AARUPADAI VEEDU INSTITUTE OF TECHNOLOGY

ACCREDITED BY NAAC APPROVED BY AICTE RECOGNIZED BY DSIR

SOIL MECHANICS LAB

LAB MANUAL

DEPARTMENT OF CIVIL ENGINEERING

HoD/Civil Engg.

CONTENTS

DETERMINATION OF SPECIFIC GRAVITY OF SOIL

AIM

To determine the specific gravity of soil fraction passing 4.75 mm I.S sieve by Pycnometer.

NEED AND SCOPE

The knowledge of specific gravity is needed in calculation of soil properties like void ratio, degree of saturation etc.

DEFINITION

Specific gravity G is defined as the ratio of the weight of an equal volume of distilled water at that temperature both weights taken in air.

APPARATUS

1. Pycnometer
2. Balance to weigh the materials (accuracy 10gm).
3. Wash bottle with distilled water.
4. Alcohol and ether.

PROCEDURE

1. Clean and dry the pycnometer
   a. Wash the pycnometer with water and allow it to drain.
   b. Wash it with alcohol and drain it to remove water.
   c. Wash it with ether, to remove alcohol and drain ether.
2. Weigh the pycnometer (W1)
3. Take about 200 gm of oven-dried soil sample which is cooled in a desiccator. Transfer it to the pycnometer. Find the weight of the pycnometer and soil (W2).
4. Put 10ml of distilled water in the pycnometer to allow the soil to soak completely. Leave it for about 2 hours.
5. Again fill the pycnometer completely with distilled water put the stopper and keep the pycnometer under constant temperature water baths (Tx^0).
6. Take the pycnometer outside and wipe it clean and dry it. Now determine the weight of the pycnometer and the contents (W3).
7. Now empty the pycnometer and thoroughly clean it. Fill the pycnometer with only distilled water and weigh it. Let it be W4 at temperature (Tx^0 C).

OBSERVATIONS

S. No.	Observation Number	1	2	3
1	Weight of pycnometer (W1 g)			
2	Weight of pycnometer + dry soil (W2 g)			
3	Weight of pycnometer + dry soil + water at temperature T_x ^{0}C (W3 g)			
4	Weight of pycnometer + water at temperature T_x ^{0} C (W4 g)			
5	Specific gravity G at T_x ^{0} C			

Average specific gravity at T_x ^{0} C

CALCULATIONS

$$\textit{Specific gravity of soil} = \frac{\text{Density of water at 27 C}}{\text{Weight of water of equal volume}}$$

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

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

8. Repeat the same process for 2 to 3 times, to take the average reading of it.

RESULT

Specific Gravity of given soil =

INFERENCE

QUESTIONS

1. If entrapped air is not removed completely, how will it affect the value of specific gravity of solids?
2. Specify the range over which the average specific gravity of soil solids will lie.
3. How is specific gravity of solids for fine grained soil (Clay) found in laboratory?
4. Mention the practical application of specific gravity of soil solids.

GRAIN SIZE DISTRIBUTION OF SOIL BY SIEVE ANALYSIS

AIM

To determine the percentage of various size particles in a soil sample, and to classify the soil.

APPARATUS

i. 1st set of sieves of size 300 mm, 80 mm, 40 mm, 20 mm, 10 mm, and 4.75 mm.

ii. 2nd set of sieves of sizes 2mm, 850 micron, 425 micron, 150 micron, and 75 micron.

iii. Balances of 0.1 g sensitivity, along with weights and weight box.

iv. Brush.

THEORY

Soils having particle larger than 0.075mm size are termed as coarse grained soils. In these soils more than 50% of the total material by mass is larger 75 micron. Coarse grained soil may have boulder, cobble, gravel and sand.

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

i. BOULDER: particle size is more than 300mm.

ii. COBBLE: particle size in range 80mm to 300mm.

iii. GRAVEL (G): particle size in range 4.75mm to 80mm.

a. Coarse Gravel: 20 to 80mm.

b. Fine Gravel: 4.75mm to 20mm.

iv. SAND (S): particle size in range 0.075mm to 4.75mm.

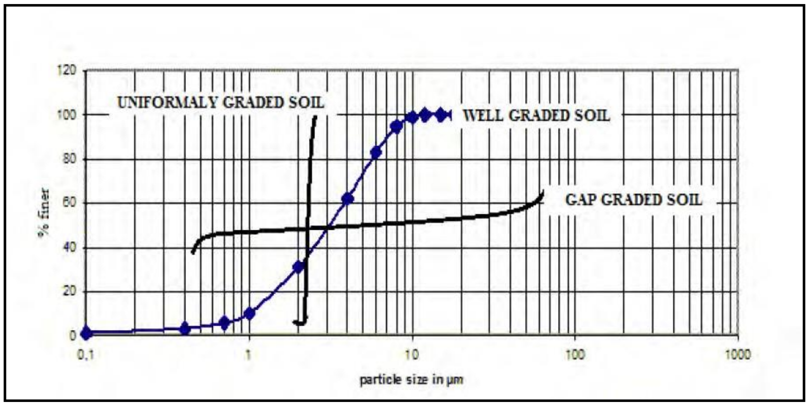
a. Coarse sand: 2.0mm to 4.75mm.

b. Medium Sand: 0.425mm to 2.0mm.

c. Fine Sand: 0.075mm to o.425mm.

Dry sieve is performed for cohesion less soils if fines are less than 5%. Wet sieve analysis is carried out if fines are more than 5% and of cohesive nature.

In simpler way the particle size distribution curve for coarse grain soil as follows,



UNIFORMALY GRADED SOIL
WELL GRADED SOIL
GAP GRADED SOIL
120
100
80
60
40
20
0
% finer
0,1
1
10
100
1000
particle size in µm

Gravels and sands may be either poorly graded (Uniformly graded) or well graded depending on the value of coefficient of curvature and uniformity coefficient.

Coefficient of curvature (Cc) may be estimated as:

$$C_c = \frac{{D_{30}}^2}{D_{10} \times D_{60}}$$

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

Uniformity coefficient (Cu) is given by:

$$C_u = \frac{D_{60}}{D_{10}}$$

Its value should be more than 4 for well graded gravel and more than 6 for well graded sand.

Were, D60 = particle size at 60% finer.

D30 = particle size at 30% finer.

D10 = particle size at 10% finer.

PROCEDURE:

i. Weight accurately about 200gms of oven dried soil sample. If the soil has a large fraction greater than 4.75mm size, then greater quantity of soil, that is, about 5.0 Kg should be taken. For soil containing some particle greater than 4.75 mm size, the weight of the soil sample for grain size analysis should be taken as 0.5 Kg to 1.0 Kg.

ii. Clean the sieves and pan with brush and weigh them upto 0.1 gm accuracy. Arrange the sieves in the increasing order of size from top to bottom. The first set shall consist of sieves of size 300 mm, 80mm, 40mm, 20mm, 10mm, and 4.75 mm. While the second set shall consist of sieves of sizes 2mm, 850 micron, 425 micron, 150 micron, and 75 micron.

OBSERVATION AND CALCULATION TABLE:

Mass of soil Sample taken for Analysis =

Sieve size (mm)	Mass of soil Retained (gms)	% of soil retained (%)	Cumulative % of soil retained (%)	% of soil passing(%)

Coefficient of curvature (Cc) may be estimated as:

Uniformity coefficient (Cu) is given by:

iii. Keep the required quantity of soil sample on the top sieve and shake it with mechanical sieve shaker for about 5 to 10 minutes. Care should be taken to tightly fit the lid cover on the top sieve.

iv. After shaking the soil on the sieve shaker, weigh the soil retained on each sieve. The sum of the retained soil must tally with the original weight of soil taken.

PRECAUTIONS:

i. During shaking the lid on the topmost sieve should be kept tight to prevent escape of soils.

ii. While drying the soil, the temperature of the oven should not be more than 105^0C because higher temperature may cause some permanent change in the 75µ fraction.

RESULT:

1. The given soil is...............................
2. Coefficient of curvature (Cc) =
3. Uniformity coefficient (Cu) =

Questions:

i. What do you understand by well graded, poorly graded and uniformly graded soils?
ii. What do you understand by dry sieve and wet sieve analysis? Which once did you perform and why?
iii. What is the grain size distribution curve? Why do you use a semi-long graph paper for plotting it?
iv. What do you understand by GW,GP,GM,GC,SW,SP,SM,SC,SW-SM,GP-SC?

ATTERBERG LIMITS TEST

AIM:

To determine the liquid limit, plastic limit, shrinkage limit of the given soil sample.

THEORY:

The definitions of the consistency limits proposed by Atterberg are not, by themselves, adequate for the determination of their numerical values in the laboratory, especially in view of the arbitrary nature of these definitions. In view of this, Arthur Casagrande and others suggested more practical definitions with special reference to the laboratory devices and methods developed for the purpose of the determination of the consistency limits. In this sub-section, the laboratory methods for determination of the liquid limit, plastic limit, shrinkage limit, and other related concepts and indices will be studied, as standardized and accepted by the Indian Standard Institution and incorporated in the codes or practice.

APPARATUS:

1. Casagrande's liquid limit device and grooving tool
2. Spatula
3. Balance
4. Glass plate
5. Hot air oven maintained at 105 ± 1^0C
6. Moisture Containers

STANDARD REFERENCE:

FOR LIQUID LIMIT:

IS: 2720(Part V)–1985.

FOR PLASTIC LIMIT:

IS: 2720, Part V–1985.

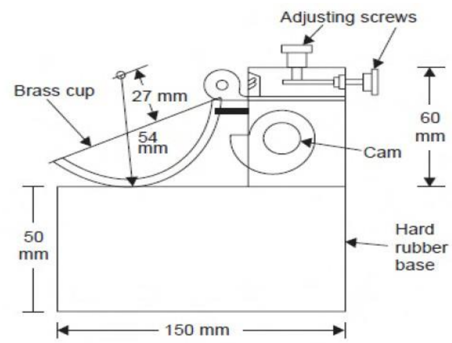
TERMS:

Shrinkage limit:

The shrinkage limit (SL) is the water content where further loss of moisture will not result in any more volume reduction. The shrinkage limit is much less commonly used than the liquid limit and the plastic limit.

Plastic limit:

The plastic limit (PL or w_P) is the water content where soil starts to exhibit plastic behaviour. A thread of soil is at its plastic limit when it is rolled to a diameter of 3 mm or begins to crumble. To improve consistency, a 3 mm diameter rod is often used to gauge the thickness of the thread when conducting the test. (AKA Soil Snake Test).



Liquid limit device

Liquid limit:

Liquid limit (LL or w_L) is defined as the arbitrary limit of water content at which the soil is just about to pass from the plastic state into the liquid state. At this limit, the soil possesses a small value of shear strength, losing its ability to flow as a liquid. In other words, the liquid limit is the minimum moisture content at which the soil tends to flow as a liquid.

PLATICITY INDEX:

Plasticity index (PI or I_p) is the range of water content within which the soil exhibits plastic properties; that is, it is the difference between liquid and plastic limits.

PI (or I_p) = (LL - PL) = (w_L - w_P)

When the plastic limit cannot be determined, the material is said to be non-plastic (NP).

Plasticity index for sands is zero.

For proper evaluation of the plasticity properties of a soil, it has been found desirable to use both the liquid limit and the plasticity index values.

SHRINKAGE INDEX:

Shrinkage index (SI OR I_s) is defined as the difference between the plastic and shrinkage limits of a soil; in other words, it is the range of water content within which a soil is in a semisolid state of consistency.

$$\text{SI (or } I_S) = (\text{SL OR } I_S) = (W_p - W_S)$$

CONSISTENCY INDEX:

Consistency index or Relative consistency (CI OR I_C) is defined as the ratio of the difference between liquid limit and the natural water content to the plasticity index of a soil:

$$\text{CI OR } I_C = (\text{LL - w}) / \text{PI} = (w_L - w) / I_P$$

Where w = natural water content of the soil (water content of a soil in the undisturbed condition in the ground).

If I_C= 0, w = LL

I_C = 1, w = PL

I_C > 1, the soil is in semi-solid state and is stiff.

I_C < 0, the natural water content is greater than LL, and the soil behaves like a liquid.

LIQUIDITY INDEX:

Liquidity index (LI OR I_L) or Water-plasticity ratio is the ratio of the difference between the natural water content and the plastic limit to the plasticity index:

LI or (I_L) = (w - PL) / PI or (I_P) = (w - w_P) / I_p

If I_L = 0, w = PL
I_L= 1, w = LL
I_L> 1, the soil is in liquid state.
I_L< 0, the soil is in semi-solid state and is stiff.

Obviously, CI + LI = 1

PROCEDURE:

1. FOR DETERMINATION OF LIQUID LIMIT:

1. About 120 gm of air-dried soil from thoroughly mixed portion of material passing 425 micron I.S sieve is to be obtained.

2. Distilled water is mixed to the soil thus obtained in a mixing disc to form uniform paste. The paste shall have a consistency that would require 30 to 35 drops of cup to cause closer of standard groove for sufficient length.

3. A portion of the paste is placed in the cup of Casagrande apparatus 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 dimension is formed.

6. Lift and drop the cup by turning crank at the rate of two revolutions per second until the two halves of soil cake come in contact with each other for a length of about 1 cm by flow only.

7. The number of blows required to cause the groove close for about 1 cm shall be recorded.

8. A representative portion of soil is taken from the cup for water content determination.

9. Repeat the test with different moisture contents at least three more times for blows between 10 and 40.

Atterberg Limits Determination

Natural water content of given soil =

Liquid Limit Determination

Can No.					
Mass of can (g)					
Mass of wet soil + can (g)					
Mass of dry soil + can (g)					
Mass of dry soil (g)					
Mass of water (g)					
Water content, (%)					
No. of drops					

Plastic Limit Determination

Can No.					
Mass of can (g)					
Mass of wet soil + can (g)					
Mass of dry soil + can (g)					
Mass of dry soil (g)					
Mass of water (g)					
Water content, (%)					

CALCULATIONS:

1. Plasticity index=
2. Shrinkage index =
3. Consistency index =
4. Liquidity index=

2. FOR DETERMINATION OF PLASTIC LIMIT:

1. Take about 20gm of thoroughly mixed portion of the material passing through 425 micron I.S. sieve obtained in accordance with I.S. 2720 (part 1).

2. Mix it thoroughly with distilled water in the evaporating dish till the soil mass becomes plastic enough to be easily moulded with fingers.

3. Allow it to season for sufficient time (for 24 hrs) to allow water to permeate throughout the soil mass

4. Take about 10gms 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 60 and 90 strokes per minute.

5. Continue rolling till you get a threaded of 3 mm diameter.

6. Kneed the soil together to a uniform mass and re-roll.

7. Continue the process until the thread crumbles when the diameter is 3 mm.

8. Collect the pieces of the crumbled thread in air tight container for moisture content determination.

9. Repeat the test to atleast 3 times and take the average of the results calculated to the nearest whole number.

3. **FOR DETERMINATION OF SHRINKAGE LIMIT**

Preparation of soil paste

1. Take about 100 gm of soil sample from a thoroughly mixed portion of the material passing through 425-micron I.S. sieve.

2. Place about 30 gm of the above soil sample in the evaporating dish and thoroughly mix it with distilled water and make a creamy paste. Use water content somewhere around the liquid limit.

Filling the shrinkage dish

3. Coat the inside of the shrinkage dish with a thin layer of Vaseline to prevent the soil sticking to the dish.

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

5. Weigh immediately, the dish with wet soil and record the weight.

Shrinkage Limit Determination

S.No	Determination No.	1	2	3
1	Wt. of container in gm,W_1			
2	Wt. of container + wet soil pat in gm,W_2			
3	Wt. of container + dry soil pat in gm,W_3			
4	Wt. of oven dry soil pat, W_0 in gm			
5	Wt. of water in gm			
6	Moisture content (%), W			
7	Volume of wet soil pat (V), in cm			
8	Volume of dry soil pat (V_0) in cm3			
9	By mercury displacement method a. Weight of displaced mercury b. Specific gravity of the mercury			
10	Shrinkage limit (WS)			
11	Shrinkage ratio (R)			

CALCULATION

First determine the moisture content

$$\text{Shrinkage limit (WS)} = \left(W - (V - V_0) \times \gamma_W / W_0\right) \times 100$$

Where, W = Moisture content of wet soil pat (%)

V = Volume of wet soil pat in cm3

V0 = Volume of dry soil pat in cm3

W0 = Weight of oven dry soil pat in gm.

6. Air-dry the wet soil cake for 6 to 8hrs, until the colour of the pat turns from dark to light. Then oven-dry the soil to constant weight at 105^0C to 110^0C say about 12 to 16 hrs.

7. Remove the dried disk of the soil from oven. Cool it in a desiccator. Then obtain the weight of the dish with dry sample.

8. Determine the weight of the empty dish and record.

9. Determine the volume of shrinkage dish which is evidently equal to volume of the wet soil as follows. Place the shrinkage dish in an evaporating dish and fill the dish with mercury till it overflows slightly. Press it with plain glass plate firmly on its top to remove excess mercury. Pour the mercury from the shrinkage dish into a measuring jar and find the volume of the shrinkage dish directly. Record this volume as the volume of the wet soil pat.

Volume of the Dry Soil Pat

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

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

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

RESULT:

For given soil:

1. Liquid limit =
2. Plastic limit =
3. Plasticity index =
4. Shrinkage index =
5. Consistency index =
6. Liquidity index=
7. Shrinkage limit =

Questions:

1. What is liquid limit?
2. What is plastic limit?
3. What apparatus is used to measure the liquid limit of a given soil sample.
4. What number of blows is taken for consideration while determining the liquid limit of a given soil sample.
5. What is plasticity index?

PERMEABILITY TEST

AIM:

To determine the coefficient of permeability of a given soil sample by

i) Constant head method
ii) Variable head method

APPARATUS REQUIRED:

i) Permeameter with all accessories for constant head
ii) Compaction equipment
iii) Stop watch
iv) Balance
v) Measuring cylinder
vi) Scale

THEORY:-

Permeability is defined as the property of porous material which permits the passage or seepage of water through its interconnected voids. The coefficient of permeability is finding out following method.

a) Laboratory method:

i. Variable head test.

ii. Constant head test.

b) Field method:

i. Pumping out test.

ii. Pumping in test.

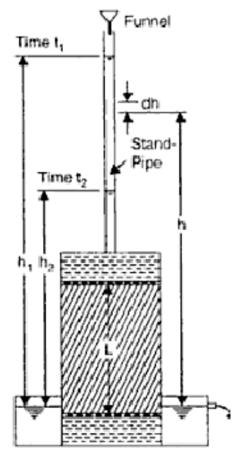
c) Indirect test:

i. Computation from grain size or specific surface.

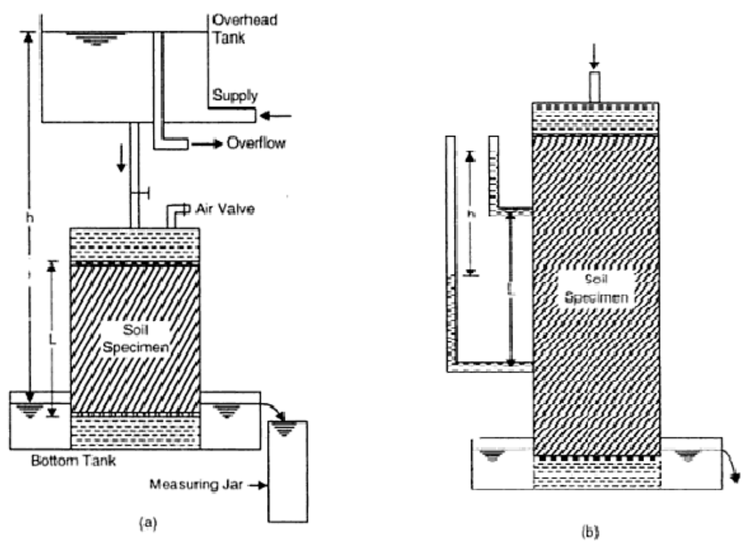
ii. Horizontal capillarity test.

iii. Consolidation test data.

The derivation of the coefficient of permeability is based on the assumption of the validity of the Darcy's law to the flow of water in soil. The term coefficient of permeability implies the velocity of flow of water through the soil under unit hydraulic gradient, and consequently has the same units as that of velocity.



FALLING HEAD TEST.



CONSTANT HEAD TEST.

A. Variable head test:

The variable head test is used for fine grained soils like silts and silty clays.

For the Variable head test the following formula is applicable:

$$k = 2.203 \frac{a * L}{A * t} log_{10} (\frac{h_1}{h_2})$$

Where, k = Coefficient of permeability at To C (cm/sec).

a = Cross Sectional area of stand pipe (cm^2).

L = Length of soil specimen (cm)

A = Cross-sectional area of soil sample inside the mould (cm^2)

t = (t_1 – t_2) = Time interval for the head to fall from h_1 to h_2.

h_1 = Initial head of water at time t_1 in the pipe, measured above the outlet.

h_2 = Final head of water at time t_2 in the pipe, measured above the outlet.

B. Constant head test:

The Constant head test is suitable for coarse grained soils like sands, sandy silts.

If Q is the total quantity of flow in a time interval t, we have from Darcy's law,

$$K = QL / (hAT)$$

Where, k = Coefficient of permeability at T^o C (cm/sec).

L = Length of soil specimen (cm)

A = Total cross-sectional area of soil sample (cm^2)

Q = Quantity of water collected in measuring jar.

t = total time required for collecting 'Q' quantity of water.

h = Difference in the water levels of the overhead and bottom tank.

APPLICATION:

Water flowing through soil exerts considerable seepage force which has direct effect on the safety of hydraulic structures.

The rate of settlement of compressible clay layer under load depends on its permeability. The quantity of water escaping through and beneath the earthen dam depends on the permeability of the embankments and its foundations respectively. The rate of discharge through wells and excavated foundation pits depends on the coefficient of permeability of the soils. Shear strength

of soils also depends indirectly on its permeability, because dissipation of pore pressure is controlled by its permeability.

The table below gives rough values of the coefficient of permeability of various soils:

Type of soil	Value of permeability (cm/sec)
Gravel	10^{3} to 1.0
Sand	1.0 to 10^{-3}
Silt	10^{-3} to 10^{-6}
Clay	less than 10^{-3}

According to U.S Bureau of Reclamations, soil are classified as follows:

Impervious	k less than 10^{-6} cm/sec
Semi-pervious	k between 10^{-6} to 10^{-4} cm/sec
Pervious	k greater than 10^{-4} cm/sec

PROCEDURE:

a) Preparation of remoulded soil specimen:

i. Weight the required quantity of oven dried soil sample. Evenly sprinkle the calculated quantity of water corresponding to the OMC. Mix the soil sample thoroughly.

ii. Clean the mould and apply a small portion of grease inside the mould and around the porous stones in the base plate. Weight the mould and attach the collar to it. Fix the mould on the compaction base plate. Keep the apparatus on solid base.

iii. The soil sample is placed inside the mould, and is compacted by the standard Proctor compaction tools, to achieve a dry density equal to the pre-determine3d MDD. Weight the mould along with the compacted soil.

iv. Saturate the porous stones. Place the filter papers on both ends of the soil specimen in the mould. Attach the mould with the drainage base and cap having saturated porous stones.

b) Saturation of soil specimen:

i. Connect the water reservoir to the outlet at the bottom of the mould and allow the water to flow in the soil. Wait till the water has been able to travel up and saturate the sample. Allow about 1 cm depth of free water to collect on the top of the sample.

ii. Fill the remaining portion of cylinder with de-aired water without disturbing the surface of soil.

iii. Fix the cover plate over the collar and tighten the nuts in the rods.

OBSERVATION AND CALCULATION TABLE FOR CONSTANT HEAD PERMIABILITY TEST:

S No	OBSERVATION	1	2	3
1	Diameter of stand pipe (cm) 'd'			
2	c/s area of stand pipe 'a = $\pi d^2/4$			
3	Diameter of cylindrical soil sample D			
4	c/s area of soil specimen 'A = $\pi D^2/4$			
5	Height of soil specimen, L			
6	Hydraulic head 'h' (cm)			
7	Time interval 't' (sec)			
8	Coefficient of permeability (cm/sec) $k = \frac{Q}{t}\ \frac{L}{h}\ \frac{1}{A}$			

Avg. Coefficient of permeability (cm/sec) = ____________

OBSERVATION AND CALCULATION TABLE FOR FALLING HEAD PERMIABILITY TEST:

Table 1:

Sr no.	Observation	1	2	3
1	Diameter of stand pipe (cm) 'd'	1.0	1.1	1.2
2	c/s area of stand pipe 'a = $\pi d^2/4$			
3	Diameter of cylindrical soil sample D			
4	c/s area of soil specimen 'A = $\pi D^2/4$			
5	Height of soil specimen, L			

Table 2:

Sr. No.	Initial Head (h_1) cm	Final Head (h_2) cm	Time required (t) sec	Permeability, $k = 2.203\ \frac{a*L}{A*t}\ log_{10}\left(\frac{h_1}{h_2}\right)$
1				
2				
3				

c) Constant head test:

i. Place the mould assembly in the bottom tank and fill the bottom tank with water up to the outlet.

ii. Connect the outlet tube with constant head tank to the inlet nozzle of the permeameter, after removing the air in flexible rubber tubing connecting the tube.

iii. Adjust the hydraulic head by either adjusting the relative height of the permeameter mould and constant head tank or by raising or lowering the air intake tube with in the head tank.

iv. Start the stop watch and at the same time put a bucket under the outlet of the bottom tank, run the test for same convenient time interval and measure.

v. Repeat the test twice more, under the same head and for the same time interval.

d) Variable head permeability test method:

i. Disconnect the water reservoir from the outlet at the bottom and connect the stand pipe to the inlet at the top plate.

ii. Fill the stand pipe with water. Open the stop cock at the top and allow water to flow out so that all the air in the cylinder is removed.

iii. Fix the height h1 and h2 on the stand pipe from the centre of the outlet such that (h1 – h2) is about 30 cm to 40 cm.

iv. When all the air has escaped, close the stop clock and allow the water from the pipe to flow through the soil and establish a steady flow.

v. Record the time interval, t, for the head to drop from h1 to h2.

vi. Take about five such observations by changing the values of h1 and h2.

vii. Measure the temperature of water.

RESULTS

Coefficient of permeability of given soil

By Constant head method =................................
By Variable head method =.................................

QUESTIONS

i. What is Darcy's law of flow velocity through soils? What are its Limitations?
ii. What are the steady and unsteady flows of water? What type of flow is assumed to occur in soils?
iii. What are the laboratory methods of determination of coefficient of permeability of soil? State their suitability.
iv. What is the effect of entrapped air on the coefficient of permeability of soil?

FIELD DENSITY TEST

A. SAND REPLACEMENT METHOD

OBJECTIVE

Determine the in situ density of natural or compacted soils using sand pouring cylinders.

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.

It is very quality control test, where compaction is required, in the cases like embankment and pavement construction.

APPARATUS REQUIRED

1. Sand pouring cylinder of 3 litre/16.5 litre capacity mounted above a pouring come and separated by a shutter cover plate.

2. Tools for excavating holes; suitable tools such as scraper tool to make a level surface.

3. Cylindrical calibrating container with an internal diameter of 100 mm/200 mm and an internal depth of 150 mm/250 mm fitted with a flange 50 mm/75 mm wide and about 5 mm surrounding the open end.

4. Balance to weigh unto an accuracy of 1g.

5. Metal containers to collect excavated soil.

6. Metal tray with 300 mm/450 mm square and 40 mm/50 mm deep with a 100 mm/200 mm diameter hole in the centre.

7. Glass plate about 450 mm/600 mm square and 10mm thick.

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

9. Suitable non-corrodible airtight containers.

10. Thermostatically controlled oven with interior on non-corroding material to maintain the temperature between 105^0C to 110^0C.

11. A dessicator with any desiccating agent other than sulphuric acid.

OBSERVATIONS AND CALCULATIONS

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

S. No	Measurement of Soil Density	1	2	3
1	Weight of wet soil from hole W_w gm			
2	Weight of sand + cylinder before pouring W_1 gm			
3	Weight of sand + cylinder after pouring W_4 gm			
4	Weight of sand in hole $W_b = (W_1\text{-}W_2\text{-}W_4)$ gm			
5	Bulk density $\gamma b = (W_w / W_b) \times \gamma_s$ gm/cc			
	Water content determination			
1	Container number			
2	Weight of wet soil			
3	Weight of dry soil			
4	Moisture content (%)			
5	Dry density $\gamma_d = \gamma_b / (1+w)$ gm/cc			

THEORY

By conducting this test it is possible to determine the field density of the soil. The moisture content is likely to vary from time and hence the field density also. So it is required to report the test result in terms of dry density. The relationship that can be established between the dry density with known moisture content is as follows:

PROCEDURE

Calibration of the Cylinder

1. Fill the sand pouring cylinder with clean sand so that the level of the sand in the cylinder is within about 10 mm from the top. Find out the initial weight of the cylinder plus sand (W_1) and this weight should be maintained constant throughout the test for which the calibration is used.

2. Allow the sand of volume equal to that of the calibrating container to run out of the cylinder by opening the shutter, close the shutter and place the cylinder on the glass sand takes place in the cylinder close the shutter and remove the cylinder carefully. Weigh the sand collected on the glass plate. Its weight (W_2) gives the weight of sand filling the cone portion of the sand pouring cylinder. Repeat this step at least three times and take the mean weight (W_2) Put the sand back into the sand pouring cylinder to have the same initial constant weight (W_1)

Determination of Bulk Density of Soil

3. Determine the volume (V) of the container be filling it with water to the brim. Check this volume by calculating from the measured internal dimensions of the container.

4. Place the sand poring cylinder centrally on the top of the calibrating container making sure that constant weight (W_1) 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 (W_3).

Determination of Dry Density of Soil in Place

5. Approximately 60 sq.cm of area of soil to be tested should be trimmed down to a level surface, approximately of the size of the container. Keep the metal tray on the level surface and excavate a circular hole of volume equal to that of the calibrating container. Collect all the excavated soil in the tray and find out the weight of the excavated soil (W_w). Remove the tray, and place the sand pouring cylinder filled to constant weight so that the base of the cylinder covers the hole concentrically. Open the shutter and permit the sand to run into the hole. Close the shutter when no further movement of the sand is seen. Remove the cylinder and determine its weight(W_3).

6. Keep a representative sample of the excavated sample of the soil for water content determination.

OBSERVATION AND CALCULATION TABLE:

Internal diameter of cutter (cm): _ _ _ _ _ _ _ _

Height of the cutter (cm): _ _ _ _ _ _ _ _

Cross sectional area of the cutter (cm^2): _ _ _ _ _ _ _ _

Volume of the cutter, V (cm^3): _ _ _ _ _ _ _ _

Calculation Table:

	sample 1	sample 2	sample 3
Mass of core cutter, W_1 (gm)			
Mass of cutter + soil from field, W_2 (gm)			
Wet density, (gm/cm3) $\gamma_t = \frac{W_2 - W_1}{V}$			
Dry density , (gm/cm3) $\gamma_d = \frac{\gamma_t}{1 + w}$			

Water/Moisture content determination:

	sample 1	sample 2	sample 3
Weight of can, W_1 (g)			
Weight of can + wet soil W_2 (g)			
Weight of can + dry soil W_3 (g)			
Water/Moisture content $w\,(\%) = \frac{(W_2 - W_3)}{(W_3 - W_1)} \times 100$			

B. CORE CUTTER METHOD

AIM

To determine the field or in-situ density or unit weight of soil by core cutter method

APPARATUS

a) Special:

i. Cylindrical core cutter

ii. Steel rammer

iii. Steel dolly

b) General:

i. Balance of capacity5 Kg and sensitivity 1 gm.

ii. Balance of capacity 200gms and sensitivity 0.01 gms.

iii. Scale

iv. Spade or pickaxe or crowbar

v. Trimming Knife

vi. Oven

vii. Water content containers

viii. Desiccator.

THEORY:

Field density is defined as weight of unit volume of soil present in site. That is

$$y = \frac{W}{V}$$

Where, γ= Density of soil, W = Total weight of soil, V = Total volume of soil

The soil weight consists of three phase system that is solids, water and air. The voids may be filled up with both water and air, or only with air, or only with water. Consequently the soil may be dry, saturated or partially saturated. In soils, mass of air is considered to be negligible, and therefore the saturated density is maximum, dry density is minimum and wet density is in between the two.

Dry density of the soil is calculated by using equation,

$$y_d = \frac{y_b}{1 + w}$$

Where, γ_d=dry density of soil, γ_b=Wet density of soil,w = moisture content of soil.

PROCEDURE:

i. Measure the height and internal diameter of the core cutter.

ii. Weight the clean core cutter.

iii. Clean and level the ground where the density is to be determined.

iv. Press the cylindrical cutter into the soil to its full depth with the help of steel rammer.

v. Remove the soil around the cutter by spade.

vi. Lift up the cutter.

vii. Trim the top and bottom surfaces of the sample carefully.

viii. Clean the outside surface of the cutter.

ix. Weight the core cutter with the soil.

x. Remove the soil core from the cutter and take the representative sample in the water content containers to determine the moisture content

PRECAUTIONS:

i. Steel dolly should be placed on the top of the cutter before ramming it down into the ground.

ii. Core cutter should not be used for gravels, boulders or any hard ground.

iii. Before removing the cutter, soil should be removed around the cutter to minimize the disturbances.

iv. While lifting the cutter, no soil should drop down

RESULT:

a. Bulk Density of soil:

By Sand Replacement method =...................................

By Core Cutter Method =..

b. Dry Density of soil:

By Sand Replacement method =...................................

By Core Cutter Method =..

QUESTIONS

i. Out of wet density, dry density, and saturated density, which one of them is maximum and minimum? Explain.

ii. What are the main factors which affect in-situ density of soil? Explain.

iii. Beside the density what other properties do you need to calculate the void ratio and degree of saturation of soils?

iv. What are the other methods to calculate the field density of soil?

COMPACTION TEST

AIM OF THE EXPERIMENT:

To determine the Optimum moisture content and maximum dry density of a soil by standard proctor compaction test.

APPARATUS REQUIRED:

a) Special:

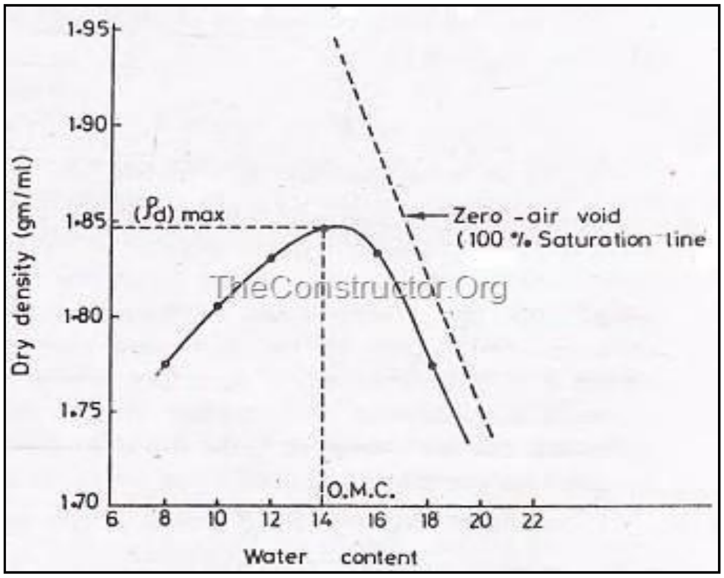
i. Proctor mould (capacity 1000.0 cc, internal diameter 100mm, and effective height 127.3 mm.
ii. Rammer for light compaction (2.6Kg, with free drop of 310 mm).
iii. Mould accessories including detachable base plate, removable Collar.
iv. I.S. sieve 4.75 mm.

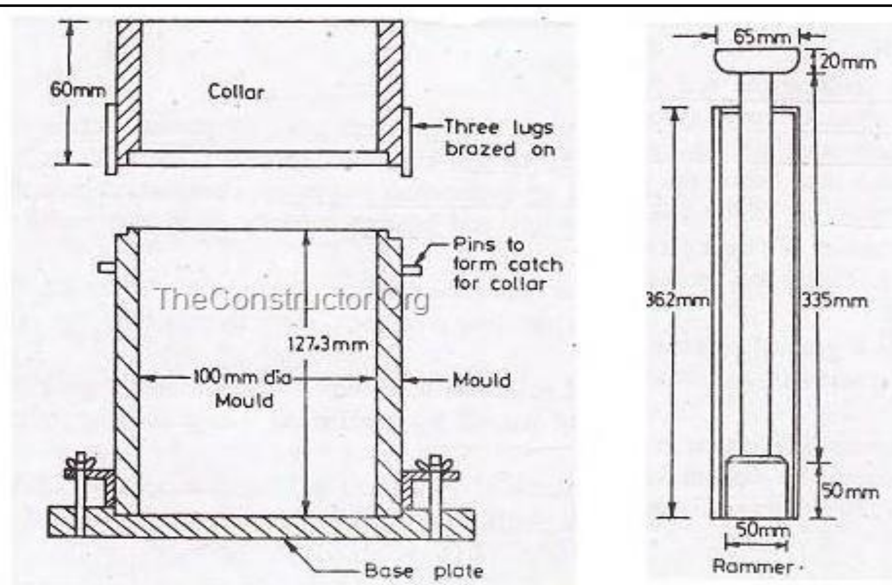
b) General:

i. Balance of capacity 10 kg, and sensitivity of 1 gm.
ii. Balance of capacity 200 gms and sensitivity of 0.01 gm.
iii. Drying oven.
iv. Desiccators.
v. Containers for water content.
vi. Graduated Jar.
vii. Trimming knife.
viii. Large mixing tray.

THEORY:

Compaction is the process of densification of soil mass by reducing air voids. The purpose of laboratory compaction test is so determine the proper amount of water at which the weight of the soil grains in a unit volume of the compacted is maximum, the amount of water is thus called the Optimum Moisture Content (OMC). In the laboratory different values of moisture contents and the resulting dry densities, obtained after compaction are plotted both to arithmetic scale, the former as abscissa and the latter as ordinate. The points thus obtained are joined together as a curve. The maximum dry density and the corresponding OMC are read from the curve.





standard proctor test apparatus

The wet density of the compacted soil is calculated as below,

$$\gamma_t = \frac{w_1 - w_2}{V}$$

Where, w_1 = Weight of mould with moist compacted soil.

w_2 = Weight of empty mould.

V = Volume of mould.

The dry density of the soil shall be calculated as follows,

$$\gamma_d = \frac{\gamma_t}{1 + w}$$

Where, γ_t = wet density of the compacted soil.

w = moisture content

APPLICATION:

Compaction of soil increases the density, shear strength, bearing capacity, thus reducing the voids, settlement and permeability. The results of this are useful in the stability of field problems like earthen dams, embankments, roads and airfield. In such compacted in the field is controlled by the value of the OMC determined by laboratory compaction test. The compaction energy to be given by a compaction unit is also controlled by the maximum dry density determined in the laboratory. In other words, the laboratory compaction tests results are used to write the compaction specification for field compaction of the soil.

PROCEDURE:

i. Take about 20 kg of soil and sieve it through 20 mm and 4.75 mm.
ii. A 100 mm diameter Proctor mould is to be used if the soil fraction that passes 4.75 mm sieve is greater than 80% by weight.
iii. Take about 2.25 kg of the soil sample and add water to get the moisture content round 8%. Leave the mix to mature for few minutes.
iv. Clean and grease gently the inside surface of the mould, and the base plate.
v. Take the weight of empty mould with the base plate.
vi. Fir the collar and place th mould on a solid base.

OBSERVATION AND CALCULATION TABLE:

i. Diameter of mould, D (cm):___ _ _ _ _ _ _

ii. Height of mould, h (cm) : _ _ _ _ _ _ _ _ _

iii. Volume of mould, V (cc) : _ _ _ _ _ _ _ _ _

Weight of empty mould + Base plate (w_1) ,kg					
Weight of compacted soil + Base plate (w_2) ,kg					
Bulk unit weight of compacted soil γ (gm/cc)					
Water content (w)					
Dry unit weight $\gamma_d = \gamma / (1 + w)$, (gm/cc)					

vii. Place first batch of soil inside the mould and apply 25 blows of Standard rammer, so that the compacted layer thickness is about one-third height of the mould Scratch the top of the compacted soil before the second layer is placed Place the second batch of wet soil and follow the same procedure In all the soil is compacted in three layers, each given 25 blows of the standard rammer weighing 2.6 Kg and having a drop of 310 mm.

viii. Remove the collar, and trim of the excess soil with trimming knife. Clean the mould, and weight the mould with the compacted soil and the base plate. ix. Take a representative sample from the mould and determine its water content.

ix. Repeat the above procedure for water content values of 13%, 17%, 20%, 22% and 25%.

RESULT

Maximum dry density =

Optimum moisture content =

QUESTIONNAIRE:

i. What is meant by dry side and wet side of optimum? Which side is preferred in the field compaction? Explain.

ii. Explain how the gravel content in the soil mass affects the laboratory compaction specifications.

iii. What is the energy imparted by the standard and modified compaction test?

iv. What are the approximate values of OMC and MDD for coarse grained and fine grained soils?

v. What are the field methods of compaction the soils?

OBSERVATION AND CALCULATION

Diameter (d) =

Length (L_0) =

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 ($_d$) =

UNCONFINED COMPRESSION (UCC) TEST

AIM:

To determine the unconfined compressive strength, this is then used to calculate the unconsolidated undrained shear strength of the clay under unconfined conditions.

THEORY:

According to the ASTM standard, the unconfined compressive strength (q_u) is defined as the compressive stress at which an unconfined cylindrical specimen of soil will fail in a simple compression test. In addition, in this test method, the unconfined compressive strength is taken as the maximum load attained per unit area, or the load per unit area at 15% axial strain, whichever occurs first during the performance of a test.

For soils, the undrained shear strength (S_u) is necessary for the determination of the bearing capacity of foundations, dams, etc. The undrained shear strength (S_u) of clays is commonly determined from an unconfined compression test. The undrained shear strength (S_u) of a cohesive soil is equal to one-half the unconfined compressive strength (q_u) when the soil is under the f = 0 condition (f = the angle of internal friction). The most critical condition for the soil usually occurs immediately after construction, which represents undrained conditions, when the undrained shear strength is basically equal to the cohesion (c).This is expressed as:

$$s_u = c = \frac{q_u}{2}$$

Then, as time passes, the pore water in the soil slowly dissipates, and the intergranular stress increases, so that the drained shear strength (s), given by s = c + s'tan f, must be used. Where s'= intergranular pressure acting perpendicular to the shear plane; and s'= (s - u), s = total pressure, and u = pore water pressure; c' and j' are drained shear strength parameters.

EQUIPMENT:

Compression device, Load and deformation dial gauges, Sample trimming equipment, Balance, 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.

Unconfined Compression Test Data

Deformation Dial: 1 unit = ...mm; Proving Ring No: ....

Load Dial: 1 unit =........................

Deformation Dial Reading	Load Dial Reading	Sample Deformation ΔL (mm)	Strain (e)	% Strain	Corrected Area A'	Load	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								

(4) Weigh the sample and record the mass on the data sheet.

(5) Calculate the deformation (DL) corresponding to 15% strain (e).

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

Where L_0 = Original specimen length (as measured in step 3).

(6) Carefully place the specimen in the compression device and centre 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.

(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.

RESULT

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

Unconfined compressive strength (qu) =

Cohesion (c) =

850									
900									
950									
1000									
1100									
1200									
1300									
1400									
1500									
1600									
1700									
1800									
1900									
2000									
2200									
2400									
2600									
2800									
3000									

DIRECT SHEAR TEST

AIM:

To determine shear strength parameters of the given soil sample by Direct Shear Test.

APPARATUS REQUIRED:

a) **Special:**

  i. Shear test frame housing the motor, loading yoke, etc.
  ii. Shear box of internal dimension 60 mm x 60 mm x 25 mm.
  iii. Water jacket for shear box.
  iv. Metallic Grid plates.
  v. Base plate.
  vi. Porous stones.
  vii. Loading pad.
  viii. Proving ring of capacity 200 Kgf.
  ix. Slotted weights to impart appropriate normal stress on soil sample.

b) **General:**

  i. Balance of capacity 1 Kg and sensitivity 0.1 gms.
  ii. Scale.
  iii. Dial Gauge of sensitivity 0.01 mm.

THEORY:

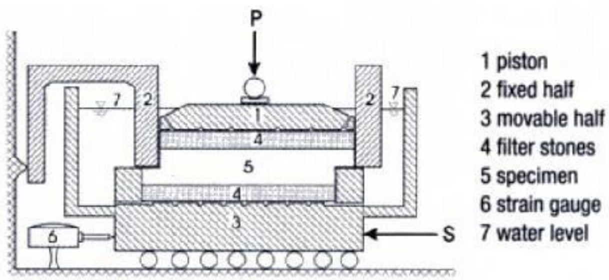
Shear strength of a soil is the maximum resistance to shearing stress at failure on the failure plane. Shear strength is composed of:

i. Internal friction which is the resistance due to friction between individual particles at their contact points and interlocking of particles. This interlocking strength is indicated through parameter φ.

ii. Cohesion which resistance due to inter-particle force which tend hold the particles together in a soil mass. The indicative parameter is called Cohesion intercept (c).

Coulomb has represented the shear strength of soil by the equation:

$$\tau_f = c + \sigma_n \tan\varphi$$



Direct shear box

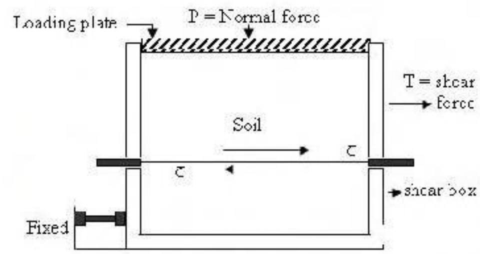
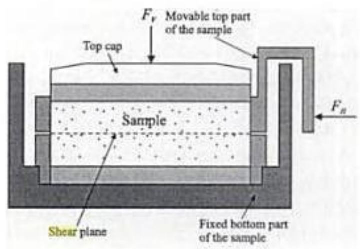
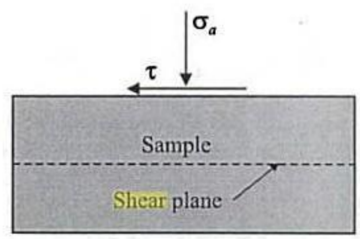


Diagram of direct shear arrangement



Schematic presentation of a direct shear box apparatus



Stresses acting on a sample in a direct shear box

Where, τ_f = shear strength of soil = shear stress at failure.

c = Cohesion intercepts

σ_n = Tot l normal stress on the failure plane

φ = Angle of internal friction or shearing resistance

The graphical representation of the above equation gives a straight line called Failure envelope.

The parameters c and are not constant for a given type of soil but depends in its degree of saturation, drainage conditions and the condition of laboratory testing.

In direct shear test, the sample is sheared along the horizontal plane. This indicates that the failure plane is horizontal. The normal stress, on this plane is the external vertical load divided by

the corrected area of the soil sample. The shear stress at failure is the external lateral load divided by the corrected of soil sample.

APPLICATION:

The purpose of direct shear test is to get the ultimate shear resistance, peak shear resistance, cohesion, angle of shearing resistance and stress-strain characteristics of the soils. Shear parameters are used in the design of earthen dams and embankments. These are used in calculating the bearing capacity of soil-foundation systems. These parameters help in estimating the earth pressures behind the retaining walls. The values of these parameters are also used in checking the stability to natural slopes, cuts and fills.

PROCEDURE:

i. Prepare a soil specimen of size 60 mm * 60mm* 25 mm either from undisturbed soil sample or from compacted or remoulded sample. Soil specimen may also be directly prepared in the box by compaction.
ii. Fix the upper part of the box to the lower box by fixing screws. Attach the base plate to the lower part.
iii. Place the porous stone in the box.
iv. Transfer the soil specimen prepared into the box.
v. Place the upper grid, porous stone and loading pad in the order on soil specimen.
vi. Place the box inside the container and mount it on loading frame.
vii. Bring the upper half of the box in contact with the proving ring assembly. Contact is observed by the slight movement of proving ring dial gauge needle.
viii. Mount the loading yoke on the ball placed on the loading pad.
ix. Put the weight on the loading yoke to apply a given value of normal stress intensity. Add the weight of the yoke also in the estimation of normal stress intensity.

OBSERVATION AND CALCULATION TABLE:

1. Size of Soil sample = Internal Dimensions of the Box
2. Weight of yoke, w_1=0.775 Kg.
3. Weight of Loading pad, w2=0.620 Kg.
4. Lever Ratio = 1:5
5. Proving ring Number=
6. Proving ring Constant (K): 1 Division = Kg.
7. Rate of strain for Horizontal Shear = 1.25 mm/min.

Load on yoke (w) (kg)					
Normal load on soil sample(N) (kg)=$(W+w_1)x5+w_2$					
Normal stress σ_n (kg/cm^2) σ_n = N/(6x6)					
Proving ring division at failure (D)					
Shear force at failure (S) =D x k					
Shear resistance at failure (τ_f) =S/(6x6)					

x. Remove the fixing screws from the box and raise slightly the upper box with the help of the spacing screws. Remove the spacing screws also.
xi. Adjust the entire dial gauge to read zero.
xii. Shear load is applied at constant rate of strain.
xiii. Record the readings of proving ring and dial readings at a fixed interval.
xiv. Continue the observations till the specimen fails.
xv. Repeat the test on the identical specimen under increasing normal stress and record the corresponding reading.

PRECAUTIONS:

i. Before starting the test, the upper half of the box should be brought in proper contact with the proving ring.

ii. Before subjecting the specimen to shear, the fixing screws should take out.

iii. Spacing screws should also be removed before shearing the specimen. iv. No vibrations should be transmitted to the specimen during the test.

v. Do not forget to add the self weight of the loading yoke in the vertical loads.

RESULT

The angle of internal friction of the given sample of sand ($) =

INFERENCE

QUESTIONNAIRE:

i. Differentiate between the angle of repose and angle of shearing resistance of soils
ii. What are the advantages and disadvantages of direct shear test?
iii. What are other laboratory tests to determine the shear strength of soils?
iv. Why do you put the grids keeping the serration at right angles to the direction of shear?
v. Are you using stress or strain controlled device?

TRIAXIAL TEST

AIM:

To find the shear strength of the soil by Undrained Triaxial Test.

APPARATUS:

a) Special:

i. A constant rate of strain compression machine of which the following is a brief description of one in common use.

- A loading frame in which the load is applied by yoke acting through an elastic dynamometer, more commonly called a proving ring which used to measure the load. The frame is operated at a constant rate by a geared screw jack. It is preferable for the machine to be motor driven, by a small electric motor.

- A hydraulic pressure apparatus including an air compressor and water reservoir in which air under pressure acting on the water raises it to the required pressure, together with the necessary control valves and pressure dials.

ii. A triaxial cell to take 3.8 cm dia and 7.6 cm long samples, in which the sample can be subjected to an all round hydrostatic pressure, together with a vertical compression load acting through a piston. The vertical load from the piston acts on a pressure cap. The cell is usually designed with a non-ferrous metal top and base connected by tension rods and with walls formed of Perspex.

b) General:

i. 3.8 cm (1.5 inch) internal diameter 12.5 cm (5 inches) long sample tubes.
ii. Rubber ring.
iii. An open ended cylindrical section former, 3.8 cm inside dia, fitted with a small rubber tube in its side.
iv. Stop clock.
v. Moisture content test apparatus.
vi. A balance of 250 gm capacity and accurate to 0.01 gm.

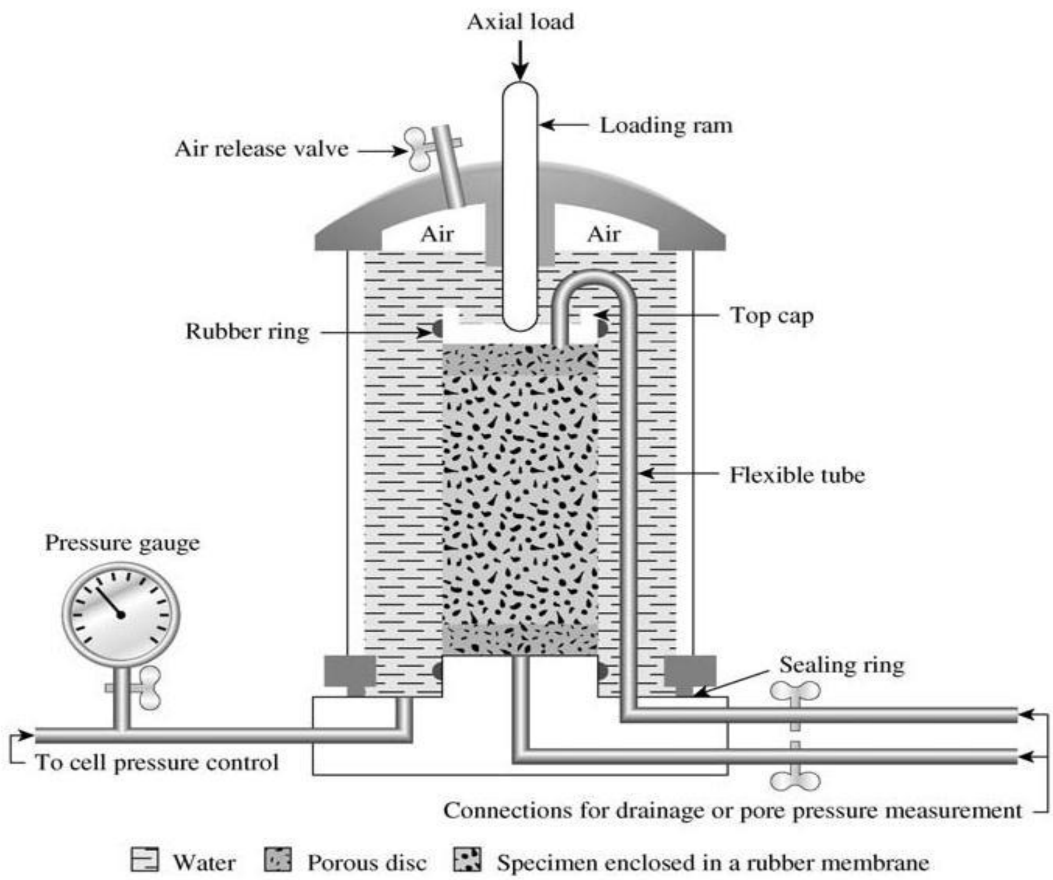


Diagram of triaxial test equipment

THEORY:

Triaxial test is more reliable because we can measure both drained and untrained 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 σ3’) 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 σ1’ is equal to the sum of σ3’ and deviator stress (σd). Measurement of σd, 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.

i. UU Triaxial test
ii. CU Triaxial test
iii. CD Triaxial test

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.

PROCEDURE:

i. The sample is placed in the compression machine and a pressure plate is placed on the top. Care must be taken to prevent any part of the machine or cell from jogging the sample while it is being setup, for example, by knocking against this bottom of the loading piston. The probable strength of the sample is estimated and a suitable proving ring selected and fitted to the machine.

ii. The cell must be properly set up and uniformly clamped down to prevent leakage of pressure during the test, making sure first that the sample is properly sealed with its end caps and rings (rubber) in position and that the sealing rings for the cell are also correctly placed.

iii. When the sample is setup water is admitted and the cell is fitted under water escapes from the beed valve, at the top, which is closed. If the sample is to be tested at zero lateral pressure water is not required.

OBSERVATION AND CALCULATION TABLE:

Size of specimen:

Length:

Proving ring constant:

Diameter: 3.81 cm

Initial area L:

Initial Volume:

Strain dial least count (const):

Sample No.	Wet bulk density (gm/cc)	Cell pressure (kg/cm^2)	Compressive stress at failure	Strain at failure	Moisture content	Shear strength (kg/cm^2)	Angle of shearing resistance
1							
2							
3							

Cell pressure kg/cm^2	Strain dial	Proving ring reading	Load on sample kg	Corrected area cm^2	Deviator stress
0.5	0				
	50				
	100				
	150				
	200				
	250				
	300				
	350				
	400				
	450				
0.5	0				
	50				
	100				
	150				
	200				
	250				
	300				
	350				
	400				
	450				

iv. The air pressure in the reservoir is then increased to raise the hydrostatic pressure in the required amount. The pressure gauge must be watched during the test and any necessary adjustments must be made to keep the pressure constant.

v. The handle wheel of the screw jack is rotated until the underside of the hemispherical seating of the proving ring, through which the loading is applied, just touches the cell piston.

vi. The piston is then removed down by handle until it is just in touch with the pressure plate on the top of the sample, and the proving ring seating is again brought into contact for the begging of the test.

vii. The machine is set in motion (or if hand operated the hand wheel is turned at a constant rate) to give a rate of strain 2% per minute. The strain dial gauge reading is then taken and the corresponding proving ring reading is taken the corresponding proving ring chart. The load applied is known. The experiment is stopped at the strain dial gauge reading for 15% length of the sample or 15% strain.

0.5	0				
	50				
	100				
	150				
	200				
	250				
	300				
	350				
	400				
	450				

GENERAL REMARKS:

i. It is assumed that the volume of the sample remains constant and that the area of the sample increases uniformly as the length decreases. The calculation of the stress is based on this new area at failure, by direct calculation, using the proving ring constant and the new area of the sample. By constructing a chart relating strains readings, from the proving ring, directly to the corresponding stress.

ii. The strain and corresponding stress is plotted with stress abscissa and curve is drawn. The maximum compressive stress at failure and the corresponding strain and cell pressure are found out.

iii. The stress results of the series of triaxial tests at increasing cell pressure are plotted on a Mohr stress diagram. In this diagram a semicircle is plotted with normal stress as abscissa shear stress as ordinate.

iv. The condition of the failure of the sample is generally approximated to by a straight line drawn as a tangent to the circles, the equation of which is t = C + a tan f. The value of cohesion 'C' is read of the shear stress axis, where it is cut by the tangent to the Mohr circles, and the angle of shearing resistance (f) is angle between the tangent and a line parallel to the shear stress.

RESULT

Shear strength of the soil =