SHANTILAL SHAH ENGINEERING COLLEGE, BHAVNAGAR

A Laboratory Manual for

Geotechnical Engineering (3130606)

B. E. Semester 3(Civil)

Directorate of Technical Education
Gandhinagar, Gujarat

SHANTILAL SHAH ENGINEERING COLLEGE, BHAVNAGAR

CERTIFICATE

This is to certify that Mr./Ms. ____ Enrollment No. ___________________of B.E. Semester **3rd** Civil Engineering of this Institute (GTU Code: **043** has satisfactorily completed the Practical work for the subject Geotechnical Engineering (3130606) for the academic year 2024-2025.

Place: __________

Date: __________

Dr. H. K. Sarvaiya

Name and Sign of Faculty member

Head of the Department

Preface

The basic aim of laboratory/practical is to enhance the required skills as well as creating ability amongst students to solve real time problem by developing relevant competencies in psychomotor domain. By keeping this in view, GTU has designed competency focused outcome-based curriculum for engineering degree programs where sufficient focus is given to the practical work. It shows importance of enhancement of skills amongst the students and pays attention to utilize every second of time allotted for practical amongst students, instructors and faculty members to achieve relevant outcomes by performing the experiments rather than having merely study type experiments. It is must for effective implementation of competency focused outcome-based curriculum that every practical is keenly designed to serve as a tool to develop and enhance relevant competency required by the various industry among every student. These psychomotor skills are very difficult to develop through traditional chalk and board content delivery method in the classroom. Accordingly, this lab manual is designed to focus on the industry defined relevant outcomes, rather than old practice of conducting practical to prove concept and theory. By using this lab manual students can go through the relevant theory and procedure in advance before the actual performance which creates interest and students can have basic idea prior to performance.

This manual also provides guidelines to faculty members to facilitate student centric lab activities through each experiment by arranging and managing necessary resources in order that the students follow the procedures with required safety and necessary precautions to achieve the outcomes.

Geotechnical engineering is very fundamental subject to study for determination of various soil parameters theoretically and experimentally based on laws of mechanics. Any civil engineering structure needs strong and stable foundation which depends on proper understanding of soil properties and its behavior. Geotechnical Engineering laboratory is planned in aligned with course outcome of the subject by finding various Index, Hydraulic and Mechanical properties of soil through various experiments.

Utmost care has been taken while preparing this lab manual however faculty may do necessary modification if required.

Practical – Course Outcome matrix

Course Outcomes (COs):
1. Determine Index properties of soil.
2. Classify the soil as per Indian standard classification system
3. Determine Compressibility characteristics of soils
4. Determine Hydraulic properties of soil.
5. Determine Strength characteristic of soil.

Sr. No.	Experiment	CO 1	CO 2	CO 3	CO 4	CO 5
1.	Identification of soils		√			
2.	Field density (Core cutter method)	√				
3.	Field density (Sand replacement method)	√				
4.	Specific gravity of soil	√				
5.	Sieve Analysis		√			
6.	Atterberg's Limit		√			
7.	Standard Proctor Test			√		
8.	Permeability Test (Constant Head Method)				√	
9.	Permeability Test (Falling Head Method)				√	
10.	Direct Shear Test					√
11.	Consolidation Test			√		
12.	Unconfined Compression Test					√

Industry Relevant Skills

The following industry relevant competencies are expected to be developed in the student by undertaking the practical work of this laboratory.

1. Able to identify the soil.
2. Able to predict behavior of soil and its suitability for various infrastructure projects.

Guidelines for the Faculty members

1. Teacher should provide the guideline with demonstration of practical to the students with all features.
2. Teacher shall explain basic concepts/theory related to the experiment to the students before starting of each practical.
3. Involve all the students in performance of each experiment.
4. Teacher is expected to share the skills and competencies to be developed in the students and ensure that the respective skills and competencies are developed in the students after the completion of the experimentation.
5. Teachers should give opportunity to students for hands-on experience after the demonstration.
6. Teacher may provide additional knowledge and skills to the students even though not covered in the manual but are expected from the students by concerned industry.
7. Give practical assignment and assess the performance of students based on task assigned to check whether it is as per the instructions or not.
8. Teacher is expected to refer complete curriculum of the course and follow the guidelines for implementation.

Instructions for Students

1. Students are expected to carefully listen to all the theory classes delivered by the faculty members and understand the COs, content of the course, teaching and examination scheme, skill set to be developed etc.
2. Students shall organize the work in the group and make record of all observations.
3. Students shall develop maintenance skill as expected by industries.
4. Student shall attempt to develop related hand-on skills and build confidence.
5. Student shall develop the habits of evolving more ideas, innovations, skills etc. apart from those included in scope of manual.
6. Student shall refer technical magazines and data books.
7. Student should develop a habit of submitting the experimentation work as per the schedule and s/he should be well prepared for the same.

Index

(Progressive Assessment Sheet)

Sr. No.	Experiment	Page No.	Date of performance	Date of submission	Assessment Marks	Sign. of Teacher with date	Remarks
1.	Identification of soils						
2.	Field density (Core cutter method)						
3.	Field density (Sand replacement method)						
4.	Specific gravity of soil						
5.	Sieve Analysis						
6.	Atterberg's Limit						
7.	Standard Proctor Test						
8.	Permeability Test (Constant Head Method)						
9.	Permeability Test (Falling Head Method)						
10.	Direct Shear Test						
11.	Consolidation Test						
12.	Unconfined Compression Test						
Total							

Experiment No: 1

IDENTIFICATION OF SOILS

IS: 1498 – 1970 (Reaffirmed 2007)

Date:

Relevant CO: 2

OBJECTIVES: To identify soils through Manual Identification Tests.

NEED AND SCOPE:

The field method is used primarily in the field to classify and describe soils; Visual observations are employed in place of precise laboratory tests to define the basic soil properties.

THEORY:

Representative sample of the soil is selected which is spread on a flat surface or in the palm of the hand- All particles larger than 80 mm are removed from the sample. Only the fraction of the sample smaller than 80 mm is classified.

The sample is classified as coarse-grained or fine grained by estimating the percentage by weight of individual particles which can be seen by the unaided eye. Soils containing more than 50 percent visible particles are coarse-grained soils, soils containing less than 50 percent visible particles are fine-grained soils.

Followings are the visual identication or quick test can be done on soils for primary identification.

1. Colour

Colour can be a useful indicator of some of the general properties of a soil.

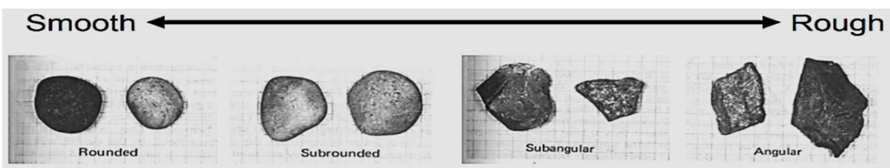
As per colour soils can be classified as Black, White/pale, Red, Yellow to yellow-brown, Brown

Soil colour is usually due to 3 main pigments:

- Black—from organic matter
- Red—from iron and aluminum oxides
- White —from silicates and salt.

2. Shape of the particles

Angular, subangular, subrounded, rounded



3. Odour

Odourless, mild chemical odour, pungent odour, etc.

4. Grain properties:

Coarse, Fine

5. Distinguishing Fine Sand from Clay or Silt

Take some soil and rub it in the palms of your hands. Then turn your hands over, palms down, and shake them. The sand grains will fall off but the silt and clay will stick to the lines in your palm. You can also look closely at the soil. The sand grains are visible to the naked eye but the individual silt and clay particles are not.

6. Distinguishing Clay from Silt

Put some soil in your hand with your palm facing upwards. Mix in some water until the soil is moldable like putty. With your other hand, firmly pat the edge of the hand holding the soil for 5 to 10 seconds. If the surface of the soil starts shining and the water rises to the surface, it’s silt. If the water does not rise, then it is clay. This is because water penetrates silt more easily than clay. Also, clay feels stickier than silt when it’s wet.

Take five different soil samples and do primary identification.

Sr. No.	Colour	Odour	Texture (Appereance/Shape)	Grain Properties (Course/Fine)	Type of soil
1					
2					
3					
4					
5					

Suggested Reference:

IS : 1498 – 1970 (Reaffirmed 2007) Classification and identification of Soils for general engineering purposes.

Experiment No: 2

IN-SITU DENSITY OF SOIL (SAND REPLACEMENT METHOD)

(IS 2720-PART-28-1974) Reaffirmed-2010

Date:

Relevant CO: 1

OBJECTIVES: To determine the field density of fine grained natural or compacted soils by core-cutter method.

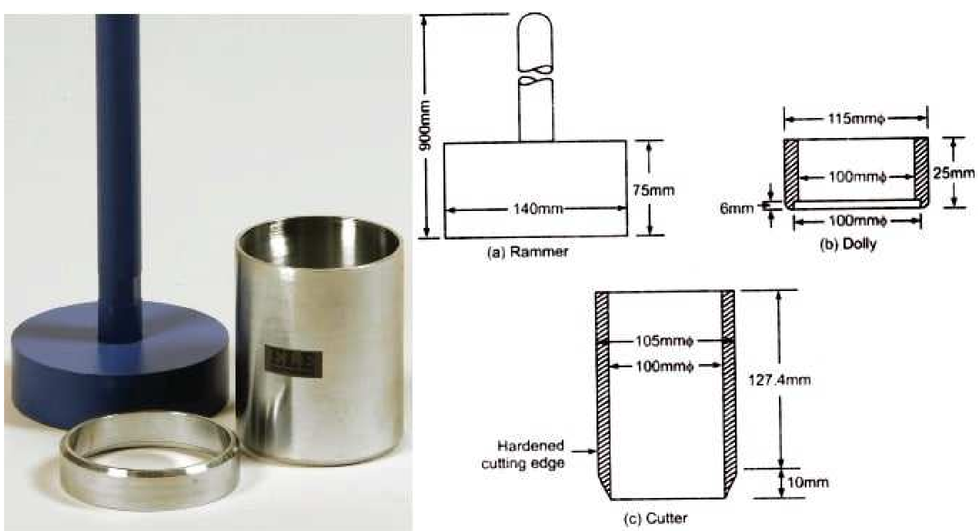
NEED AND SCOPE: The in situ density of natural soil is needed for the determination of bearing capacity of soils, for the purpose of stability analysis of slopes, for the determination of pressures on underlying strata for the calculation of settlement and the design of underground structures.

LIMITATIONS

This method can not be used for gravelly soil, in which the sharp edges of the core-cutter would deteriorate on ramming. Moreover, it can' not be used for purely cohesionless soil, where the soil is not able to stick to the inner surface of core cutter. In such cases, core cutter can not retain the soil; hence sand replacement method shall be used.

APPARATUS:

1. Cylindrical Core- Cutter
2. Steel Dolly
3. Vernier Callipers
4. Steel Rammer
5. Straight edge
6. Balance 20 kg capacity accurate to 1g.
7. Small containers
8. Balance with a sensitivity of 0.01 gm
9. Oven controlled at 105˚ C



THEORY:

On field the moisture content of soil is likely to vary from time to time and hence the field density also. The relationship that can be established between the dry densities with known moisture content is as follows:

Dry Density of Soil $\gamma_d = \gamma_b /1+w$

Where, = dry density , γ_b = Bulk density , w = water content

PROCEDURE:

Determination of In-Situ Bulk Density

1. Take the empty weight of core cutter and measure the internal diameter and height of the core cutter using a vernier callipers.
2. Level the soil surface, where we need to find the in-situ density and place the core cutter vertically on the surface, with a dolly over it.
3. Using the rammer, give blows to the core cutter assembly to drive it inside the ground. Stop ramming when the dolly is just around the surface.
4. Dig out the cutter containing the soil out of the ground and trim off any solid extruding from its ends, so that the cutter contains a volume of soil equal to its internal volume determined from dimensions of core cutter.
5. Determine the weight of the cutter containing soil core to the nearest gram.
6. Find the in-situ bulk density of soil sample.
7. Take out the soil from the core cutter and take three soil samples for moisture content determination.

Determination of Moisture Content

1. Take the weight of empty containers used for moisture content determination.
2. Place the wet soil sample in the container and take the weight of the container filled with wet soil.
3. Place the containers with wet soil in an oven set at 105˚ C temperature for at least 24 hours for drying.
4. Take out the containers from oven after 24 hours and weigh the container filled with dry soil.
5. Find moisture content of samples.
6. Take average of the moisture content of three samples and report the average moisture content of soil sample

OBSERVATIONS:

Dimensions of Core Cutter

Internal diameter of core cutter = cm

Height of core cutter = cm

Volume of core cutter = cm^3

Bulk density:

Wt. of Core-Cutter (W1)	=	g
Wt. of Core-Cutter + Wet Soil (W2)	=	g
Wt. of Wet Soil (Ws = W2 – W1)	=	g
Volume of Core-cutter (Vc)	=	cm^3
Bulk Density of Soil (γ_b = Ws/Vc)	=	g/cm^3

Moisture Content:

CONTAINER No.			
Wt. of container, Wc (g)			
Wt. of container + Wet soil, Ww (g)			
Wt. of container + Dry Soil , Wd (g)			
Wt. of water, Ww-Wd (g)			
Wt. of dry soil, Wd -Wc (g)			
Moisture Content, w % = (Ww-Wd / Wd-Wc) * 100			
Average Moisture Content, w%			

CALCULATION:

Dry Density:

Dry Density of Soil $\gamma_d = \gamma_b / 1+w$ g/cm^3

RESULT:

(i) Dry Density of Soil

(ii) Water content of the soil (%)

Suggested Reference:

(i) IS: 2720 (Part XXIX)-1975 Determination of dry density of soil in-place by the core cutter method

(ii) IS: 2720 (Part-II)-1973 Determination of water content; Section-I Oven dry method

(iii) Soil Mechanics Virtual Lab: https://smfe-iiith.vlabs.ac.in/

(iv) NPTEL Course: Geotechnical Engineering Laboratory: https://nptel.ac.in/courses/105101160

References used by the students:

Experiment No: 3

IN-SITU DENSITY OF SOIL (SAND REPLACEMENT METHOD)

(IS 2720-PART-28-1974) Reaffirmed-2010

Date:
Relevant CO: 1

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

NEED AND SCOPE:
The in situ density of natural soil is needed for the determination of bearing capacity of soils, for the purpose of stability analysis of slopes, for the determination of pressures on underlying strata for the calculation of settlement and the design of underground structures.

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APPARATUS:

1. Sand pouring cylinder
2. Calibration cylinder
3. Glass plate or Perspex plate
4. Vernier caliper
5. Metal tray with a central hole
6. Tools for excavating hole
7. Balance accurate to 1 g
8. Metal containers to collect excavated soil
9. Thermostatically controlled oven to maintain temperature at 110 $\pm$ 5˚ C

Clean, uniformly graded natural sand passing through 1.00 mm IS sieve and retained on the 600micron IS sieve. It shall be free from organic matter and shall have been oven dried and exposed to atmospheric humidity.

THEORY:
Sand replacement method is used to determine the in-situ density of soil. The in-situ density is defined as the density of soil measured at its actual depth on the field. The in-situ moisture content of soil varies with time, resulting in variable in-situ bulk density. To avoid variation with time, the in-situ density should be reported in terms of the dry density with moisture content. The relationship that can be established between the dry density with known moisture content is as follows:

$$\gamma_d = \gamma_b / (1 + w)$$

γ_d = Dry density

γ_b = Bulk density

w = water content

PROCEDURE:

Calibration of the Apparatus

1. Pour sand into the sand pouring cylinder with valve closed and determine weight of cylinder filled with sand (W1) and this weight should be maintained constant throughout the test for which the calibration is used.
2. Place the apparatus on a smooth glass plate and open the valve to fill the conical portion. After the sand stops running from apparatus, close the valve and remove the cylinder carefully. Weigh the sand collected on the glass plate (W2) .Repeat this step at least three times and take the mean weight (W2) Put the sand back into the sand pouring cylinder to have the same initial constant weight (W1)
3. The weight (W1 – W2) represents the weight of sand required to fill the cone of the apparatus.

Bulk density of sand (γs):-

1. Determine the volume (V) of the calibrating container by filling it with water to the brim. Check this volume by calculating from the measured internal dimensions of the container.
2. Place the sand poring cylinder centrally on the calibrating container making sure that constant weight (W1) is maintained. Open the shutter and permit the sand to run into the container. When no further movement of sand is seen close the shutter, remove the pouring cylinder and find its weight (W3).

Measurement of Soil Density (γ_b)

Prepare the surface of the location to be tested so that it is a level plane.

1. Keep the metal tray with central hole firmly on the surface. Excavate with hand tools a hole with diameter equal to that of the hole of the plate and about 10 cm in depth with smooth walls and rounded bottom edges.
2. Place the extracted soil from hole in a container being careful to avoid losing any material and determine the weight of extracted soil (Ww).
3. Remove the metal tray and place the already weighed sand pouring apparatus filled with sand (W1) on the hole of the tray. Open the valve and after the sand has stopped flowing close the valve.
4. Weigh the pouring cylinder with remaining sand (W4)
5. Take three representative samples from the extracted soil for moisture content determination.

Determination of Moisture Content (w):

1. Take the weight of empty containers used for moisture content determination.
2. Place the wet soil sample in the container and take the weight of the container filled with wet soil.
3. Place the containers with wet soil in an oven set at 105˚ C temperature for at least 24 hours for drying.
4. Take out the containers from oven after 24 hours and weigh the container filled with dry soil.
5. Find moisture content of samples.
6. Take average of the moisture content of three samples and report the average moisture content of soil sample.

From the known density of sand and the weight of sand occupying the hole, calculate the volume of hole. From the weight of the soil scooped out of hole whose volume is now known and the value of moisture content, calculate the wet and dry density of soil.

OBSERVATIONS:

Dimensions of Calibration Cylinder

Internal diameter of calibration cylinder = cm

Height of calibration cylinder = cm

Volume of calibration cylinder from the dimensions = cc

Volume of calibration cylinder from the weight of filled water = cc

Calibration

1	Weight of sand (+cylinder) + before pouring (W1), g	
2	Weight of sand in cone (of pouring cylinder) (W2), g	
3	Weight of sand (+cylinder) after pouring sand in container (W3) g	
4	Weight of sand to fill calibrating container (Wa = W1-W3-W2) g	
5	Bulk density of sand (γ_s) = Wa/V , (g/cc)	

Measurement of the soil density

1	Weight of wet soil from excavated hole (Ww), g	
2	Weight of sand (+cylinder) + before pouring (W1), g	
3	Weight of sand (+cylinder) after pouring sand in hole (W4), g	
4	Weight of sand in excavated hole (Wb = W1-W4-W2) g	
5	Bulk density of in-situ soil (γ_b) = (Ww/Wb)* γ_s , (g/cc)	

Moisture Content

CONTAINER No.			
Wt. of container, Wc (g)			
Wt. of container + Wet soil, Ww (g)			
Wt. of container + Dry Soil , Wd (g)			
Wt. of water, Ww-Wd (g)			
Wt. of dry soil, Wd -Wc (g)			
Moisture Content, w % = (Ww-Wd / Wd-Wc) * 100			
Average Moisture Content, w%			

CALCULATION:

Dry Density of Soil

Dry Density of Soil $\gamma_d = \gamma_b /1+w$ g/cm^3

Result:

(i) Dry Density of Soil =

(ii) Water content of the soil (%)=

Suggested Reference:

(i) IS: 2720 (Part XXVIII)-1974 Determination of dry density of soils in-place by the Sand Replacement method

(ii) IS: 2720 (Part-II)-1973 Determination of water content; Section-I Oven dry method

(iii) NPTEL Course : Geotechnical Engineering Laboratory :https://nptel.ac.in/courses/105101160

References used by the students:

Experiment No: 4

SPECIFIC GRAVITY TEST

(IS-2720-PART-3/section-1-1980) (Reaffirmed-2002)

Date:

Relevant CO: 1

OBJECTIVES: Determine the specific gravity of soil fraction passing 4.75 mm IS sieve by density bottle.

NEED AND SCOPE:

The knowledge of specific gravity is needed in calculation of soil properties like void ratio; degree of saturation etc. The specific gravity is used in the computations of the laboratory tests such as hydrometer test and oedometer test (1-D consolidation test). 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 value in range of 2.75-2.85 indicates the presence of iron or any other metal in the soil.

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APPARATUS:

1. Density bottle of 50 ml capacity with stopper
2. Balance to weigh the materials (accuracy 0.001g)
3. Wash bottle with distilled water.
4. Alcohol and ether.

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.

PROCEDURE:

1. Take the weight of the empty density with stopper ‘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.
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.
6. Determine the weight of the bottle with water and soil, ‘W3’.
7. Then remove the soil and water from the bottle and clean it.
8. Fill the bottle completely with water up to the mark and take the weight of bottle filled with water, ‘W4’.
9. From data obtained determine specific gravity of the soil.

OBSERVATIONS:

Test No.	1	2	3
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 ^{o}c G = (W2 - W1) ./(W4 – W1) – (W3 – W2)			
Average			

RESULT:
Specific gravity of soil sample is

Suggested Reference:
(i) IS-2720(PART-III/sec-1-1980) (Reaffirmed-2002) Determination of Specific Gravity
(ii) Soil Mechanics Virtual Lab: https://smfe-iiith.vlabs.ac.in/
(iii) NPTEL Course: Geotechnical Engineering Laboratory: https://nptel.ac.in/courses/105101160

References used by the students:

Experiment No: 5

SIEVE ANALYSIS

IS: 2720 (Part 4) – 1985 (Reaffirmed-2006)

Dry sieve analysis

Date:

Relevant CO: 2

OBJECTIVES: To determine the percentage of different grain sizes contained within a soil.

NEED AND SCOPE:

The results of grain size analysis are used for the soil classification. Grain size distribution curves are also used in the design of filters for earth dams and to determine the suitability of soils for road construction.

LIMITATIONS

Dry Sieving shall be applicable only to soils which do not have an appreciable amount of clay.

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APPARATUS:

1. A series of sieve sets ranging from 4.75mm to 75µm with pan (4.75mm, 2.00mm, 1.00mm, 600 µm, 425µm, 300µm, 212µm, 150µm, 75µm)
2. Balance sensitive to ± 0.01g
3. Mechanical sieve shaker (Optional)
4. Wire brush

THEORY:

In order to classify a soil for engineering purposes, one needs to know the distribution of the size of grains in a given soil mass. Sieve analysis is a method used to determine the grain-size distribution of soils. Sieves are made of woven wires with square openings.

The following particle classification names are given depending on the size of the particle:

1. Boulder: Particle size is more than 300mm.
2. Cobble: Particle size in range of 80mm to 300mm.
3. Gravel (G): Particle size in range of 4.75mm to 80mm.
   i. Coarse Gravel: 20 to 80mm.
   ii. Fine Gravel: 4.75mm to 20mm.
4. Sand (S): Particle size in range of 0.075mm to 4.75mm.
   i. Coarse sand: 2.0mm to 4.75mm
   ii. Medium Sand: 0.425mm to 2mm
   iii. Fine Sand: 0.075mm to o.425mm.

Name of the soil is given depending on the maximum percentage of the above components.

Broadly, soil can also be classified as:

1. Uniformly graded - Majority percentage of the particles fall within the same range of size.
2. Well graded - The soil contains almost equally distributed percentage of each size of particles.

Grain size distribution curve can be drawn on semi logarithmic chart by plotting percentage finer (ordinary scale) vs particle size (log scale) and obtain the following quantities to help us classify the soil:

1. Coefficient of curvature: $C_c = D_{30}^2 / (D_{60} * D_{10})$

    D_{30} is particle size for which 30% of the soil is finer
    D_{60} is particle size for which 60% of the soil is finer
    D_{10} is particle size for which 10% of the soil is finer.

    All these values are obtained from the plot.

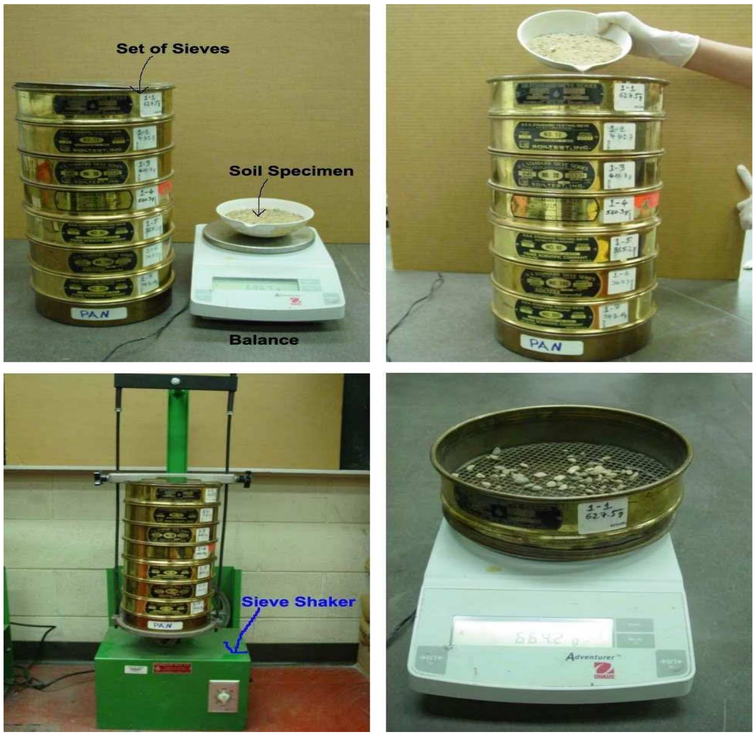
2. Uniformity coefficient: $C_u = D_{60} / D_{10}$

Coefficient of curvature (C_c) should lie between 1 and 3 for well graded gravel and sand.

Similarly, the uniformity coefficient (C_u) value should be more than 4 for well graded gravel and more than 6 for well graded sand. Higher value of C_u indicates that the soil mass consists of soil particles with different size ranges.

PROCEDURE:

1. Take a sample of soil and dry it in oven.
2. Weigh the required quantity of soil and soak it with water. Depending upon the maximum size of the particles present in the sample, the quantity of soil to be taken for the test is decided.
3. Stir the soil-water solution thoroughly and pass it through 4.75mm sieve which segregate gravel fraction from soil.
4. Pass then mixture of soil-water passed through 4.75mm sieve, through 75µ sieve. This will separate silt and clay particles from sand fraction.
5. Place the soil retained on 75µ sieve in the oven for drying.
6. Sieve the dried soil passed through 4.75 mm and retained on 75 µ sieve by using mechanical sieve shaker. The following sets of sieves are used: 2mm, 1mm, 600 µ, 425 µ, 300 µ, 212 µ, 150 µ, 75 µ.
7. Minimum of 10 minutes sieving is required in mechanical sieve shaker.
8. Take the weight of soil retained on each sieve and calculate the cumulative percentage retained in each sieve. Cumulative percentage finer is then calculated.
9. Particle size distribution curve is plotted on a semi-log graph paper.



OBSERVATIONS:

Wt. of Dry Sample: gm

Mass of retained on 4.75 mm sieve: gm

Mass passing through 75 micron sieve: gm

Sieve size	Weight retained sieve (gm)	Cumulative weight retained(gm)	Cumulative (%) weight retained(gm)	Cumulative % Finer (N)
4.75 mm				
2 mm				
1 mm				
600µ				
425 µ				
300 µ				
212 µ				
75 µ				
PAN				

CALCULATION:

Plot Grain Size Distribution curve

From Grain Size Distribution Curve:

% Gravel =

% Sand =

% Clay =

D10 =_________mm

D30 =_________mm

D60 =_________mm

Cc =

Cu=

RESULT:

IS or Unified Classification of Soil: __________

Suggested Reference:

(i) IS: 2720 (Part 4) – 1985 (Reaffirmed-2006) Grain Size Analysis

(ii) Soil Mechanics Virtual Lab: https://smfe-iiith.vlabs.ac.in/

(iii) NPTEL Course: Geotechnical Engineering Laboratory: https://nptel.ac.in/courses/105101160

References used by the students:

Experiment No: 6

ATTERBERG'S LIMIT TEST

(A) LIQUID LIMIT TEST

IS: 2720 (Part 5) – 1985 (Reaffirmed-2006)

Date:
Relevant CO: 2

OBJECTIVES: To determine Liquid Limit fine-grained soil using Casagrande apparatus.

NEED AND SCOPE:
Liquid limit is used for soil classification. It gives an idea of the consistency of the soil in the field, if the in-situ moisture content is known. If the in-situ moisture content of soil is closer to liquid limit, the soil can be considered as soft. If the moisture content is lesser than liquid limit, the soil is brittle and stiffer. From the results of the liquid limit, the compression index may also be estimated. The compression index value helps in settlement analysis.

APPARATUS:

1. Casagrande Liquid limit device
2. Grooving tools of standard tool or ASTM tool
3. 425 μ IS sieve
4. Glass plate, Spatula, Palette Knives, Aluminum Containers
5. Weighing Balance sensitivity 0.01g,
6. Wash bottle filled with distilled water
7. Drying oven set at 105°C.

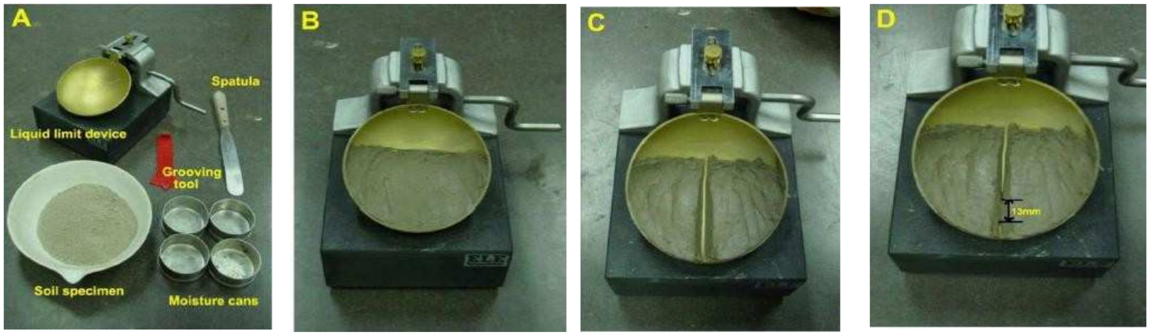
THEORY:
The liquid limit is the moisture content at which the groove, formed by a standard tool into the sample of soil taken in the standard cup, closes for 10 mm on being given 25 blows in a standard manner. At this limit the soil possess low shear strength.

PROCEDURE:

1. About 120 gm of air-dried soil from thoroughly mixed portion of material passing 425 micron IS sieve is to be obtained.
2. Distilled water is mixed to the soil in the mixing dish or the flat glass plate to form uniform paste. The paste shall have a consistency that would require 30 to 35 drops of cup to cause the required closer of the standard groove.
3. A portion of the paste is placed in the cup of LIQUID LIMIT device and spread into portion with few strokes of spatula.
4. Trim it to a depth of 1cm at the point of maximum thickness and return excess of soil to the dish.
5. The soil in the cup shall be divided by the firm strokes of the grooving tool along the diameter through the centre line of the follower so that clean sharp groove of proper dimensions is formed.
6. Lift and drop the cup by turning crank at the rate of two revolutions per second until the two

halves of soil cake come in contact with each other for a length of about 12mm by flow only.

7. The number of blows required to cause the groove close for about 12mm shall be recorded.
8. A representative portion of soil is taken from the cup for water content determination.
9. Repeat the test with different moisture contents at least three more times for blows between 15 and 35.The test should proceed from drier to the wetter condition of soil or vice versa.



OBSERVATIONS:

Sample No.	1	2	3	4
Number of blows (N)				
Container Number				
W_1 = Weight of container (gm)				
W_2= Weight of container + wet soil (gm)				
W_3 = Weight of container + dry soil (gm)				
Weight of water (Ww=W2-W3) (gm)				
Weight of dry soil (Ws=W3-W1) (gm)				
Water content, w% = Ww/Ws				

CALCULATION:

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

Liquid limit, W_L = (At 25 blows, from semi log- graph of water content Vs. No. of blows)

RESULT:

Liquid Limit (LL) of soil is %

(B) PLASTIC LIMIT TEST

IS: 2720 (Part 5) – 1985 (Reaffirmed-2006)

OBJECTIVES: To determine Plastic Limit of fine-grained soil.

NEED AND SCOPE:

Plastic Limit (PL or WP) is the water content of the soil at the boundary between the plastic and semi-solid states. The plastic limit is used for the classification of soils. In addition, the plastic limit of soil is also used, either individually or with other soil properties to correlate engineering properties such as compressibility, permeability, compactability, shrink swell, and shear strength.

APPARATUS:

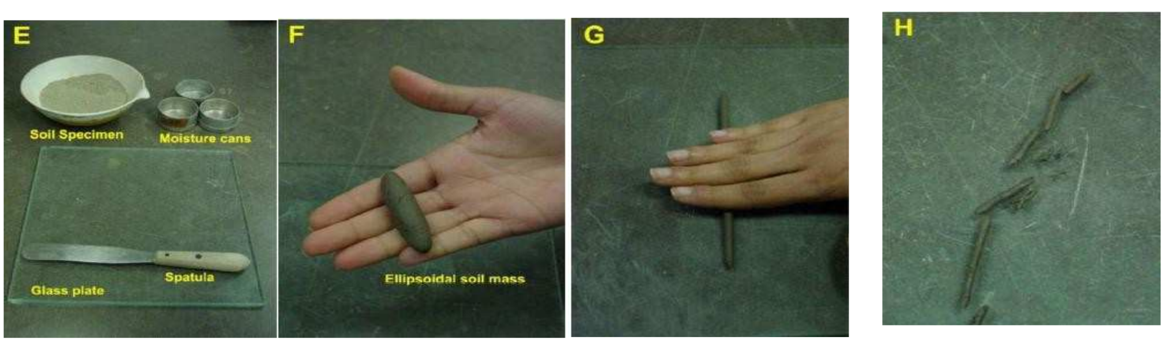
1. Glass plate
2. 425 µ IS sieve
3. 3mm diameter metallic rod about 10 cm long
4. Aluminum Containers for moisture content determination
5. Weighing Balance sensitivity 0.01g
6. Wash bottle filled with distilled water
7. Drying oven set at 105°C.

THEORY:

The plastic limit (PL) is the minimum water content, in percent, at which a soil will just beginto crumble when rolled into a thread of approximately 3 mm in diameter.

The soil in the plastic state can be molded into various shapes. As the water content is reduced, the plasticity of the soil decreases. Ultimately, the soil passes from the plastic state to the semi-solid state when it stops behaving as a plastic. It cracks when molded.

It may also be defined as the water content at which soil changes from plastic state to the semi-solid state.



PROCEDURE:

1. Take about 20gm of thoroughly mixed portion of the material passing through 425 micron IS sieve obtained in accordance with IS 2720 (part 1).
2. Mix it thoroughly with distilled water in the evaporating dish till the soil mass becomes plastic enough to be easily shaped into a balls.
3. Allow it to season for sufficient time (for clay 24 hrs.) to allow water to permeate throughout the soil mass

4. Take about 8gm of this plastic soil mass and roll it between fingers and glass plate with just sufficient pressure to roll the mass into a threaded of uniform diameter throughout its length. The rate of rolling shall be between 80 and 90 strokes per minute.
5. Continue rolling till you get a threaded of 3 mm diameter.
6. Knead the soil together to a uniform mass and re-roll again.
7. Continue the process of alternate rolling and kneading until the thread crumbles under the pressure required for rolling and the soil can no longer be rolled into thread.
8. Collect the pieces of the crumbled thread in air tight container for moisture content determination.
9. Repeat the test to at least 3 times and take the average of the results calculated to the nearest whole number.

OBSERVATIONS:

Sample No.	1	2	3
Number of blows (N)			
Container Number			
W_1 = Weight of container (gm)			
W_2= Weight of container + wet soil (gm)			
W_3 = Weight of container + dry soil (gm)			
Weight of water (Ww=W2-W3) (gm)			
Weight of dry soil (Ws=W3-W1) (gm)			
Water content, w% = Ww/Ws			
Average Plastic Limit,PL (%)			

Plasticity Index, (IP) = (LL - PL)

=

=

Interpretation:

1- Soil classification according to their plasticity index, IP

Plasticity index, IP (%)	**Soil description**
0	Non-plastics
<7	Low plastic
7-17	Medium plastic
>17	Highly plastic

2- Relationship between plasticity index (IP) and swelling potential

Plasticity index, IP (%)	Swelling potential
0 - 15	Low
10 - 35	Medium
20 - 35	High
35 and above	Very high

RESULT:

Plastic limit of soil in % =

Soil classification according to plasticity index –

Swelling potential of soil-

Suggested Reference:

(i) IS: 2720 (Part 5) – 1985 (Reaffirmed-2006) Determination of Liquid and Plastic Limit
(ii) Soil Mechanics Virtual Lab: https://smfe-iiith.vlabs.ac.in/
(iii) NPTEL Course: Geotechnical Engineering Laboratory: https://nptel.ac.in/courses/105101160

References used by the students:

Experiment No: 7

COMPACTION TEST-(LIGHT WEIGHT/STANDARD PROCTOR COMPACTION)

(IS 2720- PART VII-1980) Reaffirmed-2011

Date:

Relevant CO: 3

OBJECTIVES: To determine relationship between water content and the dry density of a soils using light compaction.

LIMITATIONS:

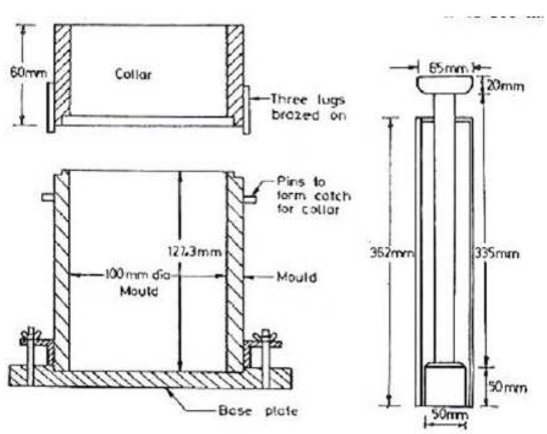
This procedure is satisfactory for cohesive soils but does not lend itself well to the study of the compaction characteristics of clean sand or gravels which displace easily when stuck with rammer.

NEED AND SCOPE:

This test provides optimum moisture content (OMC) and maximum dry density (MDD) of a given soil, which is important for man-made (compacted) earth structures. The results obtained from this test will be helpful in increasing the bearing capacity of foundations, decreasing the undesirable settlement of structures, controlling undesirable volume changes, reducing hydraulic conductivity, increasing the stability of slopes and so on.

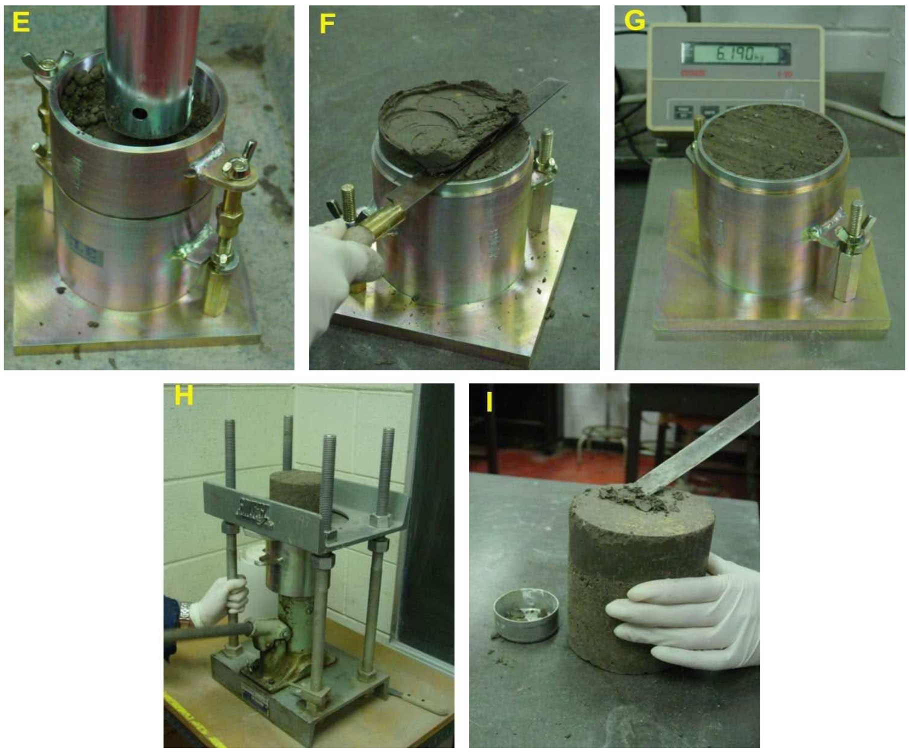
APPARATUS:

1. Proctor mould having a capacity of 1000 cc with an internal diameter of 100 mm and a height of 127.3 mm. The mould shall have a detachable collar assembly and a detachable base plate
2. A hand operated metal rammer having a 50.8 mm face diameter and a weight of 2.6 kg. The rammer shall be equipped with a suitable arrangement to control the height of drop to a free fall of 310 mm.
3. Sample extruder, mixing tools such as mixing pan, spoon, towel, and spatula..
4. A balance of 10 kg capacity with sensitivity 1g and other capacity 200g and sensitivity 0.01g, moisture tins. Sensitive balance.
5. Straight edge.
6. Graduated cylinder.
7. Mixing tools such as mixing pan, spoon, towel, spatula etc.
8. Container for water content determination.



THEORY:

Compaction is the process by which soil particles are packed more closely together by expulsion of air from the pores. Compaction is done by application of mechanical energy such as by tamping, rolling and vibration. It increases the density of soil. Maximum dry density is determined from standard proctor test. The moisture content at which dry density is maximum for a given compactive effort is called OMC .Water content, beyond OMC, tends to keep the soil particles apart without causing an appreciable change in air voids, which results in low dry density and high void ratio. Hence knowledge of OMC is essential to achieve a particular compaction.



PROCEDURE:

1. Take a representative oven-dried sample, approximately 5 kg passing the 20 mm IS sieve.in the given pan. Thoroughly mix the sample with sufficient water to dampen it with approximate water content (for cohesion less soils approx. 4-6% and for cohesive soils approx.14- 18%).
2. Weigh the proctor mould without base plate and collar (W1). Fix the collar and base plate.
3. Place the soil in the Proctor mould and compact it in 3 layers giving 25 blows per layer with the 2.6 kg rammer falling from height of 310mm. The blows shall be distributed uniformly over the surface of each layer.
4. Remove the collar; trim the compacted soil even with the top of mould using a straight edge and weigh (W2).
5. Divide the weight of the compacted specimen by volume of the mould and record the result as the bulk density (γb).
6. Remove the sample from mould and slice and obtain a small sample from mid layer for water content determination.
7. Thoroughly break up the remainder of the material until it will pass 4.75 mm sieve as judged by the eye.
8. Add water in sufficient amounts to increase the moisture content of the soil sample by one or

two percentage and repeat the procedure mentioned in 3 to 6 for each increment of water added. Continue this series of determination until there is either a decrease or no change in the wet unit weight of the compacted soil.

OBSERVATIONS:

Density Determination:

Mould Diameter ………... cm

Height ………… cm

Volume ………. cc

Weight ………… gm

Sample No.	**1**	**2**	**3**	**4**	**5**
Container Number					
M_1 = Mass of empty mould (gm)					
M_2=Mass of mould+ compacted soil (gm)					
Mass of compacted soil = M= M_2 - M_1					
Bulk density, γ_b = M / V gm/cm^3					
w = Water content, w%					
Dry density, γ_d = γ_b / 1+w gm/cm^3					

Water Content Determination:

CONTAINER No.					
Wt. of container, Wc (g)					
Wt. of container + Wet soil, Ww (g)					
Wt. of container + Dry Soil , Wd (g)					
Wt. of water, Ww-Wd (g)					
Wt. of dry soil, Wd -Wc (g)					
Moisture Content, w % = (Ww-Wd / Wd-Wc) * 100					
Average Moisture Content, w%					

CALCULATION:

Plot dry density vs. moisture content and find out the max dry density and optimum moisture for the soil.

GENERAL REMARKS:

• The peak point of the compaction curve:

The peak point of the compaction curve is the point with the maximum dry density γd max.; corresponding to the maximum dry density γ d max is a water content known as the optimum water content (also known as the optimum moisture content, OMC).

Note that the maximum dry density is only a maximum for a specific compactive effort and method of compaction. This does not necessarily reflect the maximum dry density that can be obtained in the field.

RESULT:

From the plot,

Optimum Moisture Content (OMC)= %

Maximum Dry Density (MDD) = gm/cm^3

Suggested Reference:

(i) IS 2720- PART VII-1980) Reaffirmed-2011 Determination of water content-Dry density relationship using Light Compaction Test

(ii) Soil Mechanics Virtual Lab: https://smfe-iiith.vlabs.ac.in/

(iii) NPTEL Course: Geotechnical Engineering Laboratory: https://nptel.ac.in/courses/105101160

References used by the students:

Experiment No: 8

PERMEABILITY TEST-CONSTANT HEAD METHOD

(IS 2720-PART-17-1986) Reaffirmed-2002

Date:

Relevant CO: 4

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

NEED AND SCOPE:

Permeability is useful in solving engineering problems involving flow of water through soils such as determining yield of water bearing strata, assessing seepage through earthen dams, computing losses from canals, Dewatering and drainage of excavation, back fills and subgrades etc. Usually, permeability of soils is determined by two methods:

1. Constant Head Permeability method
2. Falling Head Permeability method.

Constant head permeability test is suitable for cohesionless (Coarse and medium Sands) soils. The falling head method of determining permeability is used for soil with low discharge

APPARATUS:

1. Permeameter mould of non-corrodible material having a capacity of 1000 ml, with an internal diameter of 100 ±0.1 mm and internal effective height of 127.3± 0.1 mm.
2. The mould shall be fitted with a detachable base plate and removable extension collar.
3. Compacting equipment: 50 mm diameter circular face, weight 2.6 kg and height of fall 310 mm as specified in IS 2720- part VII 1980.
4. Drainage bade: A bade with 12 mm thick porous disc having its permeability 10 times of that for soil.
5. Drainage cap: A porous disc of 12 mm thick, having a fitting for connection to water inlet or outlet.
6. Constant head tank: A suitable water reservoir capable of supplying water to the Permeameter under constant head.
7. Graduated glass cylinder to receive the discharge.
8. Stop watch to note the time, and a meter scale to measure the head differences and length of specimen.

THEORY:

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

Coefficient of permeability for a constant head test is given by

$$k = Q.L / (A.h.t)$$

Q: Quantity of discharge

L: Length of specimen

A: Area of specimen cm

h:Height of water

t: time

GENERAL REMARKS:

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

   a. High permeability: $k > 10^{-4}$ cm/sec
   b. Medium permeability: 10^{-7} cm/sec $< k < 10^{-4}$ cm/sec
   c. Low permeability: $k < 10^{-7}$ cm/sec

4. General values of permeability for different types of soils are given below:
   a. Gravel: 10^{-3} to 1 cm/sec
   b. Medium and Coarse Sand: 1 to 10^{-3} cm/sec
   c. Fine Sand and Silt: 10^{-3} to 10^{-6} cm/sec
   d. Clay: less than 10^{-7} cm/sec
   e. Fly Ash: 1×10^{-4} to 5×10^{-4} cm/sec

PROCEDURE:

Preparation of Test Specimen:

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

A. Undisturbed soil specimen

Note down-sample no., borehole no., depth at which sample is taken.

1. Remove the protective cover (wax) from the Shelby tube.
2. Place the Shelby tube in the sample extractor and push the plunger to get a cylindrical shaped specimen not larger than 85 mm diameter and height equal to that of the permeameter mould.
3. This specimen is placed centrally over the porous stone of base plate.
4. Porous stone is also placed at the top of the sample .
5. The specimen is now ready for test.

B. Remolded specimen

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

Preparation of Dynamically Compacted (Remolded) sample:

1. Take 2.5 kg of representative soil and mix it with water to get O.M.C
2. Assemble the permeameter for dynamic compaction. Grease the inside of the mould and place it upside down on the dynamic compaction base. Weigh the assembly correct to a gm .Put the collar to the other end.
3. Now, compact the wet soil in 3 layers with 25 blows to each layer with a 2.6 kg dynamic tool. Remove the collar and then trim off the excess. Weigh the mould assembly with the soil.
4. Place the filter paper or fine wire mesh on the top of the soil specimen and fix the perforated base plate on it.
5. Turn the assembly upside down and remove the compaction plate. Insert the sealing gasket and place the top perforated plate on the top of soil specimen. And fix the top cap.
6. Now, the specimen is ready for test

Constant Head Test

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

The flow is very low at the beginning, gradually increases and then stands constant.
For the purpose of getting a quantitative description of the state of the sample, after the test, the weight of wet soil specimen *Wt*, is measured and recorded. Its dry weight *Ws*, is measured after drying for 24 hours. The water content, *w* is computed and noted. From the knowledge of the specific gravity *Gs*, of specimen and water content *w*, void ratio *e* and degree of saturation *S* are determined.

OBSERVATIONS:

Details of sample

Diameter of specimen ((D) ………………. cm

Length of specimen (L) …..…………… cm

Area of specimen (A) ……………..…….cm^2

Volume of specimen (V) …………….cm^3

Experiment No.	1	2	3
Discharge Q (cm^3)			
Time t (sec)			
Height of water h(cm)			
Temperature (^oC)			
Coefficient of Permeability at …… ^oCk = Q.L / (A.h.t) cm/sec			
Average Permeability, k cm/sec			

Result:

Permeability of soil at ^oC is cm/s

Suggested Reference:

(i) IS 2720-PART-17-1986) Reaffirmed-2002 Laboratory determination of permeability

(ii) Soil Mechanics Virtual Lab: https://smfe-iiith.vlabs.ac.in/

(iii) NPTEL Course: Geotechnical Engineering Laboratory: https://nptel.ac.in/courses/105101160

References used by the students:

Experiment No: 9

PERMEABILITY TEST-FALLING HEAD METHOD

(IS 2720-PART-17-1986) Reaffirmed-2002

Date:

Relevant CO: 4

OBJECTIVES: To determine the coefficient of permeability of a soil using falling head method

NEED AND SCOPE:

Permeability is useful in solving engineering problems involving flow of water through soils such as determining yield of water bearing strata, assessing seepage through earthen dams, computing losses from canals, Dewatering and drainage of excavation, back fills and subgrades etc. Usually, permeability of soils is determined by two methods:

1. Constant Head Permeability method
2. Falling Head Permeability method.

Constant head permeability test is suitable for Cohesionless (Coarse and medium Sands) soils.
The falling head method of determining permeability is used for soil with low discharge

APPARATUS:

1. Permeameter with drainage base and drainage cap
2. Set of Stand pipes
3. De-aired water
4. Balance to weigh up to 1gm
5. IS sieves 4.75 mm
6. Mixing pan
7. Stop watch
8. Measuring jar
9. Meter scale
10. Thermometer
11. Container for water
12. Trimming knife

THEORY:

The passage of water through porous material is called seepage. A material with continuous voids is called a permeable material. Hence permeability is a property of a porous material which permits passage of fluids through interconnecting conditions.
The rate of flow under laminar flow conditions through a unit cross sectional are of porous medium under unit hydraulic gradient is defined as coefficient of permeability.

Coefficient of permeability (k) :

$$k = 2{\cdot}3\,\frac{a \cdot L}{A \cdot t}\log_{10}\frac{h_1}{h_2}$$

where, a = c/s area of stand pipe (cm^2)

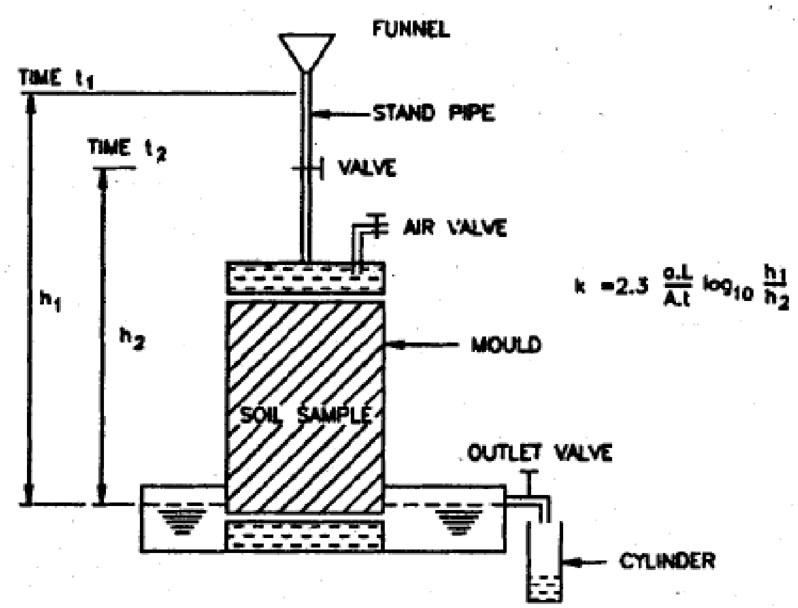
A = c/s area of soil sample = $\frac{\pi}{4} \times D^2$ (cm^2)

L = length of soil sample (cm)

t = time interval to fall head from h_1 to h_2

h_1 = initial head (cm)

h_2 = final head (cm).



PROCEDURE:

1. Prepare the soil specimen as specified.
2. Saturate the specimen preferably by using De-aired water.
3. Assemble the permeameter.
4. Inlet nozzle of the mould is connected to the stand pipe. Allow the water to flow until steady flow is obtained.
5. Note down the time interval ‘t’ for a fall of head in the stand pipe ‘h’.
6. Repeat step 5 three times to determine ‘t’ for the same head.

OBSERVATIONS:

Details of sample

Diameter of specimen (D)= ………………. cm

Length of specimen (L)= …..…………… cm

Area of specimen (A) = ……………..…….cm^2

Volume of specimen (V) = …………….cm^3

Area of stand pipe (a) =………….. cm^2

Experiment No.	1	2	3
Initial reading of stand pipe (h1)cm			
Final reading of stand pipe (h2) cm			
Time (t) sec.			
Temperature of water (^{o}C)			
Coefficient of permeability at …….. ^{o}Ck = 2.303.a.L.(log10 (h1/h2))/ (A.t)			
Average Permeability, k cm/sec			

RESULT:

Mention the value of permeability at T ^{o}C in cm/s

Suggested Reference:

(i) IS 2720-PART-17-1986) Reaffirmed-2002 Laboratory determination of permeability

(ii) Soil Mechanics Virtual Lab: https://smfe-iiith.vlabs.ac.in/

(iii) NPTEL Course: Geotechnical Engineering Laboratory: https://nptel.ac.in/courses/105101160

References used by the students:

Experiment No: 10

DIRECT SHEAR TEST

(IS-2720-PART-13-1986) Reaffirmed-2002

Date:

Relevant CO: 5

OBJECTIVES: To determine the shearing strength of the soil using the direct shear apparatus.

NEED AND SCOPE:

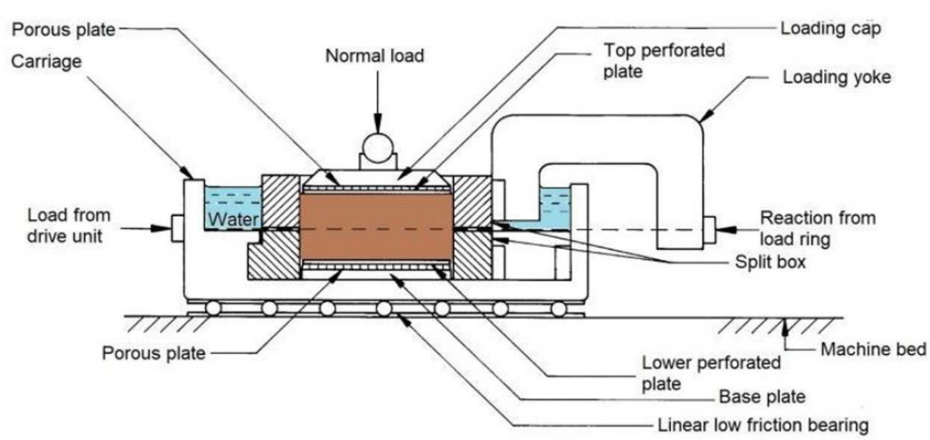
The concept of direct shear is simple and mostly recommended for granular soils, sometimes on soils containing some cohesive soil content. The shear strength is one of the most important engineering properties of a soil, because it is required whenever a structure is dependent on the soil's shearing resistance. The shear strength is needed for engineering situations such as determining the stability of slopes or cuts, finding the bearing capacity for foundations and calculating the pressure exerted by a soil on a retaining wall.

APPARATUS:

1. Direct shear box apparatus and Loading frame (motor attached).
2. Two Dial gauges, proving ring, Weighing Balance with an accuracy of 0.01g.
3. Sample Extractor (Undisturbed sample) / Sampler for preparation of a remolded sample of dimension (60mm*60mm*25mm).
4. Tamper, Straight edge, Spatula.
5. Filter paper
6. Two porous stones
7. Two corrugated metallic plates with perforation (drained) / metallic imperforated plates with corrugation (undrained)
8. Metallic Pressure pad

Knowledge of Equipment:

Strain-controlled direct shear machine consists of a shear box, soil container, loading unit, proving ring, and dial gauge to measure shear deformation and vertical deformation. A proving ring is used to indicate the shear load taken by the soil along the shearing plane.



Typical setup for a direct shear test

THEORY:

The test is carried out on either undisturbed samples or remolded samples. To facilitate the remolding purpose, a soil sample may be compacted at optimum moisture content in a compaction mould. Then specimen for the direct shear test could be obtained using the correct cutter provided. Alternatively, sand sample can be placed in a dry state at a required density, in the assembled shear box. A normal load is applied to the specimen and the specimen is sheared across the pre-determined horizontal plane between the two halves of the shear box. Measurements of shear load, shear displacement and normal displacement are recorded. The test is repeated for two or more identical specimens under different normal loads. From the results, the shear strength parameters can be determined.

The strength of a soil depends of its resistance to shearing stresses. It is made up of basically the components;

1. Frictional – due to friction between individual particles.
2. Cohesive - due to adhesion between the soil particles

The two components are combined in Coulomb's shear strength equation,

$$\tau_f = c + \sigma_f \tan ø$$

Where,

τ_f = shearing resistance of soil at failure

c = apparent cohesion of soil

σ_f = total normal stress on failure plane

ø = angle of shearing resistance of soil (angle of internal friction)

PROCEDURE:

1. Check the inner dimension of the soil sampler, and put the parts of the direct shear apparatus together.
2. Calculate the volume of the sampler. Weigh the sampler.
3. Place the soil inside the sampler in three smooth and equal layers. If the dense sample is desired, tamp the soil with appropriate equal number of blows in each layer for the required density.
4. After completing three layers, level the top layer and weigh the soil sampler with soil. Find the weight of wet soil and calculate the density of soil to confirm whether the required density is achieved.
5. Place the base plate in the shear box and perforated grid plate (for submerged condition) over it in such a way that the serrations of the grid plate are perpendicular to the direction of shear. Then, put the filter paper and place the soil specimen over it.
6. Lock the upper and lower half of the shear box with locking screws. After locking, place the upper filter paper, perforated grid plate, porous stone, and loading pad sequentially on the top of soil.
7. Create a small gap of approximately 1 mm between two parts of the shear box using spacing screws.
8. Place the whole assembly in the box of the loading frame and put the loading yoke on top of the loading pad.
9. Adjust the dial gauges and proving ring to zero position after setting up the specimen set up. Apply the desired normal stress say, 0.5 kg/cm^2 , add water (if soaked condition) at the top of the direct shear box set up, and wait for at least 20 minutes to ensure saturation (until the

reading in vertical dial gauge becomes constant) and then remove the locking screws.

10. Measure the final vertical dial gauge reading which measures the deformation in the vertical direction due to saturation.
11. Record the initial reading of the horizontal dial gauge and proving ring values before starting the shearing.
12. Check all adjustments to see that there is no connection between two parts except soil.
13. Set the strain-controlled frame to the required strain rate. Start the motor. Take the reading of the shear force in the proving ring with respect to the change in horizontal dial gauge reading and vertical deformation in vertical dial gauge till failure.
14. The steps from 1 to 13 have to be repeated for another two normal stresses ($1.0\ kg/cm^2$ and $1.5\ kg/cm^2$)

OBSERVATIONS:

Size of the sample = 60 mm x 60 mm x 25 mm

Area of the sample (Cross Sectional) = 36 sq.cm

Volume of the sample = 90 cm^3

Least count of dial gauge (Horizontal) = _______

Least count of dial gauge (Vertical) = _______

Proving Ring No. = _______

Proving ring constant = _______

Density of the sample (gm/cc) = _______

For Normal Load = 0.5 kg/cm^2

Strain Gauge Reading	Proving Ring Reading	Load (Kg)	Corrected Area (cm^2)	% Strain	Shear Stress (kg/cm^2)

For Normal Load = 1 kg/cm^2

Strain Gauge Reading	Proving Ring Reading	Load (Kg)	Corrected Area (cm^2)	% Strain	Shear Stress (kg/cm^2)

For Normal Load = 1.5 kg/cm^2

Strain Gauge Reading	Proving Ring Reading	Load (Kg)	Corrected Area (cm^2)	% Strain	Shear Stress (kg/cm^2)

CALCULATIONS:

1. Shear stress (τ) on the horizontal failure plane is calculated as $\tau = S/A$; Where S is shear force. A is the horizontal cross-sectional area of the sample, which decreases slightly with the horizontal deformations.
2. Corrected area (Acorr) needs to be calculated for calculating the shear stress at failure.
   Acorr = A0*(1-δ/6), where δ is horizontal displacement due to the shear force applied to the specimen. A0 is the initial area of the soil specimen. A0 and δ are in cm.
3. i. Shear Stress = (Proving ring reading x Proving ring constant)/Acorr

ii. Horizontal displacement = Horizontal dial gauge reading x Least count of horizontal dial gauge
iii. Vertical displacement = Vertical dial gauge reading x Least count of vertical dial gauge

4. Shear stress at failure needs to be calculated for all three tests performed at three different normal stresses to plot the failure envelope.

RESULT:

Cohesion Intercept (c)
Angle of shearing resistance (ϕ)

Suggested Reference:

(i) (IS-2720-PART-13-1986) Reaffirmed-2002 Direct Shear Test
(ii) Soil Mechanics Virtual Lab: https://smfe-iiith.vlabs.ac.in/
(iii) NPTEL Course: Geotechnical Engineering Laboratory: https://nptel.ac.in/courses/105101160

References used by the students:

Experiment No: 11

CONSOLIDATION TEST- (OEDOMETER TEST)

(IS 2720-PART-15-1986) Reaffirmed-2002

Date:

Relevant CO: 3

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

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

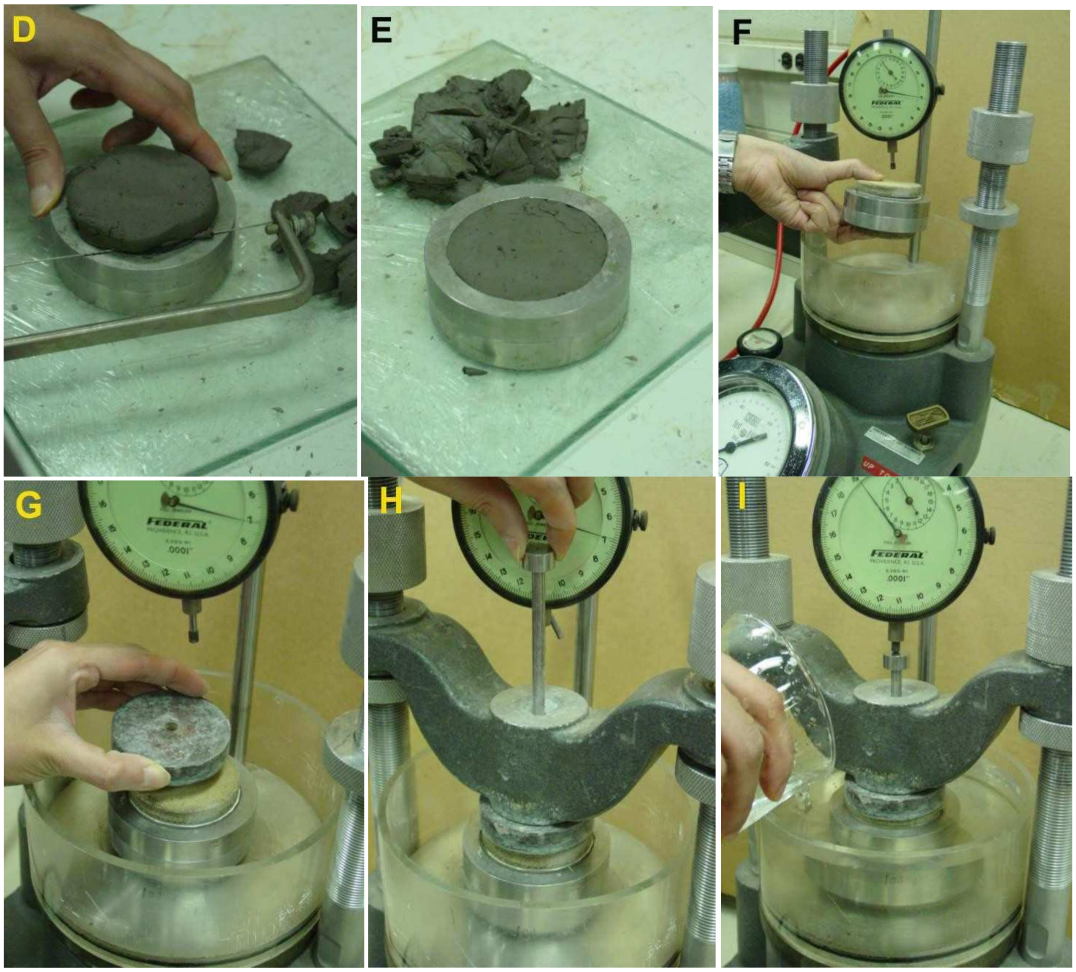
The above information can be used to predict the time rate and extent of settlement of structures founded on fine-grained soils. It is also helpful in analyzing the stress history of soil.

APPARATUS:

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

THEORY:

When compressive load applied to the soil mass, a decrease in its volume takes place. This tendency of soil to decrease its volume under pressure is known as compressibility. In saturated soil its voids are filled with incompressible water, decrease in volume takes 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 load is applied on saturated soil mass, the entire load is carried by pore water in the beginning. As water start escaping from voids. The hydrostatic pressure on water gets gradually dissipate and the load is shifted to the soil solid which increases effective pressure on them, as a result the soil mass decrease in volume. The rate of escape of water depends onthe permeability of the soil.



PROCEDURE:
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.

CONSOLIDATION TEST

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.

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.

OBSERVATIONS:

Before Test

Ring Dimensions: Diameter (cm): _____________

Area (cm^2): ______________

Height (cm): ______________

Initial Data: Specimen Ht (cm).____________

Weight of Ring (g): ____________

Specific Gravity of Soil: ____________

Weight of wet soil + Ring (g): ___________

Bulk Density (g/cc): __________

After Test

Water Content determination:

Weight of Saturated Sample + Ring (g): _____________

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

Water Content (%): __________

TableI: Data Sheet for Consolidation Test: Time-Displacement Relationship

Pressure intensity (kg/cm^2)		0.1	0.2	0.5	1	2	4	8
Elapsed time, min	$\sqrt{t}$							
0								
0.25								
1								
2								
4								
8								
15								
30								
1 hr.								
2 hrs.								
4 hrs.								
8 hrs.								
24 hrs.								
unloading								
0- loading								

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

Applied Pressure	Final dial reading	Change in specimen Height	Final specimen Height	Void ratio	Average Height during Consolidation	Fitting Time, t90	Coefficient of Consolidation, cv
0							
0.1							
0.2							
0.5							
1							
2							
4							
8							
2							
0.5							
0.1							

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 σ_v')

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

ii. $Cv = 0.848\ d^2 / t_{90}$ (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 Cv are recorded in Table II.

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 Cc.
5. Coefficient of compressibility.
It is calculated as follows $a_v = \Delta e / \Delta \sigma'$
Δe – Change in void ratio
$\Delta \sigma'$ - Change in vertical stress
6. Coefficient of permeability.
It is calculated as follows
$k = C_v . a_v . \gamma_w / (1+e_o)$

RESULT:

Compression Index (Cc) =

Coefficient of consolidation (Cv) =

Suggested Reference:
(i) (IS 2720-PART-15-1986) Reaffirmed-2002 - Determination of Consolidation Properties
(ii) Soil Mechanics Virtual Lab: https://smfe-iiith.vlabs.ac.in/
(iii) NPTEL Course: Geotechnical Engineering Laboratory: https://nptel.ac.in/courses/105101160

References used by the students:

Experiment No: 12

UNCONFINED COMPRESSION TEST

(IS-2720-PART-10-1991) Reaffirmed-2006

Date:

Relevant CO: 5

OBJECTIVES: To determine unconfined compressive strength of a cohesive soil.

NEED AND SCOPE:

Unconfined compression test gives undrained shear strength (Su) of cohesive soils. *Su* is useful in determination of bearing capacity of soil, stability of earthen dam embankments (cohesive soil is used in the core of earthen dam) etc. One of the critical conditions for stability of earthen embankments occurs, immediately after construction, which represents the undrained condition. In such conditions, undrained shear strength obtained from UC test can be helpful for stability analysis.

APPARATUS:

1. Unconfined compression apparatus, proving ring type
2. Proving ring, capacity 1 KN, accuracy 1 N
3. Dial gauge, accuracy 0.01 mm
4. Weighing balance
5. Oven
6. Stop watch
7. Sampling tube
8. Split mould, 38 mm diameter, 76 mm long
9. Sample extractor
10. Knife
11. Vernier calipers
12. Large mould

THEORY:

Unconfined compression (UC) test also known as uniaxial compression tests, is a special case of a triaxial test, where confining pressure is zero. It is very quick and simple test as compared to triaxial test and does not require the sophisticated triaxial setup. In this test, a cylindrical specimen of soil without lateral support is tested to failure in simple compression, at a constant deformation rate. Compressive load per unit area required to fail the specimen without any confinement is called unconfined compressive strength of the soil. This test is mainly performed for the cohesive soil, whose specimens can stand without any support.

The unconfined compressive strength (qu) is the load per unit area at which the cylindrical specimen of a cohesive soil fails in compression

$$qu = P/A$$

The undrained shear strength (s) of the soil is equal to one half of theunconfined compressive strength, Su = qu / 2

PROCEDURE:

Sample preparation:

1. For the desired water content and the dry density, calculate the weight of the dry soil, W_S, required for preparing a specimen of required dimensions (diameter and height)
2. Add required quantity of water, w_w, to this soil. $W_W = WS \times W/100$ gm
3. Mix the soil thoroughly with water.
4. Divide the wet soil into equal parts same as the number of the layers in which the soil is to be compacted.
5. Apply silicon spray coating on the inner side of split mold and bottom plate of mold.
6. Place the soil required for one layer in the split mold arrangement with bottom cap and collar.
7. Compact the soil using the cylindrical block and rammer until the required height of layer is achieved.
8. Check the height of the layer using the markings on the cylindrical block.
9. Scratch the layer before placing the soil for next layer to assure the proper bonding between two layers.
10. Repeat steps 7-9 for each layer until required height of specimen is achieved.
11. Extract the specimen from the split mold.
12. Record the height, weight and diameter of the specimen.

COMPRESSION TEST

1. Place the bottom platen on the loading frame and then place the specimen on bottom platen.
2. Place the top cap on the specimen and a steel ball on the circular impression of top cap.
3. Adjust the center line of the specimen such that the proving ring and the steel ball are in the same line.
4. Fix a dial gauge to measure the vertical compression of the specimen.
5. Adjust the gear position on the load frame to give suitable deformation rate. The deformation rate of 1.25 mm/min is commonly used to conduct the UC test on soil specimens of 38 mm diameter
6. Start applying the load and record the readings of the proving ring and compression dial for every 25 dial gauge reading.
7. Continue loading till failure or 20% axial strain (whichever is reached earlier) and then take the picture of the failure pattern of the specimen
8. Repeat the procedure for at least three specimens

OBSERVATIONS:

Type Undisturbed/Remoulded:

Dry density = ______________ g/cc

Water content (%) = ______

Degree of saturation = _______ %

Diameter (Do) of the sample ______ cm

Area of cross-section = _______ cm^2

Initial height (Lo) of the sample =______ cm

Proving ring constant = _______

Dial gauge constant = _______mm

Deformation rate= __________ mm/min

Elapsed time (minutes)	Compression dial reading (divisions)	Axial deformation, ΔL (mm)	Axial Strain (ε)= (ΔL / Lo)	Corrected Area A= Ao / (1- ε) (cm)	Proving ring reading (Divns)	Axial load (kN)	Compressive stress (kPa)

CALCULATIONS:

1. Axial stress = (Proving ring reading x Proving ring constant) / Acorr
2. Acorr= A_0/ (1-ε); A_0 is initial cross-sectional area of the soil specimen; ε is the axial strain at that point of loading.
3. Plot the axial stress- axial strain curve for all three specimens on a single plot
4. Maximum axial stress is obtained, which is also considered to be the failure point of the specimen. Find the average value of maximum axial stress obtained in all three UC tests.
5. Unconfined compression strength of the soil, qu = average value of maximum axial stress of three tests (If the plots are not overlapping and the variation in the maximum values are quite high, then the tests should be repeated until three similar plots are obtained)
6. Shear strength of the soil (cohesion, c) = qu/2

RESULT:

Unconfined compression strength of the soil (qu) =

Shear strength of the soil (Su) =

Suggested Reference:

(i) (IS-2720-PART-10-1991) Reaffirmed-2006- Determination of Unconfined Compressive Strength
(ii) Soil Mechanics Virtual Lab: https://smfe-iiith.vlabs.ac.in/
(iii) NPTEL Course: Geotechnical Engineering Laboratory: https://nptel.ac.in/courses/105101160

References used by the students: