Precautions

1 Before starting the test upper half of the box should be brought in contact of the proving ring assembly

2. Before subjecting the specimen to shear, the fixing screws should be taken out.
3. Spacing screws should also be removed before shearing the specimen.
4. The vertical stress on the sample should remain uniform, vertical and constant during the test.
5. The rate of strain should be constant throughout the test.
6. The shearing strain and stress should be applied in the same plane as the dividing plans of the two part of the box.
7. No vibrations should be transmitted to the specimen during the test.
8. For drained test, the porous stones should be deaired and saturated boiling.
9. Do not forget to add the self weight of the loading yoke in the vertical loads
10. Do not mix with each other the least counts and readings of the three dial gauges.

Observation and Calculation

1. Calculate the normal stress by dividing the total normal load with the area of the shear box. Normal stress,
2. Calculate the normal displacement by multiplying the normal dia gauge divisions with the least count of that dial gauge.
3. Calculate the shear displacements by multiplying shear dial gauge division with the least count of the dial gauge
4. Calculate the shear strains by dividing the shear displacement with the length of the specimen.
5. Calculate the shear force by multiplying the proving ring dial gauge division with the proving ring constant.
6. Calculate the shear stress by dividing the shear force with the shear area (equal to area of shear box.)
7. Use sheet 3 [graph paper] to draw the shear stress-strain curves, taken shear strain on X-axis, corresponding to each normal stress.
8. Read the maximum value of shear stress if failure has occurred, otherwise read the shear stress at 20% strain which is defined as failure shear stress.
9. Use sheet 4 [graph paper] to plot the normal stress on X-axis and corresponding

shear stress at failure on Y-axis. Join the points by smooth curve. This is defined as the shear strength envelope.

10. Read the slope of the line, which is defined as the angle of shearing resistance and the intercept of the line with Y axis the cohesion of the soil.

Soil Sample No

(i) Size of box,(cm)=

(ii) Thickness of sample, cm =

(iii) Area of box, (cm) =

(iv) Volume of the sample (cm^3) =

Eperiment 7

Aim:

(i) To determine the optimum moisture content and maximum dry density of a soil by proctor test.
(ii) To plot the cure of zero air void.

Theory:

Compaction is the process of densification of soil mass by reducing air voids. This process should not be confused with consolidation which is also a process be confused with consolidation which is also a process of densification of soil mass but continuously acting static load over a long period. The degree of compaction of a soil is m easured in terms of its dry density the degree of compaction mainly depends upon its moisture content, compaction energy and type of soil. For a given compaction mainly depends upon soil. For a given compaction energy every soil attains the maximum dry density at a particular water content. In the dry side, water acts as a lubricant and helps in the closer packing of soil grains. In the wet side, water starts to occupy the space of soil grains and hinders in the closer packing of grains.

Apparatus

Special

1. Cylindrical mould (capacity 1000 cc, internal dia 100 mm. effective height 127.3 mm) Cylindrical mould (capacity 2250cc, internal dia 150 mm. effective height 127.30m.m)
2. Rammer for light compaction (face diameter 50 mm mass of 2.6 kg free drop 310 mm) or Rammer for heavy compaction (face diameter 50 mm mass of 4.89 kg free drop 450 mm) .
3. Mould accessories (detachable base plate removable collar)
4. I.S. serves
(20 mm,
4.75mm)

General

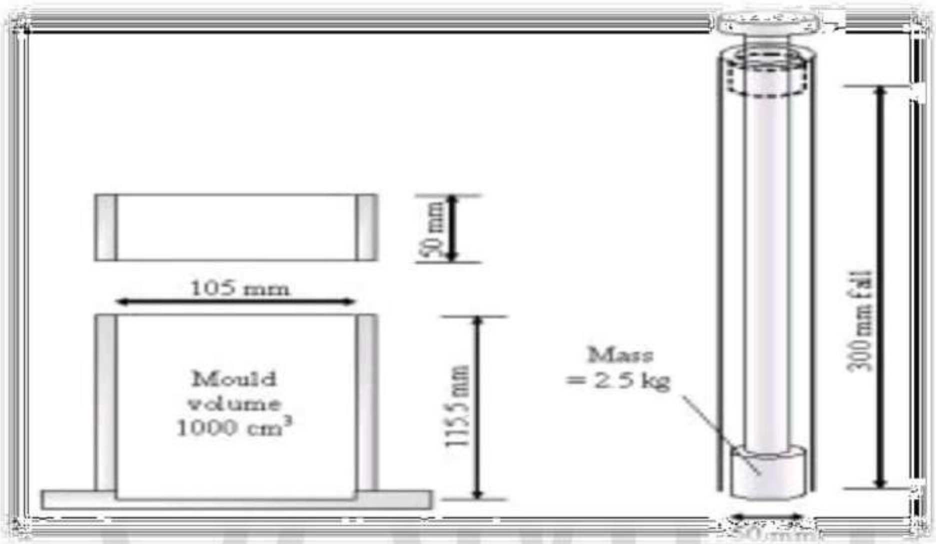
1. Balance (capacity 10kg, sensitivity 1gm)
2. Balance (capacity 200kg, sensitivity 0.01gm)
3. Drying oven (temperature 1000 C to 110 C)
4. Desiccators

5. Drying crucibles
6. Graduated jars
7. Straight edge
8. Large mixing pan
9. Spatula
10. Scoop

Procedure

1. Take about 20 kg for 100cc mould or 45 kg for 2250 cc mould of air dried and mixed soil.
2. Sieve this through 20mm and 4.75 mm sieves.
3. Calculate the percentage retained on 20 mm and 4.75mm sieves and passing from 4.75 mm sieve. Do not use the soil retained on 20 mm sieve.
4. Use a mould of 10 cm diameter if percentage retained on 4.75mm sieve is less than 20 or use a mould of 15cm diameter if percentage retained on 4.75 mm sieve more than 20.
5. Mix the soil retained on 4.75 mm sieve and passing from 4.75 mm sieve thoroughly in the proportion obtained in step3
6. Take about 2.5kg of the soil for 1000 cc mould or take about 2.8 kg or the soil for 1000 cc mould or 6.5kg for 2250 cc mould for heavy compaction.
7. Add water to it bring its moisture content to about 4% in coarse grained soils and 8% in fine grained soils
8. Clean, dry and grease lightly the mould and base plate. Weigh the mould with base plate.
9. Fit the collar and place the mould on a solid base.
10. For light compaction, compact wet soil in three equal layers by the rammer of mass 2.6 kg and free fall 31 cm with 25 evenly distributed blows in each layer for 10 cm diameter mould and 56 blows for 15cm diameter mould. Alternatively for heavy compaction compact the soils using the rammer of mass 4.89 kg and free fall 45 cm in five layers. Each layer being given 25 blows for 10 cm diameter mould and 56 blows for 15 cm diameter mould.
11. Remove the collar and trim off the soil flush with the top of the mould. In removing the collar rotate it to break the bond between it and the soil before lifting it off the mould.
12. Clean the outside of the mould and base plate, weigh the mould with soil and base plate.

13. Remove the soil from the mould and obtain a representative soil sample from the bottom middle and top for water content determination.
14. Weigh the drying crucible with samples and put samples and put in the drying oven



at temperature 1050c to 1100 c or 24 hours.
15. Repeat the above procedure with 7,10,13,16,19,22% of water contents on coarse grained fresh soil samples and 11,14,17,20,23 and 26% of water contents of fine grained fresh soil samples approximately.
16. Next day first weigh the crucibles with dry soil samples and then the empty crucibles.

Fig - Compaction mould

Precautions

1. Adequate period is allowed for mixing the water with soil before compaction
2. The blows should be uniformly distributed over the surface of each layer.
3. Each layer of compacted soil is scored with a spatula before placing the soil for the succeeding layer.
4. The amount of soil used be just sufficient to fill the mould i.e. at the last layer the Surface of the soil should be slightly (5mm) above the top rim of the mould.
5. Mould should be placed on a solid foundation during compaction.

Observations and Calculation

1. Enter all observations in table 1 and calculate the wet density.
2. Calculate the dry density by using the equation

$$\rho d = (\rho b/1+w)$$

Where ρd = dry density (g/cc) ρb = wet density (g/cc); w = water content

3. Plot the water content on X-axis and dry density on Y-axis draw the smooth curve, called the compaction curve.
4. Calculate the dry density at 100% saturation.
5. Plot the 100% saturation or Zero Air Voids curve on the same graph.
6. Read the point of maximum density from compaction curve.
7. Calculate the degree of saturation at optimum moisture content using above equation

Soil Sample No

Soil retained on 20mm sieve (%) = Soil retained on 4.75mm sieve (%) =
Soil passing from 4.75mm sieve (%) =

Specific Gravity of soil = Type of test =
Diameter of mould, d (cm) = Wt.of rammer =
Height of mould, h (cm) = No. of layers =
Volume of mould, V (cm3) = No. of blows/layer = Mass of mould, W (gm)

Dry Density at 100% Saturation (gm/cc)

RESULT:

1. Optimum Moisture Content = ------------ %
2. Maximum Dry Density =--------------- gm/cc
3. Degree of Saturation at OMC=---------- %

TABLE -1

Sr. No.	Determination No.	1	2	3	4	5
1	Mass of mould + compacted soil (gm)					
2	Mass of compacted soil Wt (gm)					
3	Wet Density, gt = Wt /V (gm/cc)					
4	Crucible No.					
5	Mass of Crusible + Wet soil (gm)					
6	Mass of Crucible + dry soil (gm)					
7	Mass of water (5-6)					
8	Mass of Crucible (gm)					
9	Mass of dry soil (gm) (6-8)					
10	Water Content, w = [7/9] x 100 (%)					
11	Dry Density, gd = gt / (1+w) (gm/cc)					

Experiment 8

Aim: To determine coefficient of permeability of given soil sample at desired density by a suitable method.

Theory

The property of the soils which permits water (fluids) to percolate through its continuously connected voids is called its permeability. Depending upon the value of Reynolds number the flow of water through soils may be 'laminar' or 'turbulent'. In laminar flow, a particle of water starting from a given position follows a definite path without crisscrossing the path of other particles. In turbulent flow the particles do not follow any definite path but have random, twisting and crisscrossing path. For laminar and steady flow, according to Darcy's law the rate of flow of water is proportional to the hydraulic gradient in uniform and homogeneous soils.

Apparatus

Special

1. Parameter mould (internal dia = 100 mm. effective height = 127.3 mm. Capacity 100cc)
2. Accessories of the permeameter (cover, base, detachable collar, porous stones, dummy plate) (common)
3. Round filter paper 100 mm. dia (common)
4. A static or dynamic compaction device (if remolded samples are used)
5. Constant head reservoir (common)
6. Graduated glass stand pipe (internal dia 5to 20 mm, preferably 10mm) (Variable head)
7. Support frame and clamps (variable head)
8. Funnel (variable head)
9. Measuring flask

(Constant head) General (Common to both the methods)

1. Metre Scale
2. Balance
3. Stop watch
4. Thermometer
5. Deaired water
6. Drying oven

7. IS: Sieve 4.75 mm (if remolded samples are used) Geotechnical Engineering- I
8. Grease
9. Straight edge
10. Drying crucibles
11. Dedicator

Procedure

A. Variable Head Method

1. Remove the cover of the mould and apply a little grease on the sides of the mould.
2. Weigh the mould with dummy plate.
3. Measure the internal diameter and effective height of the mould, then attach the collar and the base plate.
4. i) Compact the soil at given dry density and moisture content by a suitable static or dynamic device for remolded samples.

(ii) For undisturbed samples, trim off the undisturbed specimen in the form of a cylinder about 85 mm in diameter and height equal to that of mould. Place the specimen centrally over the bottom porous dise & filter paper. Fill the annular space between the mould and the specimen with an impervious material such as cement slurry or bentonite slurry to provide sealing against leakage from the sides.

5. Remove the collar & base plate, trim off the excess soil and level with the top of the mould.
6. Clean the outside of the mould and dummy plate.
7. Weigh the mould with soil and dummy plate. Difference of this mass and the mass taken in step 2 will give the mass of soil used.
8. Apply grease around the porous stone and base plate, put the porous stone inside the base plate and filter paper on porous stone.
9. Remove the dummy plate and place the mould with washer on the base plate.
10. Put the small quantity of the soil sample in drying oven to determine the moisture content.
11. Clean the edges of the mould and the collar and apply grease in the grooves around them.
12. Place a filter paper, porous stone and washer on the top of the soil sample and fix up the collar again.
13. Connect the reservoir with water to the outlet at the bottom of the mould and allow

the water to flow in. wait till the water has been able to travel up and saturate the sample .Allow about one cm depth of free water to collect on the top of the sample.

14. Fill the remaining portion of the cylinder with deaired water without disturbing the surface of the soil.
15. Fix the cover plate over the collar and tighten the nuts in the rods.
16. Disconnect the reservoir from the outlet at the bottom and connect the stand pipe to the inlet at the top plate. Fill the stand pipe with water.
17. Open the stop cock at the top and allow water to flow out so that all the air in the cylinder is removed.
18. Fix the height h1 and h2 won the pipe from the centre of the outlet such that (h1-h2) is about 30 to 40 cm. Mark the level of √ h1 h2 from the centre of the outlet.
19. When all the air has escaped, close the stop cock and allow the water from the pipe to flow through the soil and establish a speedy flow.
20. Record the time intervals for the head to fall from √ h1 h2√ h1 h2 to h2. The time intervals should be same, otherwise steady flow in established.
21. Change the height h1 and h2 and record the time intervals.
22. Stop the flow of water, disconnect all parts.
23. Take a small quantity of the soil sample from the mould in the drying crucible and put inside the drying oven for moisture content determination.
24. Measure the temperature of the water.

B. <u>Constant Head method</u>

1. Take steps 1 to 16.
2. Disconnect the reservoirs from the outlet as the bottom and connect to the inlet at the top plate.
3. Open stop cock at the cover and allow water to flow out so that all the air in the cylinder is removed.
4. When all the air has escaped close the stop cock and open the outlet. Allow the water to flow through the soil and established a steady flow.
5. When steady flow is reached collect the water in a measuring flask for a convenient time interval. Repeat this thrice quantity of water collected must be same, otherwise observations are repeated.
6. Repeat step (5) for at least two more different time intervals.
7. Repeat steps (22), (23) and (24)

Precautions

1. All the possibilities of leakage at the joints must be eliminated .All the joints and washer must be thoroughly cleaned so that there are no soil particles between them.
2. Apply the grease liberally between mould, base plate and collar.
3. Rubber washer must be moisture with water before placing.
4. Porous stones must be sutured just before placing
5. Desired and distilled water must be used to avoid the chocking of flow water.
6. Soil samples must be fully saturated before taking the observations.
7. In order to ensure laminar flow condition, cohesion less soil must be tested under low hydraulic gradient.
8. Steady floe must be established before taking the observations.
9. In constant head method, quantity of water collected must be sufficient and measured very accurately to eliminate large errors.

Observations and Calculations

(a) Enter all observations of variable head method in table 2 and of constant head method in table 3. (b)Calculate the coefficient of permeability of the soil using the following equations. kT = 2.303 [aL/At] log10 (h1/h2)

For **Variable Head Method**

Where, KT = Coefficient of Permeability at Test temperature
T0C (cm/sec) a= Cross-Sectional area of stand pipe (cm2)
L= Effective length of sample (cm)
A= Cross-Sectional area of Sample (cm2)
t= Time Interval to fall the head from h1 to h2 (sec)
h1= Initial height of water in the pipe above
the outlet (cm) h2= Final height of water in the
pipe above the outlet (cm)

For **Constant Head Method**

KT = Q.L/At. h
Where, KT = Coefficient of Permeability at Test temperature
T0C (cm/sec) Q = Quantity of Water collected in time t (ml)
L = length of soil sample (cm)
A= Cross-Sectional area of Soil
Sample (cm2) h = Constant

hydraulic head (cm)

Soil Sample No

1. Length of sample, L (cm) =
2. Diameter of sample, d (cm) =
3. Area of sample, A (cm2) =
4. Mass of Mould + dummy plate, W1 (gm) =
5. Mass of Mould + soil + dummy plate, W2 (gm) =
6. Mass of soil, W= (W1-W2) (gm) =
7. Volume of Soil sample (cm3) =
8. Density of soil sample [ρb= W/V] (gm/cc) =
9. Moisture Content at the start, w1 =
10. Dry Density of soil sample [ρd = (ρb/1+w1)] (gm/cc) =
11. Void ratio, e= [Gs/ρd]-1=

TABLE 1

Sr. NO	Determination No.	At the Start (before saturation)			At the end (after saturation)		
1	Container No.						
2	Mass of Container + Wet soil (gm)						
3	Mass of Container + dry soil (gm)						
4	Mass of Container (gm)						
5	Mass of soil (3-4) (gm)						
6	Mass of water (2-3) (gm)						
7	Water Content, w = [6/5]x 100						
8	Degree of Saturation = (w x Gs) / e						

Soil Sample No

Variable Head Method Date

Vision of the Institute	Mission of the Institute
"To become a leading institute of providing professionally competent and socially responsive technocrats with high moral values."	⇨ To create an eco-system for the dissemination of technical knowledge, to achieve academic excellence. ⇨ To develop technocrats with creative skills and leadership qualities, to solve local and global challenges. ⇨ To impart human values and ethics in students, to make them socially and Eco-friendly responsible.

1. Diameter of stand pipe (cm) =
2. Cross sectional area of pipe (cm2) =
3. Temperature of water, T0 c =
4. Correction factor due to temperature, Ct = T/ 27 =
5. Constant Factor = 2.303 [aL/A] =

TABLE 2

Sr. No.	Determination No.	1	2	3
1	Initial Head, h1 (cm)			
2	Final Head, h2 (cm) 3 Head Ö (h1-h2) (cm) 4 Time Interval (sec) A From h1 to Ö (h1-h2) B From Ö (h1-h2) to h2 C From h1 to h2, t = A+B 5 Log10 h1/h2 6 Coefficient of permeability k (cm/sec) K at test temperature T0c = (2.303 [aL/A] x 5) / 4C			
3	Head sq. root of (h1-h2) (cm)			
4	Time Interval (sec)			
5	From h1 to sq. root of (h1-h2)			
6	From sq. root (h1-h2) to h2			
7	From h1 to h2, t = A+B			
8	Coefficient of permeability k (cm/sec) ,K at test temperature T0c = (2.303 [aL/A] x 5) / 4C			

9	Coefficient of permeability k (cm/sec) K at test temperature 270c = 6 x hT/h27			

Result

1. Average value of coefficient of permeability at test temperature, KT =
2. Average value of coefficient of permeability at standard temperature 270 c , K27 =
3. Void ratio of soil sample, e =
4. Type of soil =

TABLE 3

Soil Sample No Constant Head Method Date

Sr. NO	Determination No.	1	2	3
1	Hydraulic Head, h (cm)			
2	Time Interval (sec)			
3	Quantity of flow, Q (ml)			
A	I test for time , t (ml)			
B	B II test for same time , t (ml)			
C	C III test for same time , t (ml)			
4	5 Average Quantity of Flow(A+B+C)/3 (ml)			
5	6 Coefficient of permeability at test temperature kT (cm/sec)			
6	7 Coefficient of permeability k27 at 270c temperature (cm/sec)			

Result

2. Average value of coefficient of permeability at test temperature, KT =
3. Average value of coefficient of permeability at standard temperature 27^{o} C, K27 =
4. Void ratio of soil sample, e =
5. Type of soil =

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Experiment 9

THEORY:

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 voids 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 begins escaping from the voids, the hydrostatic pressure in water gets gradually dissipated and the load is shifted to the soil particles 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.

NEED AND SCOPE:

This test simulates one dimensional primary consolidation with double drainage. The following parameters are determined by conducting Consolidation test on fine grained soils:

a. Pressure-void ratio relationship
b. Compression and Recompression index
c. Coefficient of consolidation at various pressures
d. Preconsolidation pressure
e. Degree of consolidation at any time
f. Rate of consolidation under vertical loads

The above information can be used 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.

APPARATUS REQUIRED:

1. Consolidometer consisting essentially:
   a) A ring of 60 mm diameter and 20 mm height
   b) Two porous stones
   c) Guide ring
   d) Outer ring
   e) Water jacket with base
   f) Pressure pad
2. Loading device consisting of frame, lever system, loading yoke, steel ball, dial gauge fixing device and weights
3. Dial gauge (accuracy of 0.01 mm), thermostatically controlled oven, stopwatch, sample extractor, balance, soil trimming tools, spatula, filter papers, sample containers, wash bottle

SAMPLE PREPARATION:

1. Undisturbed sample:
   From the sample tube (Shelby 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 wire saw. Clean the ring from outside and keep it ready for weighing.
2. Remolded sample:
   a. Choose the density and water content at which sample has to be compacted from the moisture-density curve, and calculate the quantity of soil and water required to mix and compact.
   b. Compact the specimen in compaction mould in three layers using the standard rammers (moist tamping technique).
   c. 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. Fittings of the Consolidometer which is to be enclosed shall be moistened.
2. Assemble the Consolidometer, with the soil specimen and porous stones at top and bottom of specimen, and providing a filter paper between the soil specimen and porous stone.
3. Position the pressure pad centrally on the top porous stone. Mount the mould assembly on the loading frame, and center it such that the load applied is axial. Make sure that the porous stone and pressure pad are not touching the walls of mould on their sides.
4. Position the dial gauge to measure the vertical compression of the specimen. The dial gauge holder should be set so that the dial gauge is in the beginning of its releases run, and also allowing sufficient margin for the swelling of the soil, if any.
5. Fill the mould with water and 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 0.05 kg/cm^2 for ordinary soils & 0.025 kg/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.
6. Note the final dial reading under the initial load. Apply first load of intensity 0.1 kg/cm^2 (Approx.) and start the stop watch simultaneously. Record the dial gauge readings at various time intervals. The dial gauge readings are taken until 90% consolidation is reached. Primary consolidation is gradually reached within 24 hrs.
7. 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 is as follows (approx.): 0.1, 0.2, 0.5, 1, 2, 4 and 8 kg/cm^2. Dial gauge reading with time should be recorded for each loading increment.

8. On completion of the final loading stage, the specimen shall be unloaded by pressure decrements which decrease the load to one-fourth of the last load. Dial gauge readings may be taken as necessary during each stage of unloading. If desired, the time intervals used during the consolidation increments may be adopted; usually it is possible to proceed much more rapidly (IS 2720- Part 15).

9. In unloading phase, the load needs to be reduced in the reverse order and allow it to stand for Atleast 2 hrs or until the dial gauge reading becomes constant. Take the final reading of the dial gauge.

10. Quickly dismantle the specimen assembly and remove the excess water on the soil specimen in oven, note its dry weight.

CALCULATIONS:

1. **Height of solids** (H_S) is calculated from the equation $H_S = W_S/(G_S.\gamma_w A)$

2. **Void ratio.** Voids ratio at the end of various pressures are calculated from equation $e = (H - H_S)/H_S$

3. **Coefficient of consolidation**. The Coefficient of consolidation at each pressure 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, and the time corresponding to 50% consolidation is determined.

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

4. Compression Index. To determine the compression index, a plot of voids ratio (e) Vs log (t) is made. The virgin 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

= ▯e/ ▯▯▯

▯e – Change in void ratio

▯▯▯ - Change in vertical stress

6. Coefficient of permeability. It

is calculated as follows k

= $C_v.a_v.$▯$_w$/ (1+e_0).

GRAPHS:

1. Dial reading Vs log of time or
2. Dial reading Vs square root of time
3. Voids ratio (e) Vs effective vertical stress (log▯v▯)

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.

<u>OBSERVATION AND READING (LOADING):</u>

Table▯: Data Sheet for Consolidation Test: Time-Displacement

Relationship

Ring Dimensions: Diameter (cm): _______ Area (cm^2): ____________ Height (cm): _________Initial Data: Specimen Ht (cm).___________

Specific Gravity of Soil: ______

Weight of wet soil + Ring (g): ______ Weight of Ring (g): _________ Bulk Density (g/cc): _____________________________

Pressure Intensity (Kg/cm^2)	0.1	0.2	0.5	1	2	4	8
Time (min)							
0							
0.25							
1							
2							
4							
8							
15							
30							
1 hr							
2 hrs							
4 hrs							
8 hrs							

24 hrs							

OBSERVATION AND READING (UNLOADING):

Removed Pressure (kg/cm²)	Retained Pressure (kg/cm²)	Dial Gauge reading
0	8	
4	4	
2	2	
1	1	
0.5	0.5	
0.3	0.2	
0.1	0.1	
0.1	0.05 (Seating pressure)	

Water Content determination:

Weight of Saturated Sample + Ring (g): _______

Weight of oven dried soil +Ring (g): ________

Water Content (%): _______

Table II: Data Sheet for Consolidation Test: Pressure-Voids Ratio

Applied Pressure	Final dial reading	Change in Specimen Height	Final Specimen Height	Height of solids	Height of voids	Void ratio	Average Height during Consolidation	Fitting Time, t90	Coefficient of Consolidation, cv
0									

0.1									
0.2									
0.5									
1.0									
2.0									
4.0									
8.0									
2.0									
0.5									
0.1									