VAISHNO COLLEGE OF ENGINEERING

Affliated to HPTU, Hamirpur and approved by AICTE

Geotechnical Engineering

Lab Manual

CE-414P (NEP Syllabus)

Department of Civil Engineering

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Vision of Institute

To emerge as an institute of eminence in the fields of engineering, technology and management in serving the industry and the nation by empowering students with a high degree of technical managerial and practical competence.

Mission of Institute

M1 To strengthen the theoretical, practical and ethical dimensions of the learning process by fostering a cultural of research and innovation among faculty members and students.

M2 To encourage long term interaction between academia and industry through the involvement of industry for hands on implementation of the curriculum.

M3 To strengthen and molding students in professional ethical, social and environmental dimensions by encouraging participation in co-curricular extracurricular and CSR activities.

Vision of the Department

To produce engineers having professional and leadership qualities with capacity to take up professional and research assignments in Civil Engineering and allied fields with focus on inter-disciplinary and innovative approach and to compete at the global level.

Mission of the department

1. To impart quality and real time education to contribute to the field of Civil Engineering.

2. To impart soft skills, leadership qualities and professional ethics among the graduates to handle projects independently.

3. To develop graduates to compete at the global level.

Program Educational Objectives (PEOs) of the department

PE01:- To impart quality education and knowledge in contemporary science and technology to meet the challenges in the field of Civil Engineering and to serve the society.

PEO2:- To impart the knowledge of analysis and design using the codes of practice and software packages.

PEO3:-To inculcate the sense of ethics, morality, creativity, leadership, professionalism, self confidence and independent thinking.

PEO4:- To motivate the students to take up higher studies and innovative research projects.

PROGRAM OUTCOMES

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

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

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

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

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

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

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

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

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

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

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

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 Outcome (PSOs)

PSO 1: The graduates of this program will be able to meet the needs of public in the design and execution of quality construction work considering principles of mechanics, mathematics and physics to construct sustainable buildings that will ensure safety and durability till the service period.

PSO 2: The graduates will calculate the loads and the stresses acting on the building, analysis for the loads and design sections of structures to sustain the loads using building analysis software packages.

PSO 3: The graduates will be able to work effectively as an individual or in a team having acquired leadership skills and manage projects in multidisciplinary environments.

VCOE

Lab Syllabus & List of Experiments

<table>
<tr><th colspan="9">CEPC-414P Geotechnical Engineering Laboratory</th></tr>
<tr><th colspan="3">Teaching Scheme</th><th rowspan="2">Credit</th><th colspan="3">Marks Distribution</th><th rowspan="2">Duration of End Semester Examination</th></tr>
<tr><th>L</th><th>T</th><th>P</th><th>Internal Assessment</th><th>End Semester Examination</th><th>Total</th></tr>
<tr><td rowspan="2">0</td><td rowspan="2">0</td><td rowspan="2">2</td><td rowspan="2">1</td><td>Maximum Marks: 30</td><td>Maximum Marks: 20</td><td>50</td><td rowspan="2">2 Hours</td></tr>
<tr><td>Minimum Marks: 12</td><td>Minimum Marks: 8</td><td>20</td></tr>
</table>

Course Objectives:

- To learn the fundamental concepts relevant to soil properties
- To provide exposure to a variety of established soil testing procedures and techniques.

Sr. No.	List of Experiments
1	Field Density using Core Cutter method
2	Field Density using Sand replacement method
3	Natural moisture content using Oven Drying method
4	Field identification of Fine-Grained soils
5	Specific gravity of soils
6	Grain size distribution by Sieve Analysis.
7	Grain size distribution by Hydrometer Analysis
8	Consistency limits: Liquid limit, Plastic limit and Shrinkage limit
9	Permeability test using Constant-head method
10	Permeability test using Falling-head method
11	Compaction test: Standard Proctor test / Modified Proctor test.
12	CBR Test
13	Consolidation Test
14	Relative density test
15	Unconfined Compression Strength (UCS) Test
16	Direct Shear Test

17	Triaxial Test (UU)
18	Vane shear test

Evaluation Scheme

Internal Assessment: 30 marks (pass marks:12)

Distribution of marks for internal assessment:

- Written/presentation/Demonstration: 05
- Viva-voice: 05
- Teacher assessment: Lab Work performance/Report/File Work:15
- Attendance: 05

External Assessment: 20 marks (pass marks: 08)

Total marks 30+20=50, Pass marks = 20

Note: Student has to pass internal & external assessment separately.

VCOE

GENERAL GUIDELINES AND SAFETY INSTRUCTIONS

1. Sign in the log register as soon as you enter the lab and strictly observe your lab timings.

2. Strictly follow the written and verbal instructions given by the teacher / Lab Instructor. If you do not understand the instructions, the handouts and the procedures, ask the instructor or teacher.

3. Never work alone! You should be accompanied by your laboratory partner and / or the instructors / teaching assistants all the time.

4. It is mandatory to come to lab in uniform and wear your ID cards.

5. Do not wear loose-fitting clothing or jewellery in the lab. Rings and necklaces are usual excellent conductors of electricity.

6. Mobile phones should be switched off in the lab.

7. Keep the labs clean at all times, no food and drinks allowed inside the lab.

8. Intentional misconduct will lead to expulsion from the lab.

9. Do not handle any equipment without reading the safety instructions. Read the handout and procedures in the Lab Manual before starting the experiments.

10. Do your wiring, setup, and a careful circuit checkout before applying power. Do not make circuit changes or perform any wiring when power is on.

11. Avoid contact with energized electrical circuits.

12. Do not insert connectors forcefully into the sockets.

13. Never try to experiment with the power from the wall plug.

14. Immediately report dangerous or exceptional conditions to the Lab instructor / teacher: Equipment that is not working as expected, wires or connectors are broken, the equipment that smells or “smokes”. If you are not sure what the problem is or what's going on, switch off the Emergency shutdown.

15. Never use damaged instruments, wires or connectors. Hand over these parts to the Lab instructor/Teacher.

16. Be sure of location of fire extinguishers and first aid kits in the laboratory.

17. After completion of Experiment, return the bread board, trainer kits, wires, CRO probes and other components to lab staff. Do not take any item from the lab without permission.

18. Observation book and lab record should be carried to each lab. Readings of current lab experiment are to be entered in Observation book and previous lab experiment should be written in Lab record book. Both the books should be corrected by the faculty in each lab.

20**. Special Precautions during soldering practice**

a. Hold the soldering iron away from your body. Don't point the iron towards you.

b. Don't use a spread solder on the board as it may cause short circuit.

c. Do not overheat the components as excess heat may damage the components/board.

d. In case of burn or injury seek first aid available in the lab or at the college dispensary.

VCOE

<u>Experiment No: 1</u>

Aim: To determine the grain size distribution of the given soil by dry sieving.

Theory: Particle size classification of soils: IS system, MIT system, Differentiation: clay size fraction and clays; particle size distribution curves, characteristic sizes, well graded and poorly graded soils; gradation characteristics.

Apparatus

1. Set of IS sieves: 4.75mm, 2mm, 1mm, 600 micron, 425 micron, 300 micron, 212 micron, 150 micron, 106 micron, 75 micron.
2. Brushes to clean the sieves
3. Mechanical sieve shaker
4. Balance
5. Trays
6. Thermostatically controlled hot air oven

Procedure

1. Oven dry the given soil sample passing 4.75 mm IS sieve.
2. Take 200 g of oven dried soil sample. Mix the sample with distilled water to form a slurry and allow it for soaking.
3. Wash the soaked soil sample through 75 micron sieve until the water passing through the sieve is substantially clear.
4. Dry the fraction of the soil retained on 75 micron sieve in oven.
5. Arrange the remaining sieves one above the other such that 2mm sieve is at the top and 75 micron sieve is at the bottom. Place a cover at the top and receiver at the bottom.
6. Fix the set of sieves to the mechanical sieve shaker. Operate the sieve shaker for a minimum of 10 minutes.
7. Carefully collect and record the mass of the soil fraction retained on each sieve and also in the receiver.
8. Calculate the cumulative mass of soil fraction retained on each sieve. Calculate the percentage finer.
9. Plot a graph of percentage finer (along y-axis) Vs equivalent particle diameter in mm (along x-axis in log scale). Draw a smooth curve encompassing the plotted points.
10. Record the values of percentage sand, percentage silt and percentage clay size fractions from the graph.
11. Record D_{10}, D_{30} and D_{60} from the graph.
12. Calculate coefficient of curvature (C_C) and coefficient of uniformity (C_U).
13. Classify the soil based on gradation.

Results and Discussions:

Contd......

VCOE

Observation and Calculations

Total mass of soil taken for analysis = M = ---------------------------- g.

IS Sieve	Practical size D, mm	Mass retained m′, g	Corrected mass retained m, g	% retained	Cumulative % retained	% finer (N)
4.75mm	4.75mm					
2mm	2 mm					
1mm	1mm					
600 micron	0.6mm					
425 micron	0.425mm					
300 micron	0.3mm					
212 micron	0.212mm					
150 micron	0.15mm					
106 micron	0.106mm					
75 micron	0.075mm					
Receiver	0.075mm					
		M′ =				

Specimen Calculations

Corrected mass retained = m = m′ x $\frac{M}{M}$ =

From the graph

1) The given soil is ______________________grained.
2) (i) % sand = (ii) % silt = (iii) % clay size =
3) (i) D_{10} = (ii) D_{30} = (iii) D_{60} =
4) (i) Coefficient of uniformity = $C_U = D_{60} / D_{10}$ = _________________________

   (ii) Coefficient of curvature = $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _______________________

5) Particle size and gradation classification of the given soil: ________________________

   (reason: ____)

Relevant BIS Code: IS 2720-Part 4, 1985

Experiment No: 2

A) Aim: To determine the dry density of the soil *in-situ* by core cutter method.

Theory: Field dry density and field moisture content – practical significance; methods of determining them. Core cutter method – practical significance.

Apparatus

1. Cylindrical core cutter of steel, 127.4 mm long and 100 mm internal diameter with a wall thickness of 3 mm, levelled at one end.
2. Steel dolly, 25 mm high and 100 mm internal diameter with a wall thickness of 7.5 mm, with a lip to enable it to be fitted on the top of the core-cutter.
3. Steel rammer
4. Knife
5. Grafting tool or pickaxe or spade
6. Straight edge
7. Balance accurate to 1g
8. Containers for water content determination.
9. Thermostatically controlled hot air oven.

Procedure

1. Measure the inner dimensions of the core cutter and calculate its volume. Determine the mass of the core cutter (without dolly) accurate to 1 g. Oil the inside surfaces of the core cutter and the dolly.
2. Level the area where the in-situ density of the soil is required to be measured. Keep the dolly on the top of the core cutter and drive the assembly in to the soil with the help of the rammer until the top of the dolly protrudes about 1.5 cm above the surface.
3. Dig out the core cutter along with the dolly from the surrounding soil such that some soil projects from the lower end of the core cutter. Take out the dolly, and trim the soil mass at both the ends of the core cutter.
4. Determine the mass of the core cutter with the soil.
5. Determine the water content of the soil by oven drying method.
6. Repeat the test at two or three locations nearby for the average result.

Results and Discussions

Observations and Calculations

(a) Determination of in-situ bulk density of the soil:

Determination No.			
1. Inside diameter of the core cutter (d)	cm		
2. Inside height of the core cutter (h)	cm		
3. Volume of the core cutter (V)	cm^3		
4. Mass of the core cutter	g		
5. Mass of the (core cutter + wet soil)	g		
6. Mass of the wet soil (M)	g		
7. Bulk density of the soil (ρ_b)	g/cm^3		

(b) Determination of filed water content:

1. Container No.			
2. Mass of the container	g		
3. Mass of the (container + wet soil)	g		
4. Mass of the (container + dry soil)	g		
5. Mass of the dry soil (M_d)	g		
6. Mass of water (M_w)	g		
7. Water content (w)	(Ratio)		

(c) Determination of in-situ dry density of the soil:

1. Dry density (ρ_d)	g/cm^3		
2. Average dry density $(\rho_d)_{av}$	g/cm^3		

Specimen Calculations

1. Volume of the core cutter = V = $\frac{\pi}{4} d^2 h$ =
2. In-situ bulk density of the soil = ρ_b= M / V
3. In-situ water content of the soil = w = M_w / M_d =
4. In-situ dry density = ρ_d= $\frac{\rho_b}{(1+w)}$ =

Relevant BIS Code: IS: 2720-Part 27, 1975

<u>Experiment No: 3 & 4</u>

A) Aim: To determine the liquid limit of the soil using Casagrande liquid limit apparatus with soft base.

Theory: Definitions: Liquid limit, Plastic limit, Shrinkage limit, Plasticity index, Consistency index, Liquidity index, Toughness index, Flow index; Applications of Atterberg limits.

Apparatus

1. Casagrande liquid limit apparatus
2. Casagrande grooving tool of standard dimensions (Type A)
3. Glass plate, 10 mm thick and about 45 cm square
4. Spatula
5. Balance, sensitive to 0.01 g
6. Thermostatically controlled hot air oven
7. Airtight and non-corrodible containers for moisture content determination.
8. Wash bottle containing distilled water.
9. 425 micron IS sieve.

Procedure

1. Using the gauge on the handle of the grooving tool or a separate gauge, adjust the height through which the cup of the Casagrande apparatus is lifted and dropped so that the point on the cup which comes in content with the base falls through exactly one centimeter for one revolution of the handle. Then, tighten the adjustment screws.
2. Take about 120 g of soil sample passing through 425 micron IS sieve and mix it thoroughly with distilled water on the glass plate to form uniform paste. Allow sufficient time to ensure uniform moisture distribution throughout the soil mass.
3. Remix the soil thoroughly. Take a portion of the soil paste with the spatula and place it in the central portion of the cup and spread it into position with the spatula so that the soil surface is parallel to the rubber base with the maximum depth of the soil as
   1.0 cm at the centre.
4. With the help of the grooving tool, divide the soil paste in the cup along the diameter of the cup (through the centre line of the cam follower) to get a clean, sharp groove of proper dimensions.

5. Turn the handle of the apparatus at a rate of 2 revolutions per second until the two parts of the soil paste come in contact at the bottom of the groove for a distance of about 12 mm and record the number of revolutions to achieve this.
6. Collect a representative sample of the soil by moving the spatula normal to the groove, width wise from the portion of the groove where the soil flowed together and put it in a container and determine its water content by oven drying method.

7. Transfer the remaining soil in the cup back on to the glass plate. Dry the soil by kneading the wet soil using spatula.
8. Repeat the steps 3 to 6 to get a minimum of 5 trials. The trials are conducted such that the number of blows is in the range 25 ± 10.
9. Plot a "flow curve" on a semi-log sheet with water content on y-axis (arithmetic scale) and number of blows on x-axis (log scale). Draw a well defined straight line through the points. Record the moisture content corresponding to 25 blows and round off to the nearest whole number and report it as the liquid limit of the soil. Measure the slope of the line, which represents the flow index (I_f).

Observations and Calculations

Soil: Period of soaking before the test:

Determination No.		1	2	3	4	5
Number of blows						
Container No.						
Mass of the (container + wet soil)	g					
Mass of the (container + dry soil)	g					
Mass of water	g					
Mass of container	g					
Mass to dry soil	g					
Moisture content (w)	%					

From the flow curve:

i) Liquid limit of the soil = w_L = ____________________

ii) Flow index = I_f = $\dfrac{(w_2 - w_1)}{\log_{10}\left(N_2/N_1\right)}$ = ___________________

Relevant BIS Code:

IS: 2720, Part-5, 1985

10. Transfer the remaining soil in the cup back on to the glass plate. Dry the soil by kneading the wet soil using spatula.
11. Repeat the steps 3 to 6 to get a minimum of 5 trials. The trials are conducted such that the number of blows is in the range 25 ± 10.
12. Plot a "flow curve" on a semi-log sheet with water content on y-axis (arithmetic scale) and number of blows on x-axis (log scale). Draw a well defined straight line through the points. Record the moisture content corresponding to 25 blows and round off to the nearest whole number and report it as the liquid limit of the soil. Measure the slope of the line, which represents the flow index (I_f).

Observations and Calculations

Soil: Period of soaking before the test:

Determination No.		1	2	3	4	5
Number of blows						
Container No.						
Mass of the (container + wet soil)	g					
Mass of the (container + dry soil)	g					
Mass of water	g					
Mass of container	g					
Mass to dry soil	g					
Moisture content (w)	%					

From the flow curve:

i) Liquid limit of the soil = w_L = ____________________

ii) Flow index = $I_f = \dfrac{(w_2 - w_1)}{\log_{10}\left(N_2/N_1\right)}$ = ____________________

Relevant BIS Code:

IS: 2720, Part-5, 1985 Contd......

B) Aim: To determine the plastic limit of the soil sample and to calculate plasticity index, Toughness index of fine-grained soil.

Apparatus

1. Flat glass plate, 10 mm thick and about 45 cm square.
2. Spatula
3. Balance, sensitive to 0.01 g
4. Thermostatically controlled oven
5. Airtight and non-corrodible containers for moisture content determination.
6. Wash bottle containing distilled water
7. 425 mircon IS sieve
8. 3 mm diameter rod of about 10 cm length.

Procedure

1. Take about 20 g of soil sample, passing 425 micron IS sieve. Mix it on the glass plate with sufficient distilled water to make it plastic enough to be shaped into a ball. Allow the soil to stand for sufficient time to ensure uniform distribution of moisture throughout the soil mass.
2. With about 8 g of soil so prepared, make a ball and roll it on the glass plate with hand, with pressure just sufficient to roll the soil mass into a thread of uniform diameter throughout its length. When the diameter of the thread reaches 3 mm, kneed the soil together to a uniform mass and once again roll it. Continue the process until the soil thread just crumbles at 3mm diameter.
3. Collect the crumbled soil threads in a container and determine the corresponding water content by oven drying method.
4. Repeat the test to have three trials.
5. Report the average water content rounded off to the nearest whole number as the plastic limit of the soil.

Observations and Calculations

Determination No.		1	2	3
Container No.				
Mass of (container + wet soil)	g			
Mass of (container + dry soil)	g			
Mass of water	g			
Mass of container	g			
Mass of dry soil	g			
Water content (w)	%			
Plastic limit (w_p)	%			

Contd......

Calculations

Plasticity index = Ip = w_L - w_p
Toughness index = I_T = I_p / I_f =
Soil classification:

Relevant IS Code: IS:
2720, Part-5, 1985

Experiment No: 5

Aim: To determine the shear strength parameters of a soil (i.e. Cohesion intercept and angle of internal friction) by direct shear test.

Theory: Direct shear test – description, merits and limitations.

Apparatus

1. Shear box assembly consisting of
   - Upper and lower parts of shear box coupled together with two pins or clamping screws.
   - Container for shear box
   - Grid plates – two pairs
   - Base plate with cross grooves on its top face to fit into the shear box.
   - Loading pad with a steel ball on its top which distributes the load over the specimen, normal to the shear plane.
2. Loading frame
3. Calibrated weights
4. Proving ring with dial gauge to measure shear force
5. Balance with weights.
6. Dial gauge
7. Spatula, straight edge, sample trimmer.

Preparation of the specimen

Remoulded specimens: Cohesive soils may be compacted to the required density and moisture content in a separate mould. The sample is extracted and trimmed to the required size.

OR

The soil may be compacted to the required density and moisture content directly into the shear box after fixing the two halves of the shear box together by means of fixing screws.

* Non Cohesive soils may be tamped in the shear box for required density with the base plate and the grid plate at the bottom of the box.

Procedure: (Undrained Test)

1. Assemble the shear box with the base plate at the bottom and a grid plate over it, the two halves of the box being connected by the locking screws. The serrations of the grid plate should be at right angles to the direction of shear.
2. Place the specimen over the bottom grid plate. Place another grid plate at the top of the specimen such that the serrations of the plate or in contact with the specimen

and at right angles to the direction of shear. Place the loading pad on the top of the grid plate.

3. Place the shear box inside the container of the shear box. The container can move over roller supports at its bottom.
4. Set the lower part of the shear box to bear against the load jack, the upper part of the box against the proving ring. Set the gauge of the proving ring to read zero.
5. Apply the required normal stress on the specimen inside the shear box through a lever arrangement.
6. Remove the locking screws or pins so that both the parts of the shear box are free to move relative to each other.
7. Conduct the test by applying a horizontal shear load to failure or to 20% longitudinal displacement, whichever occurs first. Take the proving ring dial readings corresponding to known displacement dial readings.
8. At the end of the test, remove the specimen from the box and determine its final water content (for cohesive soil only).
9. Repeat the test on identical specimens, under different normal stresses (0.25 kgf/cm^2, 0.5 kgf/cm^2, 1 kgf/cm^2, 1.5 kgf/cm^2, 2 kgf/cm^2, and 2.5 kgf/cm^2 etc.). A minimum of three (preferably four) tests shall be made on separate specimens of the same density.

Results and Discussions:

Observations and Calculations

1. Type of soil:
2. Are of the specimen (A_o) =-- cm^2
3. Volume of the specimen (V) =--- cm^3
4. Bulk density (ρ_b) =-- g/cm^3
5. Moisture content (w) =--- %
6. Rate of strain = ---------------------------------------
7. Proving ring constant = ---------------------------------------
8.

Trial No.	Normal stress (σ) kgf/cm^2	Displacement dial reading Div.	Displacement (δ) cm	Corrected Area (A)	Proving ring reading Div.	Shear force (P) kgf	Shear Stress (τ) kgf/cm^2
1.							

10. Place the shear box inside the container of the shear box. The container can move over roller supports at its bottom.
11. Set the lower part of the shear box to bear against the load jack, the upper part of the box against the proving ring. Set the gauge of the proving ring to read zero.
12. Apply the required normal stress on the specimen inside the shear box through a lever arrangement.
13. Remove the locking screws or pins so that both the parts of the shear box are free to move relative to each other.
14. Conduct the test by applying a horizontal shear load to failure or to 20% longitudinal displacement, whichever occurs first. Take the proving ring dial readings corresponding to known displacement dial readings.
15. At the end of the test, remove the specimen from the box and determine its final water content (for cohesive soil only).
16. Repeat the test on identical specimens, under different normal stresses (0.25 kgf/cm^2, 0.5 kgf/cm^2, 1 kgf/cm^2, 1.5 kgf/cm^2, 2 kgf/cm^2, and 2.5 kgf/cm^2 etc.). A minimum of three (preferably four) tests shall be made on separate specimens of the same density.

Results and Discussions:

Observations and Calculations

9. Type of soil:
10. Are of the specimen (A_o) =-- cm^2
11. Volume of the specimen (V) =--- cm^3
12. Bulk density (ρ_b) =-- g/cm^3
13. Moisture content (w) =--- %
14. Rate of strain = ---------------------------------------
15. Proving ring constant = ---------------------------------------
16.

Trial No.	Normal stress (σ) kgf/cm^2	Displacement dial reading Div.	Displacement (δ) cm	Corrected Area (A)	Proving ring reading Div.	Shear force (P) kgf	Shear Stress (τ) kgf/cm^2
1.							

Contd......

Specimen Calculation

Corrected area = A = A_o x $(1 - \delta/3)$ = --- cm^2

Shear load = P = Proving ring reading x Proving ring constant =------------------------ kgf

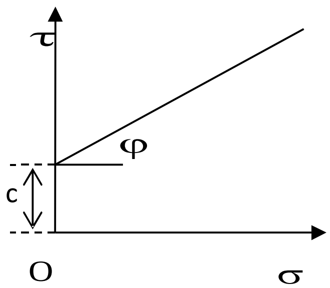
Shear stress = τ= P/A = ---

* Conduct the test for different normal stresses (at least four normal stresses). For each test, plot shear stress vs displacement curve to obtain maximum shear stress at failure.

17.

Trial No.					
Normal stress (σ)	kg/cm^2				
Shear stress at failure (τ_f)	kgf/cm^2				

Plot the graph of normal stress (x – axis) vs. maximum shear stress (y-axis). Adopt same scale to plot both normal stress and maximum shear stress.



i) Cohesion intercept = c = ... kgf/cm^2

ii) Angle of shearing resistance = φ=

Relevant BIS Code: IS:
2720, Part-13, 1986

Experiment No: 6

Aim: To determine the water content of soil solids by Oven Drying method.

The water content (w) of a soil sample is equal to the mass of water divided by the mass of solids.

Specifications:

This test is done as per IS: 2720 (Part II) – 1973. The soil specimen should be representative of the soil mass. The quantity of the specimen taken would depend upon the gradation and the maximum size of the particles. For more than 90% of the particles passing through 425 micron IS sieve, the minimum quantity is 25g.

Equipments Required:

a) Non-corrodible airtight containers.
b) Balance weighting to accuracy of 0.04% of the weight of the soil taken for test.
c) Desiccators with suitable desiccating agent.
d) Thermostatically controlled oven to maintain temperature 110 °C ± 5 °C.
e) Other accessories.

Theory:

In almost all soil tests natural moisture content of the soil is to be determined. The knowledge of the natural moisture content is essential in all studies of soil mechanics. To sight a few, natural moisture content is used in determining the bearing capacity and settlement. The natural moisture content will give an idea of the state of soil in the field. Water content, w of a soil mass is defined as the ratio of mass of water in the voids to the mass of solids:

$$W = (W_2-W_3)/ (W_3-W_1) \times 100\ \%$$

Where, W_1= Weight of empty container in grams
W_2 = Weight of container + wet soil in grams W_3 =
Weight of container + dry soil in grams

Precautions:

- Ensure that soil samples are between 350 to 400g. Larger samples take too long to dry, while smaller samples lead to inaccurate results.
- Ensure that the oven temperature is maintained at 110º C ± 5º C. Do not allow the oven door to stay open for too long, as it takes a while for the oven to regain the drying temperature.
- Do not put moist samples in the oven on a shelf below dry samples. Moist samples should be placed on the top shelf and all partially dried samples placed on the lower shelf.
- Do not over-load the oven, as this will create a much longer drying time.
- Do not allow dried samples to pick up moisture after they are removed from the oven. Weigh them immediately after drying.
- Soils and aggregates may contain bacteria and/or organisms which can be harmful for one's health. Wearing dust masks and protective gloves when handling materials is advised. The use of heat resistant gloves/mitts or pot holders to remove samples from the ovens is recommended.
- Prior to handling oven, testing or disposing of any waste materials, students are required to read do's and don'ts of the Geotechnical engineering laboratory.

Procedure:

a) Clean the container with lid and find the mass (W_1 in g).
b) Select the required quantity of moist soil sample, place it in the container, place the lid on it, and weigh it (W_2 in g).
c) Keep the container in the oven with lid removed and dry it for at least 24 hr. at a temperature of 110 °C till the mass remains constant.
d) Remove the container from the oven, replace the lid, and cool it in desiccators. Find the mass (W_3 in g).
e) Determine the water constant w by using the above equation.
f) Repeat the experiment with other test samples

Pre-viva Questions:

1. Water content is also called?
2. Which method is mostly used to determine the water content in field?
3. What is water content for clay soil?
4. On which factor water content is depended?
5. Ground Penetrating Radar (GPR) method is also used for measuring water content (True or False?)

6 Name different types of soil textures?

7. The percentage of water remaining in an air-dry soil is called ______________________.

Observation Table:

Table 3: Weights of container

Sl No	**Particulars**	Test No1 (w_1)	Test No2 (w_2)	Test No3 (w_3)
1	Weight of empty container (W_1), g			
2	Weight of container + wet soil (W_2), g			
3	Weight of container + dry soil (W_3), g			
4	Water content, w			
5	Average water content, $w = (w_1 + w_2 + W_3)/3$			

Specimen calculations:

$$W = (W_2 - W_3)/(W_3 - W_1) \times 100\ \%$$

Result:

Average of w =

Verification/ Validation:

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

Conclusion:

The experiment is conducted as per the procedure laid down. The water content of the soil sample is determined. Water content, w = _____%. The value is verified and the three phase system is sketched.

Post-Viva Questions

1. Draw the schematic diagram of the three phase system based on the result.
2. Is there a possibility of the soil getting burnt? In that case, what will be effect on the water content value?
3. How does air-dry soil differ from oven-dry soil?
4. Is this method the most direct method to compute the water content of soil?
5. To get accurate result, how much gram of soil have you taken to conduct the test?

Experiment No: 7

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

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

Specifications:

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

Equipment Required:

a) Typical equipment for proctor test is given in figure.
b) Other accessories are: Balance, oven, straight edge, sieves, metal hammer, etc.

Theory:

The objectives of compaction are:

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

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

1. Bulk density $\gamma_b = (M_2 - M_1)/V$
2. Dry density $\gamma_\delta = \gamma b/(1 + w)$

3. Dry density ρd for zero air voids line.

$$\gamma_d = G.\gamma_w/(1 + (w.G/S))$$

Where, M_1 = mass of mould used for proctor test M_2 =

mass of mould + compacted soil. M = mass of

wet soil.

V = volume of mould.

γ_w = density of water.

G = Specific gravity of soils. W =

water content.

S = degree of saturation.

Precautions:

1. Thoroughly breakup the sample by running it through the screen before compacting it in the mould.
3. Pound within a moisture range from optimum to 4 percent below optimum. The closer to optimum the moisture content is, the more accurate the test will be.
4. Make sure the clamp on each mold section is tight.
5. Make sure the wing nuts on the base plate are secured with equal tension.
6 Place the mould on a solid block that is supported on firm soil or pavement.
7 Hold the rammer vertically so that it will fall freely.
8 Drop the 25 kg rammer weight freely
9 Use exactly 25 blows on each layer.
10 Place 3 equal layers in the mold

4. Dry density ρd for zero air voids line.

$$\gamma_d = G.\gamma_w/(1 + (w.G/S))$$

Where, M_1 = mass of mould used for proctor test M_2 = mass of mould + compacted soil. M = mass of wet soil.

V = volume of mould.

γ_w = density of water.

G = Specific gravity of soils. W = water content.

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11 Place the mould on a solid block that is supported on firm soil or pavement.
12 Hold the rammer vertically so that it will fall freely.
13 Drop the 25 kg rammer weight freely
14 Use exactly 25 blows on each layer.
15 Place 3 equal layers in the mold

Procedure

a) Select a representative soil sample of about 25 kg. The material used for the test must be finer than 20 mm sieve. Air-dry sample.
b) Add sufficient water to the sample (about 7 % for sandy soils and 10 % for clay soils), which will be less than the estimated optimum moisture content. Mix the soil thoroughly and keep this in an airtight container for a period of 20 hours.
c) Fix the mould to the base plate after cleaning its inside surface. Find the mss of the mould with the base plate (M1).
d) Attach the extension collar to the mould.
e) Take about 2.5 kg of soil in an air tight container and compact it in the mould in three equal layers each layer is compacted by giving 25 blows by the hammer weighing 2.6 kg and dropping from a height of 310 mm. The compaction must be

Uniform over the whole area, and a spatula scratches each layer before adding another layer. The filling must be such that the last layer projects into the collar by about 5 mm. After the completion of compaction, remove the collar and remove the excess soil with the help of a straight edge. Find the mass of the mould with the base plate and the soil (M2). Remove the soil from the mould by making use of an ejector and take a representative sample for water content determination.

f) Carry out the tests 3 to 4 times by repeating the steps from (e) onwards. Each time use a fresh soil sample.

Observations and tabulation:

The following observations were made on the compaction of a soil by standard proctor test. Six tests were carried out on the selected samples of soil by varying the water content. Water contents of samples of each test were found out by the procedure explained earlier.

Table 15: Weight of Soil for varying water content

Test No.	1	2	3	4	5	6
Mass of empty mould M_1 gm						
Volume of mould, cm^3						
Mass of mould + Sample, M_2 gm						
Mass of wet soil, M, gm						
Wet density, γ_b g/cm^3						
Water content, w%						
Dry density, γ_d, gm/cm^3						
W1 for calculation of saturation line %						
γ_d, gm/cm^3 of S=100%						
γ_d, gm/cm^3 of S=80%						

Pre-Viva Questions:

1. What is the difference between standard proctor test and modified proctor test?
2. What is relative density of soil?
3. What is voids ratio? What is zero air voids line?
4. What is the practical implication of conducting standard proctor test?
5. How to determine OMC of soil? Explain.

Result:

Maximum dry density γ_d = _____ g/cm3

Optimum moisture content, w = ____ %

Verification and Validations:

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

Zero air voids curve:

The curve represents the fully saturated condition (S = 100 %). (It cannot be reached by compact ion)

Conclusion:

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

Post-Viva Question:

1. How is compaction different from consolidation?
2. Did you watch any civil engineering construction compaction is carried out? Explain.
3. Is there any other method other than standard proctor test to determine maximum density?

Laboratory Experiment Evaluation Rubric

Category	Outstanding (Up to 100%)	Accomplished (Up to 75%)	Developing (Up to 50%)	Beginner (Up to 25%)
Written/Presentation/Demonstration	The write-up is clear, well-organized, and follows the prescribed format. All required sections (aim, apparatus, theory, procedure, diagram, etc.) are present and well-written. Demonstration is clear and thorough.	The report follows the specified format, but some sections (like the diagram or theory) are missing or incomplete. The demonstration is understandable but lacks depth.	The report includes most sections but lacks clarity, coherence, or completeness in some parts (e.g., diagram missing, unclear theoretical explanation). The demonstration is incomplete or unclear.	The report is poorly written and organized. Many sections are missing or incorrect (e.g., no diagram, incomplete procedure). The demonstration lacks clarity or is missing.
Viva-Voice	Demonstrates a deep understanding of the experiment, underlying principles, and outcomes.	Demonstrates a general understanding of the experiment and principles but struggles with some aspects.	Struggles with some fundamental concepts and principles. Answering questions requires additional	Lacks a basic understanding of the experiment. Unable to answer most questions accurately. Demonstrate

Category	Outstanding (Up to 100%)	Accomplished (Up to 75%)	Developing (Up to 50%)	Beginner (Up to 25%)
	Answers questions confidently and accurately.	Provides correct answers to most questions.	prompts, with a few errors in understanding.	s significant gaps in knowledge.
Performance/Report/File Work	Performs the experiment accurately and efficiently. The report is thorough, with correct observations, calculations, and analysis. Data is recorded neatly and with appropriate units. All relevant calculations and interpretations are included.	Performs the experiment well with minor errors or delays. The report is complete but may contain some inaccuracies or missing components in calculations or observations.	Completes the experiment but with notable mistakes, either in the setup or the data. The report has several missing or inaccurate components, including incorrect or incomplete calculations.	Struggles to perform the experiment correctly. Significant errors in setup, data collection, and analysis. The report is poorly structured with major inaccuracies or missing sections.
Attendance	Consistently attends all lab sessions, actively participates, and engages	Attends most lab sessions with occasional absences. Participation	Attends some lab sessions but has frequent absences or	Misses several lab sessions and shows minimal to no

Category	Outstanding (Up to 100%)	Accomplished (Up to 75%)	Developing (Up to 50%)	Beginner (Up to 25%)
	with the experiment and group discussions.	is generally good but lacks consistency or depth.	minimal participation.	participation in class or group activities.