TAGORE INSTITUTE OF ENGINEERING AND TECHNOLOGY

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(Approved by AICTE, New Delhi and Affiliated to Anna University, Chennai)

Accredited by NAAC

Department of Civil Engineering

III Year- V Semester – Civil Engineering

CE8511 SOIL MECHANICS LABORATORY

LAB MANUAL

Academic Year 2020-2021

(2017 Regulation)

List of Experiments

CYCLE 1

1. Grain size distribution - Sieve analysis
2. Grain size distribution - Hydrometer analysis
3. Specific gravity of soil grains
4. Relative density of sands
5. Atterberg limits test
6. Determination of moisture - Density relationship using standard Proctor test.
7. Permeability determination (constant head and falling head methods)

CYCLE 2

8. Determination of shear strength parameters.
9. Direct shear test on cohesionless soil
10. Unconfined compression test on cohesive soil
11. Triaxial compression test (demonstration only)
12. One dimensional consolidation test (Demonstration only)
13. Field density test (Core cutter and sand replacement methods)

OBSERVATIONS & CALCULATIONS

Weight of the soil taken for testing (W) =

Sl.No	Aperture size of sieve in mm	Weight of soil retained (gm)	% Weight Retained	Cumulative Percentage Retained	Percentage Finer
1	4.75mm				
2	2.36mm				
3	1.18mm				
4	0.600mm				
5	0.300mm				
6	0.212mm				
7	0.150mm				
8	0.075mm				

Ex No. 01	DETERMINATION OF GRAIN SIZE DISTRIBUTION OF SOIL BY SIEVE ANALYSIS
Date:	

AIM

To conduct sieve analysis of soil to classify the given coarse grained soil.

THEORY AND APPLICATION

Grain size analysis is used in the engineering classification of soils. Particularly coarse grained soils. Part of suitability criteria of soils for road, airfield, levee, dam and other embankment construction is based on the grain size analysis. Information obtained from the grain size analysis can be used to predict soil water movement. Soils are broadly classified as coarse grained soils and fine grained soils. Further classification of coarse grained soils depends mainly on grain size distribution and the fine grained soils are further classified based on their plasticity properties. The grain size distribution of coarse grained soil is studied by conducting sieve analysis.

APPARATUS REUQIRED

1. A set of Sieves 4.75 mm, 2.36 mm ,1.18 mm ,0.60mm, 0.30 mm 0.15 mm 0.075mm including lid and pan
2. Tray
3. Weighing Balance
4. Oven
5. Sieve Shaker
6. Brush

PROCEDURE

1. Weigh 500gms of oven dry soil sample, of which grain size distribution has to be studied.
2. Take the soil sample into 75μ sieve.
3. Wash the soil sample keeping it in the sieve. Washing of soil sample means: place the soil in the sieve and gently pour water over the soil so that it wets the soil and remove the fine particles in the form of mud, leaving only the sand and gravel size particles in the sieve.

4. Transfer the soil retained in the sieve after washing into a tray. Invert the sieve into the tray and pour water gently so that all the soil particles retained in the sieve are transferred into the tray.
5. Keep the tray in the oven for 24 hours at 105ºc to dry it completely.
6. Weigh the oven dry soil in the tray (W)
7. The weight of the fine grained soil is equal to 500 – W
8. Clean the sieve set so that no soil particles were struck in them.
9. Arrange the sieves in order such that coarse sieve is kept at the top and the fine sieve is at the bottom. Place the closed pan below the finest sieve.
10. Take the oven dried soil obtained after washing into the top sieve and keep the lid to close the top sieve.
11. Position the sieves set in the sieve shaker and sieve the sample for a period of 10 minutes.
12. Separate the sieves and weigh carefully the amount of soil retained on each sieve, This is usually done by transferring the soil retained on each sieve on a separate sieve of paper and weighing the soil with the paper.
13. Enter the observations in the Table and calculate the cumulative percentage of soil retained on each sieve.
14. Draw the grain size distribution curve between grain size on log scale on the abscissa and the percentage finer on the ordinate.

Plot the graph between percentage finer and logarithmic grain size (mm).From the graph, obtain the percentage of coarse, medium and fine sands.

Uniformity coefficient $\boldsymbol{C_u} = \frac{\boldsymbol{D_{60}}}{\boldsymbol{D_{10}}}$

Coefficient of Curvature $\boldsymbol{C_u} = \frac{\boldsymbol{D_{30}}^2}{\boldsymbol{D_{60}D_{10}}}$

RESULT

Percentage of gravel (>4.75mm) =
Percentage of coarse sand (4.75mm – 2.00 mm) =
Percentage of medium sand (2.00mm – 0.425 mm) =
Percentage of fine sand (0.425mm – 0.0.075 mm) =
Percentage of fines (<0.075 mm) =
Uniformity Coefficient C_u =
Coefficient of Curvature C_c =

Ex No. 02	DETERMINATION OF GRAIN SIZE DISTRIBUTION OF SOILS BY HYDROMETER ANALYSIS
Date:	

AIM

To conduct Hydrometer analysis of soil to study the grain size distribution of the fine grained soil.

APPARATUS

1. Hydrometer
2. Dispersion cup with mechanical stirrer with complete accessories
3. Glass jar 1 lt capacity
4. Deflocculating agent
5. Stop watch
6. Thermometer

PROCEDURE

A. For soils containing considerable amount of fines

1. Take about 50g in case of clayey soils and 100g in case of sandy soil and weigh it correctly to 0.1g.

2. In case the soil contains considerable amount of organic matter or calcium compounds, pre –treatment of the soil with Hydrogen peroxide or hydrochloric acid may be necessary. In case of soils containing less than 20 percent of the above substances pre-treatment shall be avoided.

3. To the soil thus treated, add 100 cc of Sodium hexametaphosphate solution and warm it gently for 10 minutes and transfer the contents to the cup of the mechanical mixer using a jet of distilled water to wash all traces of the soil.

4. Stir the soil suspension for about 15 minutes.

5. Transfer the suspension to the Hydrometer jar and make up the volume exactly to 1000cc ,by adding distilled water.

6. Take another Hydrometer jar with 1000cc distilled water to store the hydrometer in between consecutive readings of the soil suspension to be recorded. Note the specific gravity readings (rw) and the temperature TºC of the water occasionally.

7. Mix the soil suspension roughly, by placing the palm of the right hand over the open end and holding the bottom of the jar with the left hand turning the jar upside down and back. When the jar is upside down be sure no soil is stuck to the base of the graduated jar.

8. Immediately after shaking, place the hydrometer jar on the table and start the stop watch. Insert the Hydrometer into the suspension carefully (avoiding circular or vertical oscillations to facilitate quick and accurate reading of the Hydrometer) and take hydrometer readings at the total elapsed times of ¼ ½, 1 and 2 minutes.

9. After the 2 minutes reading, remove the hydrometer and transfer it to the distilled water jar and repeat step no 8.Normally a pair of the same readings should be obtained before proceeding further.

10. Take the subsequent hydrometer readings at elapsed timings of 4, 9, 16, 25,36,49,60 minutes and every one hour thereafter. Each time a reading is taken remove the hydrometer from the suspension and keep it in the jar containing distilled water. Care should be taken when the hydrometer recorded to see that the hydrometer is at rest without any movement. As the time elapses, because of the fall of the solid particles the density of the fluid suspension decreases readings, which should be checked as a guard against possible error in readings of the hydrometer.

11. Continue recording operation of the hydrometer readings until the hydrometer reads 1000 approximately.

B. When the soil contains a small portion of fines.

1. Conduct sieve analysis on the soil.

2. Take 50g of the soil passing 75µ sieve and run the hydrometer analysis as explained above

C. Calibration of the hydrometer

1. Note the mid length of the bulb.++

2. Note the distance Zr cm from the first and the last readings and any intermediate redings also on the stem of the hydrometer to find the mid length of the bulb.

3. Plot a curve (A) between the hydrometer reading Rh against depth Zr. This curve is applicable for readings obtained from the first two minutes with the hydrometer continuously

kept inside the hydrometer jar. For all subsequent readings of the hydrometer a correction has to be applied by subtracting the volume effect of the
hydrometer from the observed values Zr. The value of this correction is Vr is the volume of the hydrometer, which can be obtained from the volume it displaces when immersed in water (g).The area of cross section of the jar may be obtained by dividing the volume of the jar between two marks by the distance between them.

4. After determining the correction factor, plot the graph ordinate of curve A. This curve is used for all the readings beyond the first two minutes.

RESULT

The grain size distribution of the fine grained soil was conducted by hrdrometer analysis successfully.

OBSERVATIONS AND CALCULATIONS

Determine the specific gravity of soil grains (G) using the following equation

$$G = \frac{(W_2 - W_1)}{(W_2 - W_1) - (W_3 - W_4)}$$

Where

W_1 = Empty weight of pycnometer.

W_2 = Weight of pycnometer + oven dry soil

W_3 = Weight of pycnometer + oven dry soil+ water

W_4 = Weight of pycnometer + water

OBSERVATION FOR SPECIFIC GRAVITY DETERMINATION

Sample Number	W_1 in gms	W_2 in gms	W_3 in gms	W_4 in gms	Specific Gravity G
1					
2					

Ex No. 03	DETERMINATION OF SPECIFIC GRAVITY OF SOIL SOLIDS
Date:	

AIM

To determine the specific gravity of soil solids.

THEORY AND APPLICATION

Specific gravity of soil solids is the ratio of weight, in air of a given volume; of dry soil solids to the weight of equal volume of water at 4ºC.Specific gravity of soil grains gives the property of the formation of soil mass and is independent of particle size. Specific gravity of soil grains is used in calculating void ratio, porosity and degree of saturation, by knowing moisture content and density.

APPARATUS REQUIRED

1. Pycnometer
2. 450 mm sieve
3. Weighing balance
4. Oven
5. Glass rod
6. Distilled water

PROCEDURE

1. Dry the pycnometer and weigh it with its cap. (W_1)
2. Take about 200gmof oven dried soil passing through 4.75mm sieve into the pycnometer and weigh again (W_2).
3. Add sufficient de-aired water to cover the soil and screw on the cap.
4. Shake the pycnometer well and remove entrapped air if any.
5. After the air has been removed, fill the pycnometer with water completely.
6. Thoroughly dry the pycnometer from outside and weigh it (W_3).
7. Clean the pycnometer by washing thoroughly.
8. Fill the cleaned pycnometer completely with water up to its top with cap screw on.
9. Weigh the pycnometer after drying it on the outside thoroughly (W_4).
10. Repeat the procedure for three samples and obtain the average value of specific gravity.

RESULT

Thus the specific gravity of soil is obtained as_____________

OBSERVATIONS AND CALCULATIONS

Observations for the determination of minimum density

Weigh of the mould =

Volume of the mould =

Sl.No	Description	Trial 1	Trial2	Trial3
1	Weight of the mould , gms			
2	Weight of the soil + mould gms			
3	Weight of the soil W gms			
4	Calibrated volume of mould V_c			
5	Minimum density			

Ex No. 04	DETERMINATION OF RELATIVE DENSITY OF COHESIONLESS SOILS
Date:	

AIM

To determine the relative density of cohesion less soil.

THEORY AND APPLICATION

Relative density is also known as density index. It is defined as the ratio of difference between the void ratio of cohesion less soil in the loosest state and any given void ratio to the difference between its void ratios in the loosest and in the densest states. The concept of density index gives a practically useful measure of compactness of such soils. The compactive characteristics of cohesion less soils and the related properties of such soils are dependent on factors like grain size distribution and shape of individual particles. The compactive characteristics of cohesion less soils s and the related properties of such soils are dependent on factors like grain size distribution and shape of individual particles. Relative density is also effected by these factors and serves as a parameter to correlate properties of soils. Various soil properties such as penetration resistance, compressibility, compaction , friction angle , permeability and CBR has been found to have simple relationships with relative density.

APPARATUS

1. **Vibratory table:** A steel table with cushioned steel vibrating deck about 75 x 75 cm. The vibrator should have a net weight of over 45 kg. The vibrator frequency of 3600 vibrations per minute, a vibrator amplitude is 0.05 and 0.65 mm under a115 kg load.
2. **Moulds:** Cylindrical metal density moulds of 3000cc 150mm dia and 169.77 mm high.
3. **One guide sleeve:** With clamp assembly should be provided with lock nuts.
4. **Surcharge base plate:** 10mm thick with handle for each mould.
5. **Surcharge weights:** The total weight of surcharge base plate and surcharge weight shall be equivalent to 140 g /cm^2. for the mould being used
6. **One dial gauge holder**
7. **Dial gauge:** A dial gauge with 50mm travel and 0.02 mm least count.
8. **A metallic calibration bar of sizes 75 x 300 x 3 mm.**
9. **Pouring devices :** Consisting of funnels 12mm and 25 mm in diameter and 150 mm long with cylindrical spots and lipped brims for attaching to 150mm and 300 mm high metal cans.
10. **Mixing pans:** Two mixing pans
11. **Weighing scale**
12. Metal hand scoop

Observations for the determination of maximum density

Weigh of the mould =
Volume of the mould =
Dial gauge reading at left =
Dial gauge reading at right =

Sl.no	Description	Trial 1	Trial 2	Trial 3
1	Gauge reading Left			
2	Gauge reading Right			
3	Average Gauge reading D_f			
4	Initial Gauge reading D_i			
5	Surface area of soil sample A in sq.cm			
6	Volume of soil $V_s = V_c - (D_i - D_f)\ A$			
7	Weight of dry soil + mould ,gms			
8	Weight of dry soil ,W gms			
9	Maximum density			

Computation of relative density

Sl.no	Description	Trial 1	Trial 2	Trial 3
1				
2				
3				
4				
5				
6				

PROCEDURE

The test procedure to determine the relative density of soil involves the measurement of density of soil in its loosest possible state ( ) and densest possible state ( ) .Knowing the specific gravity of soil solids (G) the void ratios of the soil in its loosest (e_{max}) and densest state (e_{min}) are computed. The density of soil in the field () (natural state) is used to compute void ratio (e) in the field. After obtaining the three void ratios the relative density is computed. For 4.75mm size particles 3000cc mould is used. Moulds are first calibrated, and then the densities of the soil are obtained.

CALIBRATION OF MOULDS

To calibrate the mould should be filled with water and a glass plate should be slide carefully over the top surface of the mould in such a manner as to ensure that the mould is completely filled with water. The volume of the mould should be calculated in cc by dividing the weight of water in the mould by the unit weight of water.

PREPARATION OF SOIL SAMPLE

A representative sample of soil should be selected. The weight of soil sample to be taken depends upon the maximum size of particles in the soil .The soil sample should be dried in an oven at a temperature of 105ºc to 110ºc .The soil sample should be pulverized without breaking the individual soil particles and sieved through the required sieve.

PROCEDURE FOR THE DETERMINATION OF MINIMUM DENSITY

1. The pouring device and mould should be selected according to the maximum size of particle. The mould should be weighed and weight recorded. Oven dry soil should be used.
2. Soil containing particles smaller than 10mm should be placed as loosely as possible in the mould by pouring the soil through the spout in a steady stream. The spout should be adjusted so that the height of free fall of the soils always 25mm.While pouring the soil the pouring device should be moved in a spiral motion from the outside towards the centre to form a soil layer of uniform thickness without segregation. The mould should be filled approximately 25mm above the top and leveled with the top by making one continuous pass with steel straight edge. If all excess material is not removed an additional continuous pass should be made. Great care shall be exercised to avoid jarring during the entire pouring and trimming operation.

3. The mould and the soil should be weighed and the weight recorded.
4. Soil containing particles larger than 10mm should be placed by means of a large scoop held as close as possible to and just above the soil surface to cause the material to slide rather than fall into the previously placed soil. If necessary large particles may be held by hand to prevent them from rolling offs the scoop.
5. The mould should be filled to overflowing but not more than 25mm above the top. The surface of the soil should be leveled with the top of the mould using the steel straight edge in such a way that any slight projections of the larger particles above the top of the mould shall approximately balance the large voids in the surface below the top of the mould.
6. The mould and the soil should be weighed and the weight recorded.

PROCEDURE FOR THE DETERMINATION OF MAXIMUM DENSITY-DRY METHOD

1. The guide sleeve should be assembled on top of the mould and the clamp assemblies tightened so that the inner surfaces of the walls of the mould and the sleeve are in line. The lock nuts should be tightened. The third clamp should be loosened, the guide sleeve removed, the empty mould weighed and its weight recorded.
2. The mould should then be filled with the thoroughly mixed oven dry soi in a loose stat.
3. The guide sleeves should be attached to the mould and the surcharge base plate should be placed on the soil surface.
4. The mould should be fixed to the vibrator deck. The vibrator control should be set at its maximum amplitude and the loaded soil specimen should be vibrated for 8 minutes.
5. The surcharge weight and the guide sleeves should be removed from the mould .The dial gauge readings on two opposite sides of the surcharge base plate should be obtained and the average recorded. The mould with the soil should be weighed and its weight recorded

RESULT

Maximum density =

Minimum density =

Relative density =

OBSERVATION AND CALCULATIONS

1. Use the table for recording number of blows and calculating the moisture content.

   Use semi-log graph paper. Take number of blows on log scale (X –Axis) and water content on nominal scale (Y – axis). Plot all the points.

2. Read the water content at 25 blows which is the value of liquid limit.

TABLE Observation for Liquid limit

Sl.No	**Description**	**1**	**2**	**3**	**4**	**5**
1	No. of blows					
2	Container number					
3	Weight of container + wet soil					
4	Weight of container +dry soil					
5	Weight of water (3) – (4)					
6	Weight of container					
7	Weigh t of dry soil (4) – (6)					
8	Moisture content (w) (5) / (7)					
9	Moisture content in percentage					

Ex No. 05	DETERMINATION OF LIQUID LIMIT AND PLASTIC LIMIT OF SOIL
Date:	

AIM

To determine liquid limit and plastic limit of the given soil sample and to find the flow index and toughness index of the soil.

THEORY AND APPLICATION

Liquid limit is the water content expressed in percentage at which the soil passes from zero strength to an infinitesimal strength, hence the true value of liquid limit cannot be determined. For determination purpose liquid limit is that water content at which a part of soil,cut by a groove of standard dimensions, will flow together for a distance of 12.5mm under an impact of 5 blows in a standard liquid limit apparatus with a height of fall of 1cm.

The moisture content expressed in percentage at which the soil has the smallest plasticity is called the plastic limit. Just after plastic limit the soil displays the properties of a semi solid

For determination purposes the plastic limit it is defined as the water content at which a soil just begins to crumble when rolled into a thread of 3mm in diameter.

The values of liquid limit and plastic limit are directly used for classifying the fine grained soils. Once the soil is classified it helps in understanding the behaviour of soils and selecting the suitable method of design construction and maintenance of the structures made-up or and resting on soils.

APPARATUS

1. Casagrande Liquid limit device
2. Grooving tool
3. Glass plate
4. 425 micron sieve
5. Spatula
6. Mixing bowl
7. Wash bottle
8. Moisture content bins
9. Drying oven
10. Sensitive balance

TABLE Observation for Plastic limit

Sl.No	Description	1	2	3	4	5
1	Container number					
2	Weight of container + wet soil					
3	Weight of container +dry soil					
4	Weight of water (2) – (3)					
5	Weight of container					
6	Weigh t of dry soil (3) – (5)					
7	Moisture content (w) (4) / (6)					
8	Moisture content in percentage					

PROCEDURE

(B) LIQUID LIMIT

1. Adjust the cup of liquid limit apparatus with the help of grooving tool gauge and the adjustment plate to give a drop of exactly 1cm on the point of contact on the base.
2. Take about 120gm of an air dried soil sample passing 425μ sieve.
3. Mix the soil thoroughly with some distilled water to form a uniform paste.
4. Place a portion of the paste in the cup of the liquid limit device; smooth the surface with spatula to a maximum depth of 1 cm. Draw the grooving tool through the sample along the symmetrical axis of the cup, holding the tool perpendicular to the cup.
5. Turn the handle at a rate of 2 revolutions per second and count the blows until the two parts of the soil sample come in contact with each other, at the bottom of the groove, along a distance of 10mm.
6. Transfer about 15 gm of the soil sample forming the wedge of the groove that flowed together to a water content bin, and determine the water content by oven drying.
7. Transfer the remaining soil in the cup to the main soil sample in the bowl and mix thoroughly after adding a small amount of water.
8. Repeat steps 4 – 7 .Obtain at least five sets of readings in the range of 10 – 40 blows.
9. Record the observations in the Table.

(C) PLASTIC LIMIT

1. Take about 30g of air dried soil sample passing through 425μ sieve.
2. Mix thoroughly with distilled water on the glass plate until it is plastic enough to be shaped into a small ball.
3. Take about 10g of the plastic soil mass and roll it between the hand and the glass plate to form the soil mass into a thread of as small diameter as possible. If the diameter of the thread becomes less than 3 mm without cracks, it indicates that the water added to the soil is more than its plastic limit, hence the soil is kneaded further and rolled into thread again.
4. Repeat this rolling and remoulding process until the thread start just crumbling at a diameter of 3mm.
5. If the soil sample start crumbling before the diameter of thread reaches 3mm (i.e when the diameter is more than 3mm) in step 3, it shows that water added in step 2 is less than the plastic limit of the soil. Hence, some more water should be added and mixed to a uniform mass and rolled again, until the thread starts just crumbling at a dia of 3mm.

6. Collect the piece of crumbled soil thread at 3mm diameter in an airtight container and determine moisture content.
7. Repeat this procedure on the remaining masses of 10g.
8. Record the observations in Table and obtain the average value of plastic limit.

Average plastic limit of the soil

Flow Index $\boldsymbol{I_f = \frac{(W_1 - W_2)}{log_{10}(N_2 - N_1)}}$

Where W1 = Water content in % at N1 blows

W2 = Water content in % at N2 blows

Toughness Index I_T = Plasticity index / Flow index

RESULT

1. Liquid limit of the soil =

2. Plastic limit of the soil =

3. Flow Index of the soil =

4. Toughness Index of the soil =

Ex No. 06	DETERMINATION OF FIELD DENSITY (UNIT WEIGHT) OF SOIL BY CORE CUTTER METHOD
Date:	

AIM

To determine the fields density of soil by core cutter method.

THEORY AND APPLICATIONS

Unit weight is designed as the weight per unit volume. Here the weight and volume of soil comprise the whole soil mass. The voids in the soil may be filled with both water and air or only air or only water consequently the soil may be wet, dry or saturated. In soils the weight of air is considered negligible and therefore the saturated unit weight is maximum, dry unit weight is minimum and wet unit weight is in between the two. If soils are below water table, submerged unit weight is also estimated.

Unit weight of soil reflects the strength of soil against compression and shear. Unit weight of soil is used in calculating the stresses in the soil due to its overburden pressure. It is useful in estimating the bearing capacity and settlement of foundations. Earth pressure behind the retaining walls and in cuts is checked with the help of unit weight of the associated soils. It is the unit weight of the soil which controls the field compaction and it helps in the design of embankment slopes. Permeability of soil depends on its unit weight .It may be noted here that , in the field the unit weight refers to dry unit weight only because the wet unit weight of soil at location varies from season to season and based on the fluctuations of the local water table level and surface water.

APPARATUS

1. Cylindrical core cutter
2. Steel rammer
3. Steel dolly
4. Balance
5. Moisture content cups

PROCEDURE

1. Measure the height (h) and internal diameter (d) of the core cutter and apply grease to the inside of the core cutter.
2. Weigh the empty core cutter (W1).
3. Clean and level the place where density is to be determined.

OBSERVATIONS AND CALCULATIONS

Internal diameter of the core cutter (d)

Height of the core cutter (h)

Volume of the core cutter (V)

Specific gravity of solids (G)

I. Calculate the wet unit weight of the soil using the following relationship.
II. Calculate dry unit weight .

   Calculate void ratio (e) porosity (n) and degree of saturation

4. Drive the core cutter, with a steel dolly on its top in to the soil to its full depth with the help of a steel rammer.
5. Excavate the soil around the cutter with a crow bar and gently lift the cutter without disturbing the soil in it.
6. Trim the top and bottom surfaces of the sample and clean the outside surface of the cutter.
7. Weigh the core cutter with soil (W2).
8. Remove the soil from the core cutter , using a sample ejector and take a representative soil sample from it to determine the moisture content (w).

RESULT

1. Dry unit weight of the soil
2. Wet unit weight of the soil
3. Void ratio of the soil
4. Porosity of the soil
5. Degree of saturation

OBSERVATIONS AND CALCULATIONS

TABLE

CALIBRATION OF UNIT WEIGHT OF SAND

Sl.No	Description	Trial No 1	Trial No 2	Trial No 3
1	Volume of the calibrating container, V			
2	Weight of SPC + sand W1			
3	Weight of SPC + sand W2 After filling conical portion on a flat surface			
4	Weight of SPC + sand W3 After filling calibrating can			
5	Weight of sand required to fill cone Wc = W1-W2			
6	Weight of sand required to fill cone and can Wcc= W2-W3			
7	Weight of sand in calibrating can Wcc – Wc			
8	Unit weight of sand Wcc – Wc / V			

Ex No. 07	DETERMINATION OF FIELD DENSITY (UNIT WEIGHT) OF SOIL BY SAND REPLACEMENT METHOD
Date:	

AIM

To determine the field density of soil at a given location by sand replacement method.

APPARATUS

1. Sand pouring Cylinder
2. Calibrating can
3. Metal tray with a central hole
4. Dry sand (Passing through 600 micron sieve)
5. Balance
6. Metal tray
7. Scraper tool
8. Glass plate

THEORY AND APPLICATIONS

In core cutter method the unit weight of soil obtained from direct measurement of weight and volume of soil obtained from field. Particularly for sandy soils the core cutter method is not possible. In such situations the sand replacement method is employed to determine the unit weight. In sand replacement method a small cylindrical pit is excavated and the weight of the soil excavated from the pit is measured. Sand, whose density is known, is filled into the pit. By measuring the weight of sand required to fill the pit and knowing the density of soil , volume of the pit is calculated .Knowing the weight of soil excavated from the pit and the volume of pit the density of soil is calculated. Therefore in this experiment there are two stages (1) Calibration of sand density and (2) Measurement of soil density.

PROCEDURE

CALIBRATION OF SAND DENSITY

1. Measure the internal dimensions diameter (d) and height (h) of the calibrating can and compute its internal volume V.
2. Fill the sand pouring cylinder (SPC) with sand with 1 cm top clearance to avoid any spillover during operation and find its weight (W1)

TABLE

DETERMINATION OF UNIT WEIGHT OF SOIL

Sl.No	Description	Trial No 1	Trial No 2	Trial No 3
1	Weight of SPC after filling the hole and Conical portion W4			
2	Weight of sand in the hole and cone W3 – W4			
3	Weight of sand in the pit Wp = (W3 – W4) – Wc			
4	Volume of sand required to fill the pit Vp = Wp /			
5	Weight of the soil excavated from the pit (W)			
6	Wet unit weight of the soil			
7	Dry unit weight of the soil			
8	Void ratio of the soil			
9	Degree of saturation			

3. Place the SPC on a glass plate, open the slit above the cone by operating the valve and allow the sand to run down. The sand will freely run down till it fills the conical portion. When there is no further downward movement of sand in the SPC, close the slit.
4. Find the weight of the SPC along with the sand remaining after filling the cone (W2)
5. Place the SPC concentrically on top of the calibrating can.Open theslit to allow the sand to rundown until the sand flow stops by itself. This operation will fill the calibrating can and the conical portion of the SOC. Now close the slit and find the weight of the SPC with the remaining sand(W3)

MEASUREMENT OF SOIL DENSITY

1. Clean and level the ground surface where the field density is to be determined.
2. Place the tray with a central hole over the portion of the soil to be tested.
3. Excavate a pit into the ground, through the hole in the plate , approximately 12cm deep (Close the height of the calibrating can) The hole in the tray will guide the diameter of the pit to be made in the ground.
4. Collect the excavated soil into the tray and weigh the soil (W)
5. Determine the moisture content of the excavated soil.
6. Place the SPC, with sand having the latest weight of W3, over the pit so that the base of the cylinder covers the pit concentrically.
7. Open the slit of the SPC and allow the sand to run into the pit freely, till there is no downward movement of sand level in the SPC and then close the slit.
8. Find the weight of the SPC with the remaining sand W4.

RESULT

1. Dry unit weight of the soil
2. Wet unit weight of the soil
3. Void ratio of the soil
4. Porosity of the soil
5. Degree of saturation

OBSERVATIONS AND CALCULATIONS

Calculate the coefficient of permeability of soil using the equation

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

Where

K = Coefficient of permeability

Q = Quantity of water collected in time t sec (cc)

t = Time required (sec)

A = Cross sectional area of the soil sample (sq.cm)

h = Constant hydraulic head (cm)

L = Length of soil sample (cm)

TABLE

(i) Length of soil sample (cm) =

(ii) Area of soil sample (sq.cm) =

Sl.No	Hydraulic head h in cm	Time interval T (sec)	Quantity of Water collected(cc)	Coefficient of Permeability(cm/sec)

Ex No. 08	DETERMINATION OF PERMEABILITY OF SOIL BY CONSTANT HEAD METHOD
Date:	

AIM

To determine the coefficient of permeability of the soil by conducting constant head method.

THEORY AND APPLICATION

The property of the soil which permits water to percolate through its continuously connected voids is called its permeability .Water flowing through the soil exerts considerable seepage forces which has direct effect on the safety of hydraulic structures. The quantity of water escaping through and beneath and earthen dam depends on the permeability of the embankment and the foundation soil respectively.

APPARATUS

1. Permeability apparatus with accessories
2. Stop watch
3. Measuring jar

PROCEDURE

1. Compact the soil into the mould at a given dry density and moisture content by a suitable device. Place the specimen centrally over the bottom porous disc and filter paper.
2. Place a filter paper, porous stone and washer on top of the soil sample and fix the top collar.
3. Connect the stand pipe to the inlet of the top plate.Fill the stand pipe with water.
4. Connect the reservoir with water to the outlet at the bottom of the mould and allow the water to flow through and ensure complete saturation of the sample.
5. Open the air valve at the top and allow the water to flow out so that the air in the cylinder is removed.
6. When steady flow is reached, collect the water in a measuring flask for a convenient time intervals by keeping the head constant. The constant head of flow is provided with the help of constant head reservoir

RESULT

Coefficient of permeability of the given soil sample =

OBSERVATIONS AND CALCULATIONS

Calculate the coefficient of permeability of soil using the equation.

$$K = \frac{2.303\ Al}{At\ log_{10}(h1/h2)}$$

K = Coefficient of permeability

a = Area of stand pipe (sq.cm)

t = Time required for the head to fall from h1 to h2 (sec)

A = Cross sectional area of the soil sample (sq.cm)

L = Length of soil sample (cm)

h1 = Initial head of water in the stand pipe above the water level in the reservoir (cm)

h2 = final head of water in the stand pipe above the water level in the reservoir (cm)

(i) Diameter of the stand pipe (cm) =

(ii) Cross sectional area of stand pipe (sq.cm) =

(iii) Length of soil sample (cm) =

(iv) Area of soil sample (sq.cm) =

Sl.No	**Initial head h1 in cm**	**Final head h 2 in cm**	**Time interval t (sec)**	**Coefficient of Permeability(cm/sec)**

Ex No. 09	DETERMINATION OF PERMEABILITY OF SOIL BY VARIABLE HEAD METHOD
Date:	

AIM

To determine the coefficient of permeability of a given soil sample by conducting Variable head test.

THEORY AND APPLICATION

The property of the soil which permits water to percolate through its continuously connected voids is called its permeability .Water flowing through the soil exerts considerable seepage forces which has direct effect on the safety of hydraulic structures.

APPARATUS

1. Permeability apparatus with accessories
2. Stop watch
3. Measuring jar
4. Funnel

PROCEDURE

1. Compact the soil into the mould at a given dry density and moisture content by a suitable device. Place the specimen centrally over the bottom porous disc and filter paper.
2. Place a filter paper, porous stone and washer on top of the soil sample and fix the top collar.
3. Connect the stand pipe to the inlet of the top plate. Fill the stand pipe with water.
4. Connect the reservoir with water to the outlet at the bottom of the mould and allow the water to flow through and ensure complete saturation of the sample.
5. Open the air valve at the top and allow the water to flow out so that the air in the cylinder is removed.
6. Fix the height h1 and h2 on the pipe from the top of water level in the reservoir
7. When all the air has escaped, close the air valve and allow the water from the pipe to flow through the soil and establish a steady flow.
8. Record the time required for the water head to fall from h1 to h2.

RESULT

Coefficient of permeability of the given soil sample =

Diameter of the mould, d (cm) =

Volume of the mould v (cm^3) =

Height of the mould, h (cm) =

Weight of the mould W1 (gms) =

TABLE

Sl.No	Description	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
1	Weight of mould + Compacted wet soil (W2) in gms					
2	Weight of Compacted wet soil W = W2 – W1 in gms					
3	Wet density of soil					
4	Bin number					
5	Empty weight of bin in gms					
6	Weight of bin + wet soil in gms					
7	Weight of bin + dry soil in gms					
8	Weight of water (6) – (7)					
9	Weight of dry soil (7) – (5)					
10	Moisture content w (8) /(9)					
11	Moisture content in percentage					
12	Dry density					

Ex No. 10	STANDARD PROCTOR COMPACTION TEST
Date:	

AIM

To determine Optimum Moisture Content and Maximum dry density for a soil by conducting standard proctor compaction test.

THEORY

Compaction is the process of densification of soil mass, by reducing air voids under dynamic loading. On the other hand though consolidation is also a process of densification of soil mass but it is due to the expulsion of water under the action of continuously acting static load over a long period.The degree of compaction of a soil is measured in terms of its dry density. The degree of compaction mainly depends upon its moisture content during compaction, compaction energy and the type of soil. For a given compaction energy, every soil attains the maximum dry density at a particular water content which is known as optimum moisture content (OMC)

APPLICATIONS

Compaction of soil increases its dry density, shear strength and bearing capacity. The compaction of soil decreases its void ratio permeability and settlements. The results of this test are useful in studying the stability earthen structures like earthen dams, embankments roads and airfields .In such constructions the soils are compacted. The moisture content at which the soils are to be compacted in the field is estimated by the value of optimum moisture content determined by the Proctor compaction test.

APPARATUS

1. Cylindrical mould of capacity 1000cc ,internal diameter 100mm and height 127.3 mm
2. Rammer
3. Mould accessories
4. Balance
5. Graduated jar
6. Straight edge & Spatula
7. Oven & Moisture bins

PROCEDURE

1. Take about 3 kg of air dried soil
2. Sieve the soil through 20mm sieve. Take the soil that passes through the sieve for testing
3. Take 2.5 kg of the soil and add water to ti to bring its moisture content to about 4% in coarse grained soils and 8% in case of fine grained soils
4. Clean , dry and grease the mould and base plate .Weigh the mould with base plate. Fit the collar.
5. Compact the wet soil in three equal layers by the rammer with 25 evenly distributed blows in each layer.
6. Remove the collar and trim off the soil flush with the top of the mould. In removing the collar rotate it to break the bond between it and the soil before lifting it off the mould.
7. Clean the outside of the mould and weigh the mould with soil and base plate.
8. Remove the soil from the mould and obtain a representative soil sample from the bottom, middle and top for water content determination
9. Repeat the above procedure with 8,12,16 and 210 % of water contents for coarse grained soil and 14,18,22 and 26 % for fine grained soil samples approximately. The above moisture contents are given only for guidance. However, the moisture contents may be selected based on experience so that, the dry density of soil shows the increase in moisture content. Each trial should be performed on a fresh sample.

OBSERVATIONS AND CALCULATIONS

1. Enter all the observations in Table and calculate the wet density.

2. Calculate the dry density by using the equation

3. Plot the moisture content on X axis and dry density on Y axis .Draw a smooth curve passing through the points called compaction curve.

4. Read the point of maximum dry density and corresponding water content from the compaction curve.

RESULT

1. Optimum Moisture Content OMC (%) =

2. Maximum dry density (gm/cc) =

OBSERVATION AND CALCULATIONS

TABLE

Sl.No	Description	Trial 1	Trial 2	Trial 3
1	Weight of dish + wet soil pat in gms			
2	Weight of dish + dry soil pat in gms			
3	Weight of water present (2-3)			
4	Weight of shrinkage dish , empty (gms)			
5	Weight of dry soil pat W_s = (2 – 4)			
6	Initial water content (W1) = (4) / (6) x100			
7	Weight of weighing dish + Mercury			
8	Weight of weighing dish empty			
9	Weight of mercury (7 – 8)			
10	Volume of wet soil pat			
11	Weight of weighing dish + displaced mercury			
12	Weight of mercury displaced			
13	Volume of dry soi pat			
14	Shrinkage limit			
15	Shrinkage ratio			
16	Volumetric shrinkage			
17	Linear shrinkage			

Ex No. 11	DETERMINATION OF SHRINKAGE LIMIT OF SOILS
Date:	

AIM

To determine shrinkage limit of the soil

APPARATUS

i) Shrinkage dish
ii) Porcelain evaporated dish
iii) Mercury
iv) Balance

PROCEDURE

1. About 30 gms of soil passing through 425 micron sieve is taken with distilled water.
2. The shrinkage dish is coated with a thin layer of Vaseline .The soil sample is placed in the dish by giving gentle taps. The top surface is surfaced with a straight edge.
3. The shrinkage dish with wet soil is weighed. The dish is dried first in air and then in oven.
4. The shrinkage dish is weighed with dry soil. After cleaning the shrinkage dish its empty weight is taken.
5. An empty porcelain dish which will be useful for weighing mercury is weighed.
6. The shrinkage dish is kept inside a large porcelain dish it is filled with mercury and the excess is removed by pressing the plain glass plate firmly over the top of the dish. The contents of the shrinkage dish are transferred to the mercury weighing dish and weighed.
7. The glass cup is kept in a large dish, filled it with over flowing mercury, the excess is removed by pressing the glass plate with three prongs firmly over the top of the cup.
8. It is placed in another large dish. The dry soil is placed on the surface of the mercury and is submerged under the mercury by pressing with the glass plate with prongs.
9. The mercury displaced by the dry soil pat is transferred to the mercury weighing dish and weighed.

RESULT

1. Shrinkage limit =
2. Shrinkage ratio =
3. Volumetric shrinkage =

Ex No. 12	DETERMINATION OF COEFFICIENT OF CONSOLIDATION
Date:	

AIM

To determine the coefficient of consolidation of a given clay soil.

THEORY AND APPLICATION

When a load is applied on a saturated soil, the load will initially be transferred to the water in pores of the soil .This results in development of pressure in pore water which results in the escape of water from voids and brings the soil particles together. The process of escape of water under applied load, leads to reduction in volume of voids and hence the volume of soil. The process of reduction of volume of voids due to expulsion of water under sustained static load is known as consolidation. The magnitude of consolidation depends on the amount of voids or void ratio of the soil. The rate of consolidation depends on the permeability properties of soil. The two important consolidation properties of soil are (i) co-efficient of consolidation (Cv) and

(ii) Compression index (Cc). The coefficient of consolidation reflects the behaviour of soil with respect to time under a given load intensity. Compression index explains the behaviour of soils under increased loads.

APPLICATIONS

Consolidation properties are required in estimating the settlement of a foundation. They provide the maximum amount of settlements under a given load and the time required for it to occur. Many times the design of foundations is carried out based on the limiting settlements. The amount of consolidation will be more in clay soils. Further due to low permeability, the rate of settlement in clay soil is very low. That means the time required for the total settlement in clay soils is very high. Hence the study of consolidation properties is important for foundation resting on clay soil.

TABULATION

Dimensions of sample: Diameter = Thickness =

Unit weight of soil =

Elapsed time In minutes, t	√t	Dial gauge reading
1	2	3
0		
0.25		
2.25		
4.00		
6.25		
9.00		
12.25		
16.00		
20.25		
25.00		
36.00		
49.00		
64.00		
81.00		
100.00		
121.00		
144.00		
169.00		
225.00		

APPARATUS

1. Consolidometer consisting of specimen ring.
2. Guide ring
3. Porous stones
4. Dial gauges
5. Stop watch

PROCEDURE

Preparation of specimen

Sufficient thickness of the soil specimen is cut from undisturbed sample. The consolidation ring is gradually inserted into the sample. The consolidation ring is gradually inserted into the sample by pressing and carefully removing the material around it. The specimen should be trimmed smooth and flush to the ends of the ring. Any voids in the specimen caused due to removal of gravel or limestone pieces should be filled back by pressing completely the loose soil in the voids. The ring should be wiped clean and weighed again with the soil. Place wet filter paper on top and bottom faces of the sample and two porous stones covering it should be in place. Place this whole assembly in the loading frame. Over the porous stone a perforated plate with loading ball is placed as shown in the figure.

The sample is put for saturation both from top and bottom. After allowing time for saturation the load is applied through the loading frame. The settlement in sample is measured using a dial gauge. The stepwise procedure for observing reading is as follows:

1. Apply the required load intensity (stress) at which Cv is to be determined.
2. As the loading is applied, the stop watch should be started.
3. Take the readings of the dial gauge at different time interval from the time of loading and record them in the table.

OBSERVATION AND CALCULATIONS

(a) Square root method

1. Record the dial gauge readings at different time interval from the point of loading in Table.
2. Plot a graph between √t on X axis and dial gauge reading on Y axis .Where t is time in minutes.
3. The curve drawn reflects three components of settlement (i) Immediate settlement or elastic compression. This will be reflected in the form of steep settlements in a small time interval and a nearly vertical line at the initial portion of the curve represents it. This is followed by (ii) Primary consolidation curve, which will be nearly a straight line with a reduced sloe. The majority of consolidation will be in this zone. After primary consolidation (iii) Secondary consolidation takes place that is marked by a curve nearly parallel to time axis.
4. Draw a straight line through a primary consolidation zone. Identification of primary consolidation zone depends on experience and eye judgement. Extent the straight line to meet Y- axis at Oc. Oc is the corrected zero.
5. Draw another straight line through Oc , with a slope equal to 1.15 times the slope of the earlier straight line.
6. The Straight line so drawn (with 1.15 times the slope of primary consolidation line) will intersect the originally plotted curve at a point. The X co ordinate of this point will give $\sqrt{t_{90}}$. Where t_{90} is the time required for 90% consolidation (in minutes)
7. The coefficient of consolidation is calculated as follows

$$\boldsymbol{Cv = 0.848\, H^2 / (t_{90} \times 60) \quad cm2/sec.}$$

Where H = length of drainage path (cm)

H = half thickness of soil sample for double drainage and

H = thickness of soil sample for single drainage

t_{90} = time required for 90% consolidation in minutes.

(b) Log - method

1. The compression dial readings should be plotted against the log of time and a smooth curve drawn to pass through the points.

2. The two straight portions of the curve should be extended to intersect at a point , the ordinate of which gives d_{100} corresponding to 100% primary compression.

3. The corrected zero point ds shall be located by the laying of above point in the neighbourhood of 0.1 minute a distance equal to the vertical distance between this point and one at a time which is four times this value

4. The 50% compression point which is halfway between the corrected zero point and the 100% compression point, shall be marked on the curve and the readings on the time axis corresponding to this point t_{50}, time to 50% primary compression, shall be noted. The readings on the dial gauge reading axis, corresponding to 100% compression gives

   d_{100}.

5. Coefficient of consolidation is calculated as follows

$$\boldsymbol{Cv = 0.197\, H^2 / \, t_{50}}$$

RESULT

Co efficient of Consolidation of the given soil sample Cv =

DIRECT SHEAR TEST DATA SHEET

Sample Number:

Visual Classification:

Shear Box inside Diameter:

Area (A):

Shear Box Height:

Soil Volume:

Initial mass of soil and pan:

Final mass of soil and pan:

Mass of soil:

Density of soil:

Ex No. 13	DETERMINATION OF SHEAR PARAMETERS OF SOIL BY DIRECT SHEAR TEST
Date:	

AIM

To determine shear strength parameters of the given soil sample at known density by conducting direct shear test.

THEORY AND APPLICATION

Shear strength of a soil is its maximum resistance to shearing stresses. It is equal to the shear stress at failure on the failure plane. Shear strength is composed of (i) internal frictions , which is the resistance due to the friction between the individual particles at their contact points and inter locking of particles. (ii) cohesion which is the resistance due to inter particle forces which tend to hold the particles together in a soil mass. Coulomb has represented the shear strength of the soil by the equation :

$$\tau_f = C + \sigma \tan \varphi$$

τ_f = shear strength of the soil

C = Cohesion, σ = normal stress on the failure plane

φ = Angle of internal friction

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 Colulomb’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)

This equation can also be written in terms of effective stresses.

Direct Shear Test Data

Displacement rate: ______
Normal stress: ________psi

Horizontal Dial Reading (0.001 in)	Horizontal Displacement (in)	Load Dial Reading	Horizontal Shear Force (lb)	Shear Stress (psi)

APPARATUS

1. Compression device
2. Load and deformation dial gauges
3. Sample trimming equipment
4. Balance & Moisture can

APPLICATION

Shear parameters are used in the design of earthen dams and embankments. The stability of the failure wedges depends on the shear resistance of the soil along the failure plane. The strength parameters C and φ are used in calculating the bearing capacity of soil foundation systems.

PROCEDURE

1. Assemble the shear box

2. Compact the soil sample in mould after bringing it to optimum moisture condition

3. Carefully transfer the sample into shear box

$$\boldsymbol{\tau_f = c' + \sigma'_f \tan ø'}$$

Where c' = apparent cohesion of soil in terms of effective stresses

σ'f = effective normal stress on failure plane

ø' = angle of shearing resistance of soil in terms of effective stresses

$$\boldsymbol{\sigma'_f = \sigma_f - u_f}$$

uf = pore water pressure on failure plane

2. Compact the soil sample in mould after bringing it to optimum moisture condition

3. Carefully transfer the sample into shear box

$$\tau_f = c' + \sigma'_f \tan ø'$$

Where c' = apparent cohesion of soil in terms of effective stresses

σ'_f = effective normal stress on failure plane

$ø'$ = angle of shearing resistance of soil in terms of effective stresses

$$\sigma'_f = \sigma_f - u_f$$

u_f = pore water pressure on failure plane

4. Place the loading plate on top of the upper porous plate. After recording the weight of the loading carrier place it is on the loading cap.

Direct Shear Test Data

Normal stress: ________psi

Horizontal Dial Reading (0.001 in)	Horizontal Displacement (in)	Load Dial Reading	Horizontal Shear Force (lb)	Shear Stress (psi)

5. Position all dial gauges and set the readings to zero. Remove the alignment screws which hold two halves of the shear box together

6. Tighten the remaining, two diagonally opposite screws, until there is a small gap between upper and lower boxes to reduce the frictional force

7. Apply the desired normal load. If there is any vertical displacement, wait till the dial gauges indicate a constant reading and then reset the dial gauge to zero

8. Check that screws have been removed and then start the motor to produce the desired constant rate of shearing

9. Take readings of,

a) Shear load from the proving ring

b) Shear displacement (i.e. Horizontal displacement)

c) Vertical displacement at every 10 division increment in horizontal dial gauge

10. Stop the test when the shear load starts to reduce or remains constant for at least three readings

11. Remove the soil and repeat the procedure with different normal loads at least for another two samples

COMPUTATION

1. For each specimen plot the following;

a. Shear stress Vs shear displacement

b. Normal displacement Vs shear displacement

c. Void ratio Vs shear displacement

2. Plot the graph of shear strength Vs normal stress for the three specimens and calculate the shear strength parameters for the soil.

UNCONFINED COMPRESSION TEST

DATA SHEET

Diameter (d) =

Length (L0) =

Mass =

Table 1: Moisture Content determination

Sample no.	
Moisture can number - Lid number	
M_C = Mass of empty, clean can + lid (grams)	
M_{CMS} = Mass of can, lid, and moist soil (grams)	
M_{CDS} = Mass of can, lid, and dry soil (grams)	
M_S = Mass of soil solids (grams)	
M_W = Mass of pore water (grams)	
W = Water content, w%	

Area (A_0) =

Volume =

Wet density =

Water content (w%) =

Dry density (d) =

Ex No. 14	DETERMINATION OF SHEAR PARAMETERS OF SOIL BY UNCONFINED COMPRESSION TEST
Date:	

AIM

To determine shear strength parameters of the given soil sample at known density by conducting direct shear test.

APPARATUS

1. Compression device
2. Load and deformation dial gauges
3. Sample trimming equipment
4. Balance
5. Moisture can

PROCEDURE:

1. Extrude the soil sample from Shelby tube sampler. Cut a soil specimen so that the ratio (L/d) is approximately between 2 and 2.5.
   Where L and d are the length and diameter of soil specimen, respectively.

2. Measure the exact diameter of the top of the specimen at three locations
   120° apart, and then make the same measurements on the bottom of the specimen. Average the measurements and record the average as the diameter on the data sheet.

3. Measure the exact length of the specimen at three locations 120° apart, and then average the measurements and record the average as the length on the data sheet.
4. Weigh the sample and record the mass on the data sheet.
5. Calculate the deformation (DL) corresponding to 15% strain (e).

$$\text{Strain (e)} = \frac{\Delta L}{L_\circ}$$

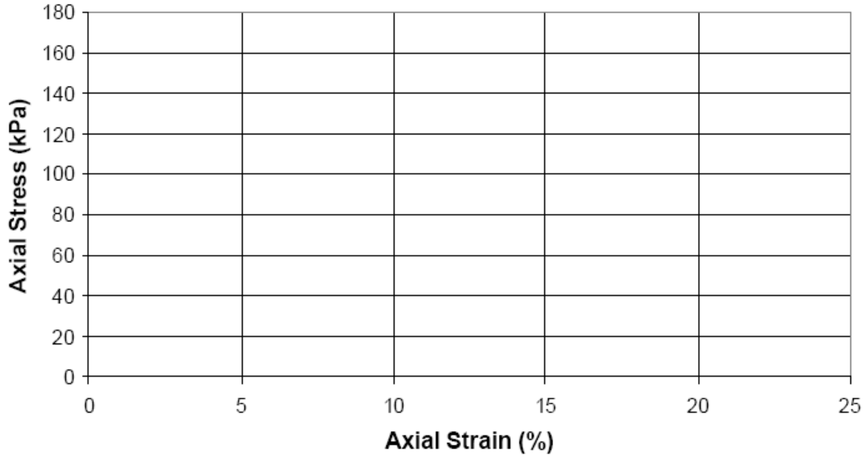
   Where L0 = Original specimen length (as measured in step 3).

6. Carefully place the specimen in the compression device and center it on the bottom plate. Adjust the device so that the upper plate just makes contact with the specimen and set the load and deformation dials to zero.

7. Apply the load so that the device produces an axial strain at a rate of 0.5% to 2.0% per minute, and then record the load and deformation dial readings on the data sheet at every 20 to 50 divisions on deformation the dial.

Table 2: Unconfined Compression Test Data (Deformation Dial: 1 unit = 0.10mm; Proving Ring No: 24691; Load Dial: 1 unit = 0.3154 lb)

Deformation Dial Reading	Load Dial Reading	Sample Deformation ΔL (mm)	Strain (ε)	% Strain	Corrected Area A'	Load (lb)	Load (KN)	Stress (kPa)
0								
20								
40								
60								
80								
100								
120								
140								
160								
180								
200								
250								
300								
350								
400								
450								
500								
550								
600								
650								
700								
750								
800								
850								
900								
950								
1000								



From the stress-strain curve and Mohr's circle:

Unconfined compressive strength (qu) = Cohesion (c) =

8. Keep applying the load until (1) the load (load dial) decreases on the specimen significantly, (2) the load holds constant for at least four deformation dial readings, or (3) the deformation is significantly past the 15% strain that was determined in step 5.
9. Draw a sketch to depict the sample failure.
10. Remove the sample from the compression device and obtain a sample for water content determination.

ANALYSIS:

1. Convert the dial readings to the appropriate load and length units, and enter these values on the data sheet in the deformation and total load columns.

   (Confirm that the conversion is done correctly, particularly proving dial gage

   readings conversion into load)

2. Compute the sample cross-sectional area

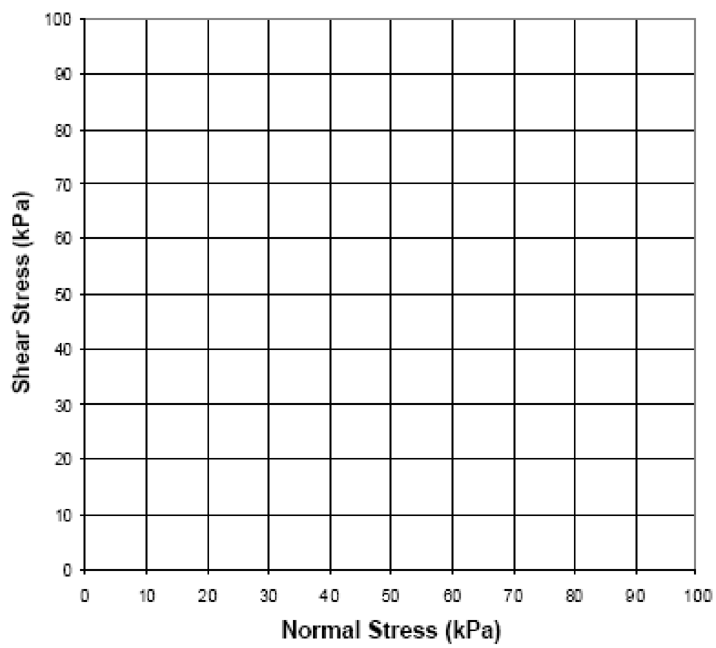
$$A_0 = \frac{\pi}{4} \times (d)^2$$

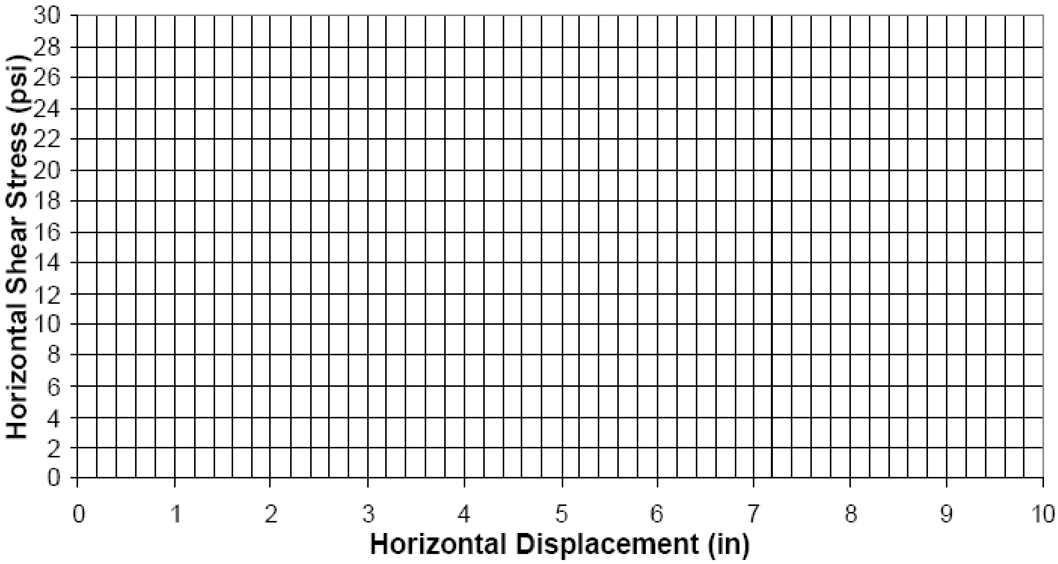
3. Compute the strain

$$e = \frac{?L}{L_0}$$

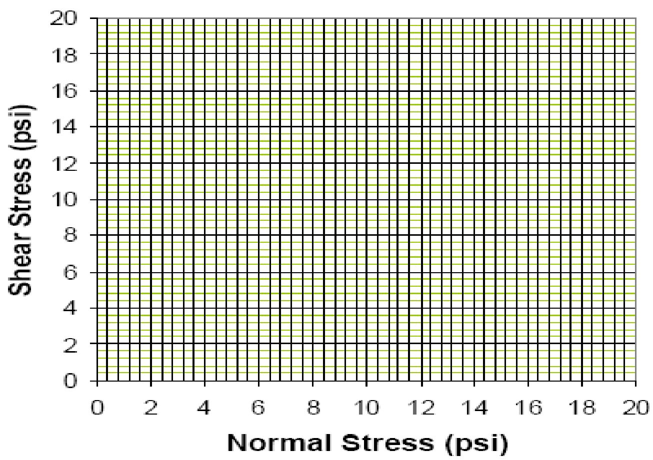
4. Computed the corrected area, A'= A0/(1-e)
5. Using A', compute the specimen stress, s c =P/A'
6. Compute the water content, w%.
7. Plot the stress versus strain. Show qu as the peak stress (or at 15% strain) of the test. Be sure that the strain is plotted on the abscissa.

8. Draw Mohr's circle using qu from the last step and show the undrained shear strength, **s_u = c (or cohesion) = q_u/2.**

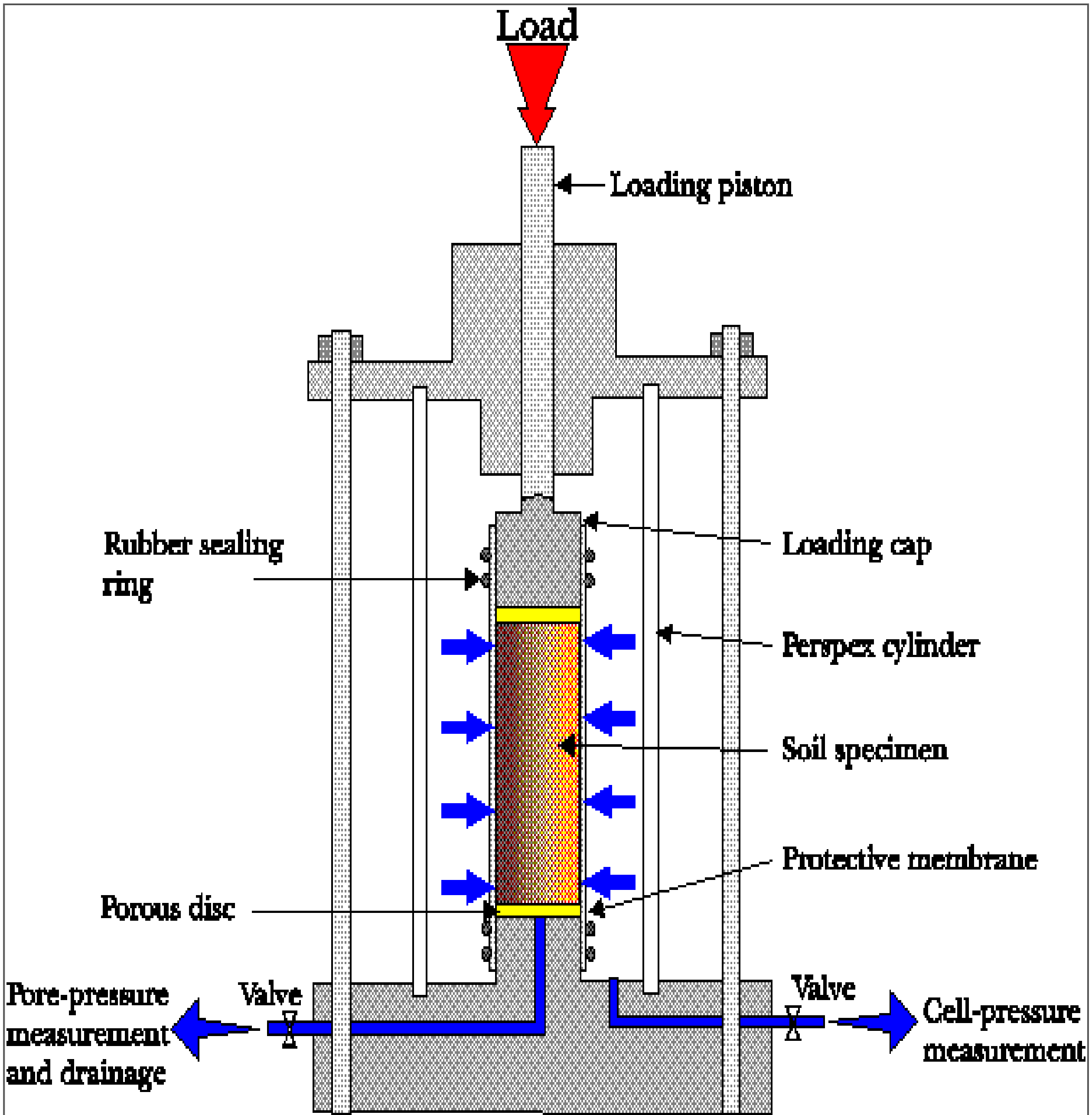




Horizontal Shear Stress (psi)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
0 1 2 3 4 5 6 7 8 9 10
Horizontal Displacement (in)



Shear Stress (psi)
20
18
16
14
12
10
8
6
4
2
0
0 2 4 6 8 10 12 14 16 18 20
Normal Stress (psi)



Triaxial apparatus

Ex No. 15	TRIAXIAL SHEAR TEST
Date:	

Aim

To determine the shear strength parameters by triaxial test

Apparatus

- Strain controlled triaxial load frame
- Triaxial cell assembly
- Cell pressure supply panel
- Scale
- Balance sensitive to 0.1 g
- Moisture cans
- Oven

Theory

Triaxial test is more reliable because we can measure both drained and undrained shear strength.

- Generally 1.4” diameter (3” tall) or 2.8” diameter (6” tall) specimen is used.
- Specimen is encased by a thin rubber membrane and set into a plastic cylindrical chamber.
- Cell pressure is applied in the chamber (which represents **σ_3’**) by pressurizing the cell fluid (generally water).
- Vertical stress is increased by loading the specimen (by raising the platen in strain controlled test and by adding loads directly in stress controlled test, but strain controlled test is more common) until shear failure occurs. Total vertical stress, which is **σ_1’** is equal to the sum of **σ_3’** and deviator stress (**σ_d**).
- Measurement of **σ_d**, axial deformation, pore pressure, and sample volume change are recorded.
- Depending on the nature of loading and drainage condition, triaxial tests are conducted in three different ways.
    - UU Triaxial test
    - CU Triaxial test
    - CD Triaxial test
- In this lab, we will conduct UU triaxial test.
- As drainage is not permitted and consolidation is not necessary, this test is very quick, and also referred as Q-test.
- As drainage is not permitted, u increases right after the application of σ3’ as well as after the application of **σ_d**.

  As $U_c = B\sigma_3$

$$U_d = \overline{A.\sigma_d}$$

$$Total\, u = B.\sigma_3 + A.\sigma d$$

$$U = B.\sigma_3 + \bar{A}.(\sigma_1 - \sigma_3)$$

- This test is common in clayey soils.

Application

UU triaxial test gives shear strength of soil at different confining stresses. Shear strength is important in all types of geotechnical designs and analyses.

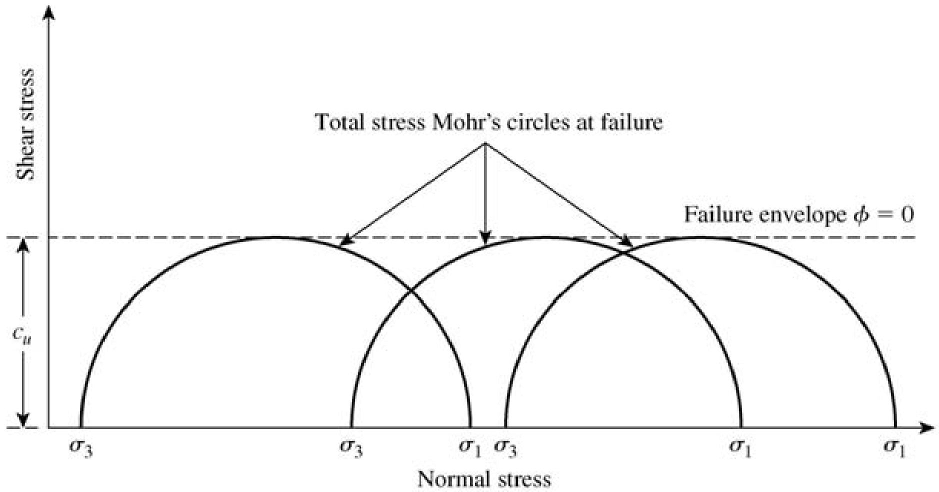


Figure 11.31 Total stress Mohr's circles and failure envelope ($\phi = 0$) obtained from unconsolidated-undrained triaxial tests on fully saturated cohesive soil

Procedure

- Measure diameter, length, and initial mass of the specimen.
- Measure the thickness of the rubber membrane.
- Set a soil specimen in a triaxial chamber.
- Increase the cell pressure to a desired value (70 kPa for the first case and 140 kPa in the second case).
- Shear the specimen at the rate of 1%/min or 0.7 mm/min (for 70 mm sample height).
- In automated device, the software calculates it automatically based on the soil type.
- Record **ΔL**, and $\boldsymbol{\sigma_d}$ in every 10 seconds (computer does it automatically).
- Continue the test until the deviator stress shows ultimate value or 20% axial strain.
- After completion of the test, release the cell pressure to 0, vent the pressure and bring the cell down by bring the lower platen down, drain the cell, and clean the porous stone and the assembly.
- Sketch the mode of failure.
- Measure the weight of the soil specimen again, and put the specimen into the oven.
- Measure the weight again after 24 hours.
- Repeat the test for the second specimen too (140 kPa of cell pressure and third specimen 210 kPa of cell pressure).

Calculations

Calculate axial strain $\boldsymbol{\varepsilon} = \frac{\boldsymbol{\Delta L}}{\boldsymbol{L}}$

ΔL = Vertical deformation of the specimen.

Calculate vertical load on the specimen.

You will get it directly from the force transducers.

Calculate corrected area of the specimen (Ac)

$$A_c = \frac{A_o}{1 - \varepsilon}$$

A_o = Initial cross-sectional area i.e. **π x $D^2/4$**

Calculate the stress σ on the specimen

$$\sigma = \frac{Load}{A_c}$$

III. MEASUREMENTS AND CALCULATIONS

Axial Deformation (ΔL)	Axial Load (P)	Axial Strain (ε_l)	Corrected Area (A)	Deviator Stress ($\Delta\sigma$)

EQUATIONS:

$\varepsilon_a = \Delta L/L_o$

$A = A_o/(1-\varepsilon_a)$

$\Delta\sigma = P/A$

$\sigma_{1f} = \sigma_3 + \Delta\sigma_f$

σ_3:
$\Delta\sigma_f$:
σ_{1f}:

- Plot **σ_d** versus axial strain separately for three tests.
- Plot **σ_d** vs **ε_a** for three tests in the same plot.
- Plot Mohr circle based on σ_1 and σ_3 at failure. They should give the same σd value.
- Add one Mohr circle for unconfined compression test too (That you did last week).

- Make a straight line, which is tangent to all Mohr's circles. This gives $\mathbf{c_u}$ with a horizontal line, i.e. $\boldsymbol{\varphi_u} = 0$. Therefore this test is called $\boldsymbol{\varphi = 0}$ test.
- $\boldsymbol{c_u = \frac{\sigma_d}{2}}$

- Calculate the moisture content of the specimen after the test.
- Calculate the initial void ratio of the specimen