Govt. Co-Ed Polytechnic Raipur

LAB MANUAL

GEOTECH (Lab)

Branch: Civil Engineering

Year & Semester: 3rd Year / 5th

Content

EXPERIMENT-1

Determine water content by oven drying method

Aim:

To determine the water content of soil solids by Oven Drying method.
The water content (w) of a soil sample is equal to the mass of water divided by the mass of solids.

Specifications:

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

Equipments Required:

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

Theory:

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

$$w=(W2-W3)/(W3-W1) \cdot \cdot 100$$

Where, W1= Weight of empty container in grams
W2 = Weight of container + wet soil in grams
W3 = Weight of container + dry soil in grams.

Precautions:

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

- Prior to handling oven, testing or disposing of any waste materials, students are required to read do's and don'ts of the Geotechnical engineering laboratory.

Procedure:

a) Clean the container with lid and find the mass (W1 in g).
b) Select the required quantity of moist soil sample, place it in the container, place the lid on it, and weigh it (W2 in g).
c) Keep the container in the oven with lid removed and dry it for at least 24 hr. at a C till the mass remains constant. · temperature of 110
d) Remove the container from the oven, replace the lid, and cool it in desiccators. Find the mass (W3 in g). e) Determine the water constant w by using the above equation.
f) Repeat the experiment with other test samples

Table:

Sl No	Particulars	Test No1 (w1)	Test No2 (w2)	Test No3 (w3)
1	Weight of empty container (W1), g			
2	Weight of container + wet soil (W2), g			
3	Weight of container + dry soil (W3), g			
4	Water content, w			
5	Average water content, w = (w1+ w2 + w3)/3			

Specimen calculations:

w=(W2-W3)/(W3-W1) · · 100

Result:

AVERAGE w=

Verification/ Validation:

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

Conclusion:

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

Pre-viva Questions:

1. Water content is also called?

2. Which method is mostly used to determine the water content in field?
3. What is water content for clay soil?
4. On which factor water content is depended?
5. Ground Penetrating Radar (GPR) method is also used for measuring water content (True or False?)
6 Name different types of soil textures?
7. The percentage of water remaining in an air-dry soil is called _____________.

Post-Viva Questions

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

EXPERIMENT-2

Determine Specific Gravity of soil by Pycnometer

Aim:

To determine the specific gravity of soil solids by Pycnometer bottle method.
Specific gravity is the ratio of the mass of unit volume of soil at a stated temperature to the mass of the same volume of gas-free distilled water at a stated temperature.

Specification:

This test is specified in IS: 2720 (Part 4) – 1985. A soil's specific gravity largely depends on the density of the minerals making up the individual soil particles. However, as a general guide, some typical values for specific soil types are as follows:

- The specific gravity of the solid substance of most inorganic soils varies between 2.60 and 2.80.
- Tropical iron-rich laterite, as well as some lateritic soils, usually have a specific gravity of between 2.75 and 3.0 but could be higher.
- Sand particles composed of quartz have a specific gravity ranging from 2.65 to 2.67.
- Inorganic clays generally range from 2.70 to 2.80.
- Soils with large amounts of organic matter or porous particles (such as diatomaceous earth) have specific gravities below 2.60. Some range as low as 2.00.

Equipments Required:

a) Pycnometer of about 1 litre capacity
b) Balance accurate to 1 g, glass rod, de-aired distilled water etc.

Theory:

Specific gravity of soil solids is defined as the weight of soil solids to weight of equal volume of water. In effect, it tells how much heavier (or lighter) the material is than water. This test method covers the determination of the specific gravity of soil solids that pass 4.75 mm sieve.
Equation for specific gravity, G:

$$G=(W2-W1)/((W2-W1)-(W3-W4))$$

Where :
W1=weight of Pycnometer in grams.,
W2 =weight of Pycnometer + dry soil in grams.
W3 =weight of Pycnometer + soil+ water grams.
W4 =weight of Pycnometer + water grams

Note: This method is recommended for coarse and fine grained soils

Precautions:

- Soil grains whose specific gravity is to be determined should be completely dry.
- If on drying soil lumps are formed, they should be broken to its original size.
- Inaccuracies in weighing and failure to completely eliminate the entrapped air are the main sources of error. Both should be avoided.
- While cleaning the glass jar, please be careful as there may be glass grains projecting out and it may tear the skin.
- Make sure, you handle the glass jar and conical cap without falling on your legs or floor. Hence, handle the equipment with care.

Procedure:

a) Clean and dry the pycnometer and weigh it along with the conical cap (W1 in gm).
b) Select about 300 gm of dry soil free of clods and put the same into the pycnometre. Weigh it (W2 in g) with cap and washer.
c) Fill the pycnometer with de-aired water up-to half its height and stir the mix with a glass rod. Add more water and stir it. Fit the screw cap and fill the pycnometer flush with the hole in the conical cap and take the weight (W3 in g).
d) Remove all the contents from the pycnometer, clean it thoroughly and fill it with distilled water. Weigh it (W4 in g).
e) Now use the above equation for determining G.
f) Repeat the same process for additional tests.

Pre-Viva Questions:

1. Why we need to compute the specific gravity of soil?
2. What is the unit of specific gravity?
3. What is specific gravity of water?
4. Explain the steps required to determine specific gravity by Pycnometer method)) · -W ·)-(W · -

W ·)/((W · - W · G= (W DEPARTMENT OF CIVIL ENGG. GCEM GEOTECHNICAL

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5. What are the calculations required in computing specific gravity by Pycnometer method?

Table:

S. No.	Particulars	Test No 1 (G1)	Test No 2 (G2)	Test No 3 (G3)
1	Weight of Pycnometer bottle (W1), g			
2	2 Weight of Pycnometer + dry soil (W2),g			
3	Weight of Pycnometer + soil + water, (W3), g			
4	Weight of Pycnomerter + water (W4), g			
5	Calculation of specific gravity, G			
6	Average G = (G1+G2+G3)/3			

Calculation:

G= (W2-W1)/((W2-W1)-(W3-W4))

Result:

AVERAGE G=

Conclusion:

The experiment is conducted as per the procedure laid down. The specific gravity of soil solids obtained is ………………. This value falls in the range 2.6 to 2.75. Hence the type of soil…………

EXPERIMENT-3

Bulk unit weight and dry unit weight of soil in field by core cutter method

Aim:

To determine the field density or unit weight of soil by Core cutter method.

Field density is used in calculating the stress in the soil due to its overburden pressure. It is needed in estimating the bearing capacity of soil foundation system, settlement of footing, earth pressures behind the retaining walls and embankments. Stability of natural slopes, dams, embankments and cuts is checked with the help of density of soil. It is the density that controls the field compaction of soils. Permeability of soils depends upon its density. Relative density of cohesionless soils is determined by knowing the dry density of soil in natural, loosest and densest states. Void ratio, porosity and degree of saturation need the help of density of soil.

Specifications:

This test is done to determine the in-situ dry density of soil by core cutter method as per IS-2720-Part-29 (1975). Core cutter method in particular, is suitable for soft to medium cohesive soils, in which the cutter can be driven. It is not possible to drive the cutter into hard and boulder soils.

Equipments Required:

1) Cylindrical core cutter, 100mm internal diameter and 130 mm long.
2) Steel dolly, 25mm high and 100mm internal diameter.
3) Steel rammer mass 9kg, overall length with the foot and staff about 900 mm.
4) Balance, with an accuracy of 1g.
5) Palette knife, Straight edge, steel rule etc.
6) Square metal tray – 300mm x 300mm x40mm.
7) Trowel.

Theory:

Field density is defined as weight per unit volume of soil mass in the field at in-situ conditions. In the spot adjacent to that where the field density by sand replacement method has been determined or planned, drive the core cutter using the dolly over the core cutter. Stop ramming when the dolly is just proud of the surface. Dig out the cutter containing the soil out of the ground and trim off any solid extruding from its ends, so that the cutter contains a volume of soil equal to its internal volume which is determined from the dimensions of the cutter. The weight of the contained soil is found and its moisture content determined.

Equations are;

$$\rho_d = \rho_t /(1+w) \text{ gm/cm}^3$$

Where, ρ_d = dry density in g/cm^3,

ρ_t = field moist density in g/cm3,

w =water content %/100,

Υ_w = density of water = 1000

Procedure:

a) Measure the height and internal diameter of the core cutter to the nearest 0.25 mm.

b) Calculate the internal volume of the core-cutter Vc in cm^3.

c) Determine the weight of the clean cutter accurate to 1 g (W1 in g).

d) Select the area in the field where the density is required to be found out. Clean and level the ground where the density is to be determined.
e) Place the dolley over the top of the core cutter and press the core cutter into the soil mass using the rammer. Stop the pressing when about 15mm of the dolley protrudes above the soil surface.
f) Remove the soil surrounding the core cutter by digging using spade, up to the bottom level of the cutter. Lift up the cutter and remove the dolley and trim both sides of the cutter with knife and straight edge.
g) Clean the outside surface of the cutter and determine mass of the cutter with the soil (W2 in g).
h) Remove the soil core from the cutter and take the representative sample in the water content containers to determine the moisture content.
i) The field test may be repeated at other places if required.
j) The water content of sample collected is determined in the laboratory as per Experiment no 1 (Determination of water content of soil solids by Oven Drying Method).
k) Use the above equation, given the theory section, for determining density of soil (ρd).

Observations:

Length of core cutter l = -------------cm
Diameter of core cutter d= ------------cm
Volume of core cutter=Vc= -----------cm

Table::

S.No.	Particulars	Test nos.		
		1 (ρ_{d1})	2 (ρ_{d2}) (ρ_{d3})	3
1.	Weight of empty cutter (W1), g			
2.	Weight of cutter + wet soil (W2), g			
3.	Volume of core cutter (V_c) cm^3			
4.	Weight ass of empty container (W3), g			
5.	Weight of container + wet soil (W4), g			
6.	Weight of container + dry soil (W5), g			
7.	Water content (w)=(W4-W5)/(W5-W3)			
8.	Field moist density ρ_t (kN/m^3) = (W2-W1)/Vc			
9.	Dry density ρ_d (kN/m^3) = $\rho_t/(1+w)$			
10.	Average density, Avg ρ_d			

Specimen calculations:

$$\text{Avg } \rho_d = (\rho_{d1} + \rho_{d2} + \rho_{d3})/3$$

Result:

Average in-situ field dry density: =--------------

Conclusion:

The value of dry density of the soil is _. The type of soil is.

EXPERIMENT-4

Bulk unit weight dry and unit weight of soil in field by sand replacement method

Aim:

To determine in-situ density of natural or compacted soil using Sand replacement method.

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. Moreover, dry density values are relevant both of embankment design as well as pavement design.

Specifications:

This test is done to determine the in-situ dry density of soil by core cutter method as per IS-2720-Part-28 (1975). In order to conduct the test, select uniformly graded clean sand passing through 600 micron IS sieve and retained on 300 micron IS sieve

Equipments Required:

a) Sand pouring cylinder of about 3 litre capacity (Small pouring cylinder as per IS 2720 Part28)
b) Cylindrical calibrating container 10 cm internal diameter and 15 cm depth
c) Glass plate, trays, containers for determining water content
d) Tools for making of a hole of 10 cm diameter and 15 cm deep, knife and other accessories
e) Metal container to collect excavated soil
f) Metal tray, 300mm square and 40mm deep with a hole of 100mm in diameterat the centre
g) Weighing balance
h) Moisture content cans
i) Glass plate about 450 mm/600 mm square and 10mm thick
j) Oven
k) Desiccators

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 reportthe test result in terms of dry density. 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 its density, the volume of pit is calculated. Knowing the weight of soil excavated from the pit and the volume of pit, the density of soil is calculated. Therefore, inthis experiment there are two stages, namely

1. Calibration of sand density
2. Measurement of soil density

Field density is defined as weight per unit volume of soil mass in the field at in-situconditions. Equations are:

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$$\Upsilon_d = \Upsilon_t/(1+w) \text{gm/cm}^3$$

or

$$\cdot_{d=} \cdot_t/(1+w) \text{ gm/cm}^3$$

$\cdot_d$ = = dry density

Υ_d = dry unit weight

$\cdot_t$ = = field moist density,

Υ_t = field moist unit weight,

w = water constant,

Υ_w = unit weight of water = 9.81 kN/m³

The basic equations in determination of density using sand replacement method are

Where,

$$V_h = W_s / (G \times \cdot_w)$$

$$\cdot_t = M / V_h$$

$$\cdot_{d=} \cdot_t/(1+w)$$

V_h = Volume of hole made in the field.

W_s = weight of the sand that fills the hole.

W = weight of moist soil removed from the hole.

w = moisture content of soil removed from the hole.

$\cdot_t$ = moist soil in-situ density.

$\cdot_d$ = dry density of the soil.

G = specific gravity of the solids.

$\cdot_w$ = density of the water

Procedure:

Stage1 –Determination of mass of sand that fills the cone

a) Measure the internal dimensions (diameter, d and height, h) of the calibrating can and compute its internal volume, $V_c = \pi d^2 h/4$
b) With the valve closed, fill the cylinder with sand
   Weight of sand filled in the cylinder +cylinder W'=---------- gms.

c) Keep the cylinder on a glass plate, which is kept on a horizontal surface.
d) Open the valve and allow the sand to fill the cone completely. Close the valve.

Weight of sand in the cylinder +cylinder W”= ------- gms

e) Determine the mass of the sand left in the cylinder. Weight of sand fills the conical portion= W_1=W’-W”

f) The difference between the mass of sand taken prior to opening of the valve and the weight of sand left in the cylinder after opening the valve gives the weight of sand that fills the cone. Let the mass be W_1.

Determination of bulk density of sand

a) Measure the internal dimensions of the calibrating container and find its volume.

Length of calibrating container l= ------------- cm

Diameter of calibrating container d=------------ cm

Volume of calibrating container V_c= ----------- cm^3

Let this volume be V_c.

b) Place the pouring cylinder concentrically on the top of the calibrating container with the valve closed. Fill the cylinder with sand up to about 1 cm below the top.

Weight of cylinder W_1=----------- g

Weight of cylinder +sand in the cylinder W_2=----------- g

Weight of sand filled in the cylinder $W_0=W_2-W_1$= ----------- g

Let the weight of sand filled be W_0.

c) Open the valve of the cylinder and allow the sand to flow into the container. When no further movement of sand is seen, close the valve. Find the weight of the sand left in the cylinder

Weight of cylinder +sand after filling the calibrating container W_3= ----------gms.

Determine the weight of sand that fills the calibrating container $W_c=W_2-W_3$=-----

d) The bulk density of sand Υ_s is

$\Upsilon_s=W_c/V_c$

Stage 2 - Determination of in-situ density:

a) Level the area where the density is required.

b) Place the metal plate on the surface, which is having a circular hole of about 10 cm diameter at the centre. Dig a hole of this diameter up to about 15 cm depth collect all the excavated soil in a container. Let the weight of the soil removed = W_2=----------g

c) Remove the plate and place the sand-pouring cylinder concentrically on the hole. Fill the cylinder with sand up to a constant level mark with the shutter valve closed. Open the valve and allow the sand to run into the hole till no movement of the sand is noticed. Close the valve and determine the mass of sand that is left in the cylinder

Weight of cylinder + sand after filling the hole completely W4=----g

Weight of sand filling only the hole in the field Ws=W2-W4-Wc=------g

Volume of the hole, V_h = Ws/ $\cdot_s$

where $\cdot_s$= bulk density of sand.

d) Bulk density of soil in-situ, $\cdot_{t,}$ is

$\cdot_t$ = W/ V_h = (W/ Ws)x $\cdot_s$

Determination of Water content of soil collected from the hole:

Weight of empty container (W5) =---------- g

Weight of container + wet soil (W6) =----- g

Weight of container + dry soil (W7) =----- g

Water content (w) = (W6-W7)/(W7-W5)

Dry density of sand $\cdot_{d=}$ $\cdot_t$/(1+w) =---------g/cm3

Pre-Viva Questions:

1) What is the objective of sand replacement method?

2) What is the relationship that can be established between the dry density with known moisture content?

3) What are the apparatus that are needed in this test?

4) What is the significance of determining the in-situ density of the soil? 5) Depth of hole is kept to 15 cm in the field. Why?

Result:

1) Weight of wet soil from the hole, W = _____ gm

2) Water content of the soil, w = __ %

3) Weight of sand that fills the hole = ____ gm

4) Volume of the hole V_h=W_s/ $\cdot_{s}$ =-------------cm³

5) Bulk density of the soil $\cdot_t$= W/V_h= ____ gm/ cm^3

6) Dry density $\cdot_{d=}$ $\cdot_t$/(1+w)=--------- gm/ cm^3

a) Dry density of soil = ___________g/cm3

b) Water content of the soil = _________%

Verification and Validations:

Sand replacement method is an indirect method of finding the density of soil. The basic principle is to measure the in-situ volume of hole from which the material was excavated from the weight of sand with known density filling in the hole. The in-situ density of material is given by the weight of the excavated material divided by the in-situ volume. The dry density of most soils varies within the range of 1.1-1.6 g/cm3 . In sandy soils, dry density can be as high as 1.6 g/cm3 ; in clayey soils and aggregated loams, it can be as low as 1.1 g/cm3

Conclusion:

The dry density of the soil is _________g/cc.

Comparing with the in-situ density by core cutter method, more or less the same value is achieved. The type of soil is silty-clay.

Post-Viva Questions:

1. Why we need to determine the unit weight of sand to determine the unit weight of soil?
2. Which method is the accurate one, core cutter or sand replacement method as per you? And why?
3. How many samples are to be collected and why?
4. What is the advantage of sand replacement method over core cutter method?
5. What is the practical application of the test?

EXPERIMENT-5

Determination of Liquid limit of given soil sample

Aim:

To determine the liquid limit of fine soil by using Casagrande Apparatus.

When water is added to dry soil, it changes its state of consistency from hard to soft. We can define liquid limit as the minimum water content at which the soil is still in the liquid state, but has a small shearing strength against flow. From test point of view we can define liquid limit as the minimum water content at which a pat of soil cut by a groove of standard dimension will flow together for a distance of 12 mm (1/2 inch) under an impact of 25 blows in the device.

Specifications:

This test is done to determine liquid limit of soil as per IS: 2720(Part 5)-1985. After receiving the soil sample it is dried in air or in oven (maintained at a temperature of 600C). If clods are there in soil sample then it is broken with the help of wooden mallet. The soil passing 425 micron sieve is used in this test.

Equipments Required:

a) A mechanical liquid limit apparatus (casagrande type) with grooving tools.

b) Evaporating dishes, wash bottle etc.

c) Balance accurate to 0.01 g.

d) Airtight container to determine water content.

e) Oven to maintain temperature at 105 · C to 110 · C

f) Sieve (425 micron).

g) Spatula

h) Desiccator and other accessories.

Theory:

Consistency of fine-grained soils may be defined as the relative ease with which a soil can be remoulded. Consistency limits may be categorized into three limits called Atterberg limits.

They are 1) Liquid limit 2) Plastic limit and 3) Shrinkage limit

Liquid limit is the moisture content that defines where the soil changes from a plastic to a viscous fluid state. Other limits will be discussed during corresponding experiments.

Precautions:

- Soil used for liquid limit determination should not be oven dried prior to testing.

- In LL test the groove should be closed by the flow of soil and not by slip between the soil and the cup
- After mixing the water to the soil sample , sufficient time should be given to permeate the water throughout out the soil mass
- Wet soil taken in the container for moisture content determination should not be left open in the air, the container with soil sample should either be placed in desiccators or immediately be weighed.
- After performing each test the cup and grooving tool must be cleaned.
- The number of blows should be just enough to close the groove.
- The number of blows should be between 10 and 40.

Procedure:

a) A representative sample of mass of about 120 gm passing through 425 sieve is taken for the test. Mix the soil in an evaporating dish with distilled water to form a uniform paste.

b) Adjust the cup of the device so that the fall of the cup on to the hard rubber base is 10 mm.

c) Transfer the portion of the paste to the cup of liquid limit device. Allow some time for the soil to have uniform distribution of water.

d) Level the soil topsoil so that the maximum depth of soil is 12 mm. A channel of 11 mm wide at the top, 2 mm at the bottom and 8 mm deep is cut by the grooving tool. The grooving tool is held normal to the cup and the groove is cut through the sample along the symmetrical axis of the top.

e) The handle of the device is turned at a rate of about 2 revolutions per second and the number of blows necessary to close the groove along the bottom distance of 12 mm is counted. A sample of soil which closes the groove is collected

f) The soil in the cup is re-mixed thoroughly (adding some more soil if required) some quantity of water which changes the consistency of soil, repeat the process. At least 4 tests should be conducted by adjusting the water contents of the soil in the cup in such a way that the number of blows required to close the groove may fall within the range of 5 to 40 blows. A plot of water content against the log of blows is made as shown in figure. The water content at 25 blows gives the liquid limit

Table:

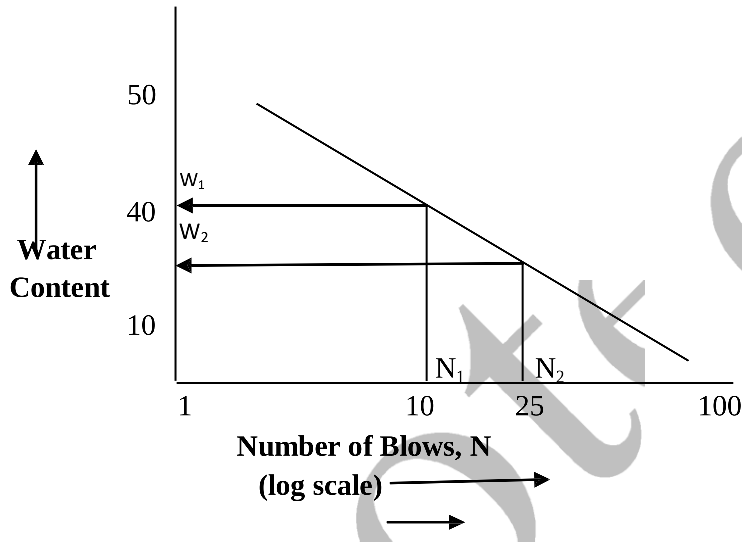
Table 8: Number of blows vs Water Content

Trial No	**1** (w1)	**2** (w2)	**3** (w3)	**4** (w4)
No of blows (N)				
Weight of Container (W1)				
Weight of Container + Wet soil (W2)				

Weight of Container + dry soil (W3)				
Water content w=(W2-W3)/(W3-W1)				
Water content, w = (w1+w2+w3+w4)/4				

Graph:

A semi-log plot of Number of blows V_s water Content is drawn from the table data.



Pre-Viva Questions:

1) Define consistency of the soil. How is it measured?
2) What is liquid limit of soil?
3) What is the apparatus used to determine the liquid limit?
4) When a soil sample is given, what is the procedure to determine the liquid limit of the sample?
5) In a liquid limit test, the moisture content at 10 blows was 70% and that at 100 blows was 20%. The liquid limit of the soil, is?

Result:

From the graph drawn, flow index I_f=(w1-w2)/log (N2/N1)= ---------

And Liquid Limit= ------------ %

Verification/Validation:

If the natural moisture content of soil is closer to liquid limit, the soil can be considered as soft if the moisture content is lesser than liquids limit, the soil is brittle and stiffer. Hence if the points on the graph are obtained scattered, we need to draw the linear curve at the mean. Flow index indicates the rate at which the soil looses shearing resistance with an increase in the water content.

Soil Type	Liquid limit
Sand	-
Silt	30-40
Clay	40 -150

Conclusion:

As per the procedure the experiment is carried out. For 25 blows, water content is ________%.

Post-Viva Questions:

1. What is the purpose of computing liquid limit of the soil?
2. With the organic matter in the soil, will the liquid limit increase or decrease?

EXPERIMENT-6

Determination of Plastic limit of given soil sample

Aim:

To determine plastic limit of the soil.

The plastic limit of fine-grained soil is the water content of the soil below which it ceases to be plastic. It begins to crumble when rolled into threads of 3mm dia.

Specifications:

This test is done to determine the plastic limit of soil as per IS: 2720 (Part 5) — 1985. Take out 30g of air-dried soil from a thoroughly mixed sample of the soil passing through 425µm IS Sieve. Mix the soil with distilled water in an evaporating dish andleave the soil mass for 24hrs

Equipments Required:

a) Porcelain evaporating dish.

b) Flat glass plate.

c) Balance accurate to 0.01 g.

d) Drying oven, maintained at 110 ± 5°C (230 ± 9°F).

e) Weighing dishes, non-absorbent, with lids.

f) Flexible spatula, blade approximately 102 mm (4 in.) long × 19 mm (0.75 in.) wide.

Theory:

The plastic limit is the moisture content that defines where the soil changes from a semi-solid to a plastic state. It may also be defined as that water content at which soil starts crumbling when rolled into threads of 3mm diameter. Use the paste from liquid limit test and begin drying. May add dry soil or spread on plate and air dry.

Precautions:

1. Soil used for plastic limit determination should not be oven dried prior to testing.

2. After mixing the water to the soil sample , sufficient time should be given to permeate the water throughout out the soil mass

3. Wet soil taken in the container for moisture content determination should not be left open. The container with soil sample should either be placed in desiccators or immediately be weighed.

Procedure:

a) Select a representative sample of fine-grained soil of about 20 g or more passing IS sieve. Mix it with distilled water thoroughly on a glass plate such · through 420 that the palm of the soil can be rolled into a thread of 3 mm diameter. Allow some time for the proper distribution mixed with water.

b) Take about 10 g of this wet sail and roll it into a thread on a glass plate with the palm of the hand. The rolling must be such that it forms a uniform thread of 3 mm diameter. If the thread cracks before attaining 3 mm diameter, and add little more water, knead it and roll again. If the rolling can be done to diameter less than 3 mm, mix some dry soil, knead it to remove same extra moisture in the soil. This process has to continue till the sample crumbles just at about 3 mm diameter. Collect the crumbled soil (at least 6 g) and measure its water content.

c) Repeat the process to get at least three water content determination (after they have been in the oven at least 16 hours).

d) The average of water content so obtained is the plastic limit of the soil.

Table:

Trail No	**1 (w1)**	**2 (w2)**	**3 (w3)**	**4 (w4)**
Weight of Container (W1), g				
Weight of Container+Wet soil (W2), g				
Weight of Container+dry soil (W3), g				
Water content w=(W2-W3)/(W3-W1), g				
Average water content, w = (w1+w2+w3+w4)/4				

Pre-Viva Questions:

1) Define plastic limit of soil
2) How is plastic limit computed in laboratory?
3) What is the practical significance of determining plastic limit of the soil?
4) What is plasticity index?
5) What is toughness index?

Result:

The Plastic limit of soil (average water content) is__________________________.Plasticity

index = w_p - w_l

Verification/Validations:

Determine the plasticity index Ip, which is the difference between liquidlimit and plastic limit. Following table list the standard values

Soil Type	w_l	w_p	I_p
Sand			Non-Plastic
Silt	30-40	20-25	10-15
Clay	40-150	25-50	15-100

Conclusion:

The plastic limit of the soil =____

plasticity index = _____________

The type of soil is_____________.

Post-Viva Questions:

1. What is meant by unified soil classification?
2. What is A-line and U-line?
3. What is liquidity index and consistency index?

EXPERIMENT-7

Determination of Shrinkage limit of given soil sample

Aim:

To determine the shrinkage limit of the soil.

The value of shrinkage limit is used for understanding the swelling and shrinkage properties of cohesive soils. It is used for calculating the shrinkage factors which helps in the design problems of the structures made up of the soils or/and resting on soil. It gives an idea about the suitability of the soil as a construction material in foundations, roads, embankments and dams.

Specifications:

The test is specified in IS: 2720(Part 6)-1972. The 30 g soil passing 425 micron sieve is used for the test.

Equipments Required:

a) 2 numbers of porcelain evaporating dish, about 12 cm in diameter within a flat bottom.
b) 3 numbers of shrinkage dish made of non-corroding metal, having a flat bottom, 45 mm diameter and 15 mm high.
c) A glass cup of about 50 mm diameter and 25 mm high.
d) Two numbers glass plates of size 75 x 75 mm, one plate of plane glass and the other with three metal prongs.
e) Spatula balance accurate to 0.01 g, oven etc.
f) Mercury.
g) Desiccator and other accessories.

Theory:

As the soil loses moisture, either in its natural environment, or by artificial means in laboratory, it changes from liquid state to plastic state to semi-solid state and then to solid state. The volume is also reduced by the decrease in water content. But, at a particular limit the moisture reduction causes no further volume change. A shrinkage limit test gives a quantitative indication of how much moisture can change before any significant volume change and to also indication of change in volume. The shrinkage limit is useful in areas where soils undergo large volume changes when going through wet and dry cycles (e.g. earth dams).

Shrinkage limits are required to be determined on two types of soils, they are

i. Remoulded soil.
ii. Undisturbed soil.

Other shrinkage factors i.e. shrinkage ratio, volumetric shrinkage may also be calculated from the test data of shrinkage limit.

Shrinkage ratio is the ratio of a given volume change expressed as a percentage of dry volume to the corresponding change in water content above the shrinkage limit.

Volumetric Shrinkage is the decrease in volume of a soil mass when the water content is reduced from given percentage to the shrinkage limit and which is expressed as percentage of dry volume of the soil mass.

Precautions:

- CAUTION : DO NOT TOUCH THE MERCURY WITH GOLD RINGS
- The water content of the soil taken in shrinkage dish should be above liquid limit but within 10% from liquid limit.
- To prevent the cake from adhering to the shrinkage dish and consequent cracking of the dry soil paste, inside of the shrinkage dish should be greased with vaseline.
- During filling the shrinkage dish with soil paste, sufficient tapping should be dne to remove the entrapped air.
- The dry soil paste should be weighed soon after it has been removed from a desiccators otherwise it picks up moisture from the air.
- Test should be repeated at least three times for each sample and the average of the results thus obtained reported.
- No air should be entrapped under the dry soil paste when pressing by the glass with prongs is being carried out.

Procedure:

a) Select a representative sample of soil of about 100 g passing through 425 · sieve.

b) Take 30 g out of it and place the same in an evaporating dish. Mix it thoroughly with distilled water and make it into a thin paste for readily filling into a dish free from air bubbles.

Determination of mass and volume of shrinkage dish:

a) Take a shrinkage dish, clean it and find its mass correct to 0.1 gm (M3). =------g
b) To determine its volume, place it in an evaporating dish. Fill the shrinkage dish with mercury till the excess overflows to the evaporating dish.
c) Coat the inside of the shrinkage dish with a thin layer of silicon grease or Vaseline. Place a part of the soil paste prepared earlier at the centre of the dish so that it may occupy about one-third of its volume
d) Find the mass of the wet soil with the dish immediately after filling (M1)=-------g
e) Keep the dish with soil exposed to air until the colour of the pat turns from black to light.
f) Select a glass cup with a flat bottom and keep ion an evaporating dish. Fill the cup with mercury and remove the excess mercury by pressing the glass plate with three prongs firmly over the top of the cup.
g) Remove the split over the mercury, take out the glass plate with the prongs, place the dry soil pat on the surface of the mercury.
h) Force the soil pat into the mercury by pressing with the same glass plate with the prongs. Collect carefully the split over mercury and find its mass (Mm)=-------g

The volume of the dry soil pat V_d is

$$V_d = Mm/ 13.6.$$

Where, 13.6 is the density of mercury in g/cm3

Calculation of shrinkage limit, Ws

Mass of wet soil = Mo = (M1-M3)=-------------g
Mass of dry soil = Ms = (M2–M3)=-------------g
Volume of shrinkage dish = Volume of wet soil = Vo = ---------------
Volume of dry soil = Vd = ---------------

Vd = Mm / 13.6 where, 13.6 g/cm3 is the density of mercury.

· Srinkage limit,Ws is

Ws = ((Mo-Ms)-(Vo-Vd)x $\cdot_{w}/M_{s}$

Shrinkage ratio, Sr = ((Vo-Vd)/Vo)x100

Shrinkage limit of undistributed soil

In this case G is known in advance. The equation to be used for determining Ws is

Ws = [(Vd/Ms)-(1/G)]x100

For the undistributed soil we need to know only the volume of an undistributed dry pot of soil sample of diameter 45 mm and thickness 15 mm. Round off its edges to prevent the entrapment of air during mercury displacement. Air dry the sample initially and then dry over the same. Find its mass (Ms) after cooling it in a desiccator, and then its volume Vd by mercury displacement method. Ws may now be found out by use of equation

Ws = [(Vd/Ms)-(1/G)]x100

Pre-Viva Questions:

1. How to measure shrinkage limit of soil?
2. Why is mercury used to determine the shrinkage limit of soil?
3. What is the density of mercury?
4. What is the difference between undisturbed and remoulded soil?
5. Is the dry unit and unit weight of soil the same?
6. What is meant by Thixotropy?

Result:

The shrinkage limit Ws=------------------

Verification/Validations:

Value of shrinkage limit varies from 13 to 26.

Conclusion: The shrinkage limit of soil is ________.

Post-Viva Question:

1. What is shrinkage limit of soil?
2. If water content is increased above shrinkage limit, what is the effect?
3. Instead of Mercury can we use any other substance as mercury may cause health hazard.

EXPERIMENT-8

Determination of grain size distribution of given soil sample by sieve

Aim:

To determine the particle size distribution by sieving (Grain size analysis)and to determine the fineness modulus, effective size and uniformilty coefficient.

This test is performed to determine the percentage of different grain sizes contained within a soil. The mechanical or sieve analysis is performed to determine the distribution of the coarser, larger-sized particles. The distribution of different grain sizes affects the engineering properties of soil. Grain size analysis provides the grain size distribution, and it is required in classifying the soil.

Specifications:

This test is specified in IS: 2720 (Part 4) – 1985 – Method of test for soil (Part 4-Grain size analysis).

Equipments Required:

a) Sieves of sizes: 4.75 mm, 2.0 mm, 1.0 mm, 600 · , 300 · , 150 · and 75 · . That is, I.S 460-1962 is used. The sieves for soil tests: 4.75 mm to 75 microns.

b) Thermostatically controlled oven.

c) Trays, sieve brushes, mortar with a rubber covered pestle, etc.

d) Mechanical sieve shaker etc.

Theory:

The grain size analysis is widely used in classification of soils. The data obtained from grain size distribution curves is used in the design of filters for earth dams and to determine suitability of soil for road construction, air field etc. Information obtained from grain size analysis can be used to predict soil water movement although permeability tests are generally used. The method is applicable to dry soil passing through 4.75 mm size sieve less than 10 % passing through 75-micron sieve.

Percentage retained on any sieve = (weight of soil retained / total weight) x100
Cumulative percentage retained = sum of percentages retained on any sieveon all coarser sieves

Percentage finer than any sieve= 100 percent minus cumulative Size, Npercentage retained.

Precautions:

- Clean the sieves set so that no soil particles were struck in them
- While weighing put the sieve with soil sample on the balance in a concentric position.
- Check the electric connection of the sieve shaker before conducting the test.
- No particle of soil sample shall be pushed through the sieves.

Procedures:

a) Take a representative sample of soil received from the field and dry it in the oven.

b) Use a known mass of dried soil with all the grains properly separated out. The maximum mass of soil taken for analysis may not exceed 500 g.

c) Prepare a stack of sieves. Set the sieves one over the other with an ascending order (sieves having larger opening sizes i.e., lower numbers are placed above the one with smaller opening sizes i.e., smaller numbers). The very last sieve is #200 (75 □ sieve). A pan is attached to the lowest 75 □ sieve to collect the portions passing #200 sieve and fit the nest to a mechanical shaker.

d) Make sure sieves are clean. If many soil particles are stuck in the openings try to poke them out using brush.

e) The whole nest of sieves is given a horizontal shaking for 10 min in sieve shaker till the soil retained on each reaches a constant value.

f) Determine mass of soil retained on each sieve including that collected in the panbelow.

Table:

The test results obtained from a sample of soil are given below.Mass of soil taken for analysis W =________________________gm

Table 7: Sieve Analysis data sheet

Sl No.	IS Sieves (mm)	Particle Size (mm)	Mass Retained (gm)	Corrected Mass Retained (gm)	Cumulative Mass Retained (gm)	Cumulative %Retained	% Finer
1	4.75	4.75					
2	2.00	2.00					
3	1.00	1.00					
4	0.600	0.600					
5	0.300	0.300					
6	0.150	0.150					
7	0.075	0.075					
8	pan						

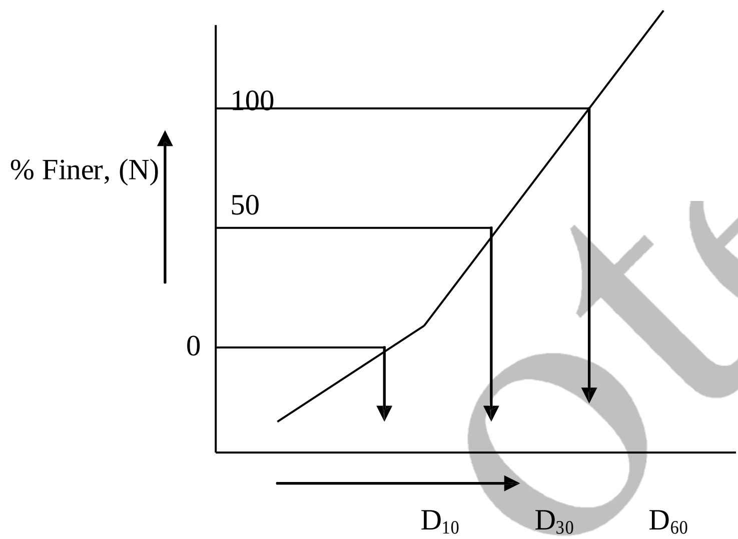
Cumulative

Mass retained W'=--------------------gms

Graph (Grain Size in mm Vs Percentage Finer in %):

Draw graph of log sieve size vs % finer. The graph is known as grading curve. Corresponding to 10%, 30% and 60% finer, obtain diameters from graph these are D10, D30, D60, using these obtain Cc and Cu which further represent how well the soil is graded i.e whether the soil is well-graded, gap-graded or poorly graded.

Graph1-Grain Size in mm Vs Percentage Finer in %



Grain Size (mm)(Log scale)

Pre-Viva Questions:

1) Define the grain size analysis and what is the silt size?
2) What is uniformity coefficient? What is the significance on computing the same?
3) What is the most basic classification of soil?
4) What are the methods of soil gradation or grain size distribution?
5) How to compute D_{10}, D_{30} and D_{60} of soil using sieve analysis?
6) How to compute CC and Cu?
7) What is poorly graded, gap graded and well graded soil?

Result:

Uniformity coefficient, Cu=

Percentage gravel=

Percentage sand=

Percentage silt=

Verification/Validations:

For the soil to be well graded the value of coefficient of uniformity Cu has to be greater than 4 and Cc should be in the range of 1 to 3. So higher the value of Cu the larger the range of the particle sizes in the soil. So if the Cu value is high it indicates that the soil mass consists of different ranges of particle sizes.

Conclusion:

The uniformity coefficient, Cu =______and Cc =_______.

The value comes in the range of well graded soil.

Post-Viva Questions:

1. Does grain distribution affect the voids ratio of the soil?
2. Could the quality of concrete enhanced by the grade of the sand?
3. If soil is uniformly graded, voids ratio is high or low?
4. Well graded aggregates require less cement or more?
5. What is the practical significance of Grain Size Distribution Anaysis?

Coefficient of curvature, Cc=

EXPERIMENT-9

Determination of coefficient of permeability by constant head test

Aim:

To determine the permeability of soil by contant-head method.

The rate of flow under laminar flow conditions through a unit cross sectional are of porous medium under unit hydraulic gradient is defined as coefficient of permeability. Water flowing through soil exerts considerable see 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 damdepends on the permeability of the embankments and its foundations respectively. The rate of discharge through wells and excavated foundation pits depends on thecoefficient of permeability of the soils. Shear strength of soils also depends indirectly on permeability of soil, as dissipation of pore pressure is controlled by its permeability.

Specifications:

IS 2720-17 (1986): Methods of test for soils, Part 17. This test is used to determine the permeability of granular soils like sands and gravels containing little or no silt.

Equipments Required:

1. Permeameter mould of non-corrodible material having a capacity of 1000 ml
2. The mould shall be fitted with a detachable base plate and removable extensioncounter.
3. Compacting equipment: 50 mm diameter circular face, weight 2.76 kg and height offall 310 mm as specified in I.S 2720 part VII 1965.
4. Drainage bade: A bade with a porous disc, 12 mm thick which has the permeability10 times the expected permeability of soil.
5. Drainage cap: A porous disc of 12 mm thick having a fitting for connection to waterinlet or outlet.
6. Constant head tank: A suitable water reservoir capable of supplying water to the permeameter under constant head.
7. Graduated glass cylinder to receive the discharge.
8. Stop watch to note the time.
9. A meter scale to measure the head differences and length of specimen.

Theory:

The knowledge of this property is much useful in solving problems involving yield of water bearing strata, see through earthen dams, stability of earthen dams, and embankments of canal bank affected by see , settlement etc. Permeability of soil can be determined from Darcy's Law. The equation to determine the permeability of soil using constant head permeability test is given by:

k = (QxL)/(Axhxt)

Where, k = coefficient of permeability

Q = volume of water collected in time t

h = head causing flow

A = cross sectional area of sample

L = length of sample

- A constant head permeameter shown schematically in the figure.
- For a typical setup the following dimensions are used
  - i. Internal diameter of the mould = 100 mm.
  - ii. Effective height of the mould = 127.3 mm.
  - iii. Detachable collar: 100 mm diameter and 60 mm height.
  - iv. Drainage base, having a porous disc.
- Weighing balance, and other accessories.

Precautions:

1. All possible leakage of joints must be eliminated.
2. Porous stones must be saturated before being put to use.
3. De-aired and distilled water should be used to prevent choking of flowing water.
4. Soil sample must be carefully saturated before taking the observations.
5. Use of high heads, which result in turbulent flows, should be avoided.

Procedure:

a) A constant-head test assembly is as given in below figure.

b) Select a representative soil mass of about 2.5 kg properly mixed.

c) Fill the soil into the mould and compact it to the required dry density by makinguse of a suitable compacting device.

d) Set the assembly as shown in figure after saturating the porous stones.

e) The water supply is properly adjusted to maintain constant head.

f) Open the valve and saturate the sample by allowing water to flow through for a sufficiently long time to remove all air-bubbles.

g) When the whole setup is ready for the test, open the valve, allow the water to flow through the sample collect water in a graduated jar starting simultaneously a stopwatch.

Note the time to collect a certain quantity of water Q.

h) Repeat the test three times and determine the average of Q for the same time interval t.

i) Measure the head h, length of sample L, and calculate the cross sectional area Aof the sample.

j) Calculate k by making use of equation

Observation:

Length of Soil sample L= cm

Diameter of Soil sample D= cm

Area of soil sample A=-----------

Constant head h= cm

Sl.No	Quantity of waterQ= ---------ml	Time t= --- sec	$k=(QL)/(A_{th})$ (cm/sec)
1			
2			
3			
4			

Pre-Viva Questions:

1. What is Darcy's law of flow velocity through soils? What are its Limitations?
2. What are the steady and unsteady flows of water? What type of flow is assumedto occur in soils?
3. What are the laboratory methods of determination of coefficient of permeability ofsoil? State their suitability.
4. What is the effect of entrapped air on the coefficient of permeability of soil?
5. Constant head method is suitable for what type of soils?
6. Soil with largest void ratio has lesser or more permeability?
7. Coefficient of permeability is also called as?

Result:

Coefficient of Permeability of soil k= -------------------------- cm/sec

Verification/Validation:

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}

Conclusion:

The type of soil tested is______________________as the permeability falls in the range as shown in the above table.

Post-Viva Questions:

1. Will the permeability of soil cause see of water through earth dams?
2. In the above case, what can we do to reduce see ?
3. What does Darcy's law state?

EXPERIMENT-10

Determination of coefficient of permeability by falling head test

Aim:

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

The passage of water through porous material is called see . A material with continuous voids is called a permeable material. Hence permeability is a property of a porous material which permits passage of fluids through interconnecting conditions. Hence permeability is defined as the rate of flow of water under laminar conditions through a unit cross-sectional area perpendicular to the direction of flow through a porous medium under unit hydraulic gradient and under standard temperature conditions.

Specifications:

IS 2720-17 (1986): Methods of test for soils, Part 17. This test is used for fine grained soils with intermediate and low permeability such as silts and clays. This testing method can be applied to an undisturbed sample.

Equipments Required:

All the accessories are the same as the constant head test and the following:

1. Graduated glass stand pipe and the clamp
2. Supporting frame for the stand pipe and the clamp

Theory:

The falling head permeability test involves flow of water through a relatively short soil sample connected to a standpipe which provides the water head and also allows measuring the volume of water passing through the sample. The diameter of the standpipe depends on the permeability of the tested soil. The test is carried out in falling head permeameter cell.

Before starting the flow measurements, the soil sample is saturated and the standpipes are filled with de-aired water to a given level. The test then starts by allowing water to flow through the sample until the water in the standpipe reaches a given lower limit. The time required for the water in the standpipe to to drop from the upper to the lower levelis recorded. Often, the standpipe is refilled and the test is repeated for couple of times. The recorded time should be the same for each test within an allowable variation of about 10% (Head 1982) otherwise the test is failed

The below equation can be used:

$$k = ((2.3 \times a \times L)/(A\times(t2-t1)))\times\log10(h1/h2)$$

Where, L = length of soil sample column

A = Sample cross-section

a = the cross-section of the standpipe

(t_2-t_1) = the recorded time for the water column to flow though the sample

h1 and h2 = the upper and lower water level in the standpipe measured using the samewater head reference

Precautions:

1. All possible leakage of joints must be eliminated.
2. Porous stones must be saturated before being put to use.
3. De-aired and distilled water should be used to prevent choking of flowing water.
4. Soil sample must be carefully saturated before taking the observations.
5. Use of high heads, which result in turbulent flows, should be avoided.

Procedure:

a) Open the valves in the standpipe and the bottom outlet. Ensure that the soil sample is fully saturated with out any entrapping of air bubble before starting thetest.
b) Fill the standpipe with water keeping the valves V1 and V2 open and allow the water to flow out through the outlet pipe for some time and then close the valves.
c) Select in advance the heights h1 and h2 for the water to fall and determine the height $\sqrt{h1h2}$ and mark this height on the stand pipe.
d) Open the valves and fill the standpipe with water up to height h1 and start thestopwatch.
e) Record the time intervals for water to fall from height h1 to $\sqrt{h1h2}$ and from $\sqrt{h1h2}$ to h2. These two time intervals will be equal if a stead flow condition hasbeen established.
f) Repeat the step (e) at least after changing the heights h1 and h2.
g) Stop the test and disconnect all the parts.
h) Take a small quantity of the sample for water content determination.

Tables:

Length of Soil sample L	cm
Diameter of Soil sample D	cm
Area of soil sample A	cm^2
Area of stand pipe a	cm^2

S.No	Initial Head (h1) cm	Final Head (h2) cm	Time t In seconds	k=((2.3 x a x L)/(Axt))xlog10(h1/h2)
1				
2				
3				
4				

Pre-Viva Questions:

1. A fully saturated soil is said to be in which phase?
2. Valid range of degree of saturation of soil in percentage is?
3. If the voids of a soil mass are full of air only, the soil is termed as?
4. Which method is the most suitable to determine the permeability of the clayeysoil?
5. Is there any connection between permeability of soil and temperature? If temperature increases, will permeability increase?
6. In the case of natural deposits, permeability is higher parallel to stratification or perpendicular to stratification?

Result:

Coefficient of Permeability of soil k= -------------------------- cm/sec

Verification/Validations:

The coefficient of permeability of a soil describes how easily a liquid will move through a soil. It is also commonly referred to as the hydraulic conductivity of a soil. This factor can be affected by the viscosity, or thickness (fluidity) of a liquid and its density. The number can also be affected by the void size, or region of non-soil, void continuity, and soil particle shape and surface roughness. It is an important factor when determining the rate at which a fluid will actually flow through a particular type of soil.

Typical permeability coefficients for different soils

Soil Type	Typical Permeability, k (cm/sec)
Gravels and Coarse Sands	$> 10^{-1}$
Fine Sands	10^{-1} to 10^{-3}

Silty Sands	10^{-3} to 10^{-5}
Silts	10^{-5} to 10^{-7}
Clays	$< 10^{-7}$

Conclusion:

As per the value of coefficient of permeability (____), type of soil from theabove table is_____.

Post-Viva Questions:

1. Why is variable head method required to find permeability?
2. What are the important steps in the experiment?
3. What is the time gap taken to take the readings?

EXPERIMENT-11

Determination of shear strength of soil using direct shear test

Aim:

To determine the shear strength of soil using the direct shear apparatus.

In many engineering problems such as design of foundation, retaining walls, slab bridges, pipes, sheet piling, the value of the angle of internal friction and cohesion of the soil involved are required for the design. Direct shear test is used to predict these parameters quickly. The laboratory report covers the laboratory procedures for determining these values for cohesion-less soils.

Specifications:

The test is conducted as per IS: 2720- 13 (1986), method of tests for soils. Onekg of air dry sample passing through 4.75mm IS sieve is required for this test.

Equipments Required:

Shear box apparatus consisting of

a) Shear box 60 mm square and 50 mm deep,
b) Grid plates, porous stones, etc.
c) Loading device
d) Other accessories.

Theory:

Box shear tests can be used for the following tests.

1. Quick and consolidated quick tests on clay soil samples.
2. Slow test on any type of soil.

Only using box shear test apparatus may carry the drained or slow shear tests on sand. As undisturbed samples of sand is not practicable to obtain, the box is filled with the sand obtained from the field and compacted to the required density and water content to stimulate field conditions as far as possible.

So far clay soil is concerned the undisturbed samples may be obtained from the field. The sample is cut to the required size and thickness of box shear test apparatus and introduced into the apparatus. The end surfaces are properly trimmed and leveled. I9f tests on remolded soils of clay samples are required; they are compacted in the mould to the required density and moisture content

Equation:

Coulombs equation is used for computing the shear parameters.

For clay soils

$$S=c+\sigma\tan\theta$$

For sand

$$S=\sigma\tan\theta$$

Where,
S = shear strength of soil in kg/cm^2
c=unit cohesion (kg/cm^2)
σ=normal load applied on the surface of the specimen (kg/cm^2)
θ=angle of shearing resistance (degrees)

In a Direct Shear test, the sample is sheared along a horizontal plane. This indicates that the failure plane is horizontal. The normal stress (s) on this plane is the external vertical load divided by the area of the soil sample. The shear stress at failure is the external lateral load divided by the corrected area of soil sample. The main advantageof direct shear apparatus is its simplicity and smoothness of operation and the rapidity with which testing programmes can be carried out. But this test has the disadvantage that lateral pressure and stresses on planes other than the plane of shear are not known during the test.

Precautions:

1. The dimensions of the shear box should be measured accurately.
2. Before allowing the sample to shear, the screw joining the two halves of the boxshould be taken out.
3. Rate of strain or shear displacement rate should be constant throughout the test.
4. The spacing screws after creating required spacing between two halves of the shearbox, should be turned back to make them clear of the lower part.
5. For drained test, the porous stones should be saturated by boiling in water.
6. Add the self weight of the loading yoke in the vertical load.
7. Failure of the soil specimen is assumed when the proving ring dial gauge reading begins to recede after reaching its maximum or at a 20% shear displacement of thespecimen length.
8. One soil specimen should be tested with not more than three normal loadingconditions as beyond this, the particle size of soil sample may change due to application of shear and normal load.

Procedure:

a) Place the sample of soil into the shear box, determine the water content and drydensity of the soil compacted.
b) Make all the necessary adjustments for applying vertical load, for measuringvertical and lateral movements and measurement of shearing force, etc.
c) Apply a known load on the specimen and then keep it constant during the courseof the test (for consolidation keep it for a long time without shearing, and quick tests apply the shearing without consolidation soon after placing the vertical load). Adjust the rate of strain as required of the specimen.
d) Shear the specimen till failure of the specimen is noticed or the shearing resistance decreases. Take the readings of the gauges during the shearingoperation.
e) Remove the specimen from the box at the end of the test, and determine the finalwater

content.

f) Repeat the tests on three or four identical specimens.

Table:

The test sample of cohesion less soil with a little cohesion is given in tabular formbelow.

(1) Soil density Y_d = 1.62 g/cm³

Data sheet for sample 1:

(for sample 2, 3, and 4 similar data sheets are to beprepared)

Initial area = Ao = 6x6 = 36 cm².

Initial thickness = 2.4 cm. □ = 0.5 kg/cm²

Table 13: Data Sheet for Direct Shear Test

Horizontal dial gauge reading	Horizontal displacem ent (mm)	Corrected area(cm^2)	Proving ring reading	Forc e (kg)	ζ (kg/ cm^2)	Vertical Dial reading	Vertical Displace ment (mm)	Ht(c m)
0	0	36	0	0				

* Corrected area in cm^2 is given by b (b-horizontal displacement)

b= width of shear box=6cm

From three samples the following results are obtained

Test No	Normal stress σ(kg/cm^2)	Shear stress atfailure ζ(kg/cm^2)
1	0.5	

2	1.0	
3	1.5	

From the results a graph of Horizontal displacement VS Shear stress is drawn

Mohr's circles are also plotted.

From Mohr's circle the following details are obtained;

Major principal stress $\sigma1$= kg/cm^2
Minor principal stress $\sigma2$= ------------kg/cm^2
Inclination to major principal stress $\theta1$=----------- degrees

Inclination to minor principal stress $\theta2$=----------- degrees

Pre-Viva Questions:

1. Why is shear strength of soil required?
2. Could we use direct shear test for sand and clay?
3. Is it at the predetermined plane the failure is happening in the direct shear test or naturally?
4. Is there any other apparatus using which we can determine the shear strength ofsoil? Name those.
5. Will this test give reliable undrained strength?

Result:

Angle of internal friction Ǿ=-----

Unit cohesion C= ------------- kg/cm^2

Verification and Validation:

The angle of shearing resistance of sands depends on state of compaction, coarseness of grains, particle shape and roughness of grain surface and grading. It varies between 28^o (uniformly graded sands with round grains in very loose state) to 46^o (well graded sand with angular grains in dense state). The friction between sand particles is due to sliding and rolling friction and interlocking action.

Conclusion:

The given soil has angle of friction as_______________, showing the type of sand as denselycoarse.

Post-Viva Questions:

1. What are the initial adjustments required for the equipment?
2. What is the proving ring capacity in direct shear test?
3. What are the steps taken to get accurate result?

EXPERIMENT-12

Determination of shear strength of soil using Laboratory Vane shear test

Aim:

To determine Cohesion or Shear Strength of Soil.

The structural strength of soil is basically a problem of shear strength. Vane shear test is a useful method of measuring the shear strength of clay. It is a cheaperand quicker method. The test can also be conducted in the laboratory. The laboratory vane shear test for the measurement of shear strength of cohesive soils, is useful for soils of low shear strength (less than 0.3 kg/cm2) for which triaxial or unconfined tests cannot be performed. The test gives the undrained strength of the soil. The undisturbed and remoulded strength obtained are useful for evaluating the sensitivity of soil

Specifications:

The test is conducted as per IS 4434 (1978). This test is useful when the soil is soft and its water content is nearer to liquid limit.

Equipment Required:

1. Vane shear test apparatus with accessories
2. The soil sample

Theory:

The vane shear test apparatus consists of four stainless steel blades fixed at right angle to each other and firmly attached to a high tensile steel rod. The length of the vane is usually kept equal to twice its overall width. The diameters and length of the stainless steel rod were limited to 2.5mm and 60mm respectively. At this time, the soil fails in shear on a cylindrical surface around the vane. The rotation is usually continued after shearing and the torque is measured to estimate the remoulded shear strength. Vane shear test can be used as a reliable in-situ test for determining the shear strength of soft-sensitive clays. The vane may be regarded as a method to be used under the following conditions.

1. Where the clay is deep, normally consolidated and sensitive.
2. Where only the undrained shear strength is required.

It has been found that the vane gives results similar to that as obtained from unconfinedcompression tests on undisturbed samples.

Procedure:

1. A post hole borer is first employed to bore a hole up to a point just above the required depth
2. The rod is pushed or driven carefully until the vanes are embedded at therequired depth.

3. At the other end of the rod just above the surface of the ground a torsion head isused to apply a horizontal torque and this is applied at a uniform speed of about 0.1 degree per second until the soil fails, thus generating a cylinder of soil
4. The area consists of the peripheral surface of the cylinder and the two roundends.
5. The first moment of these areas divided by the applied moment gives the unitshear value.

Observations:

Force observed P=--------- kg
Eccentricity (lever arm) x=---------cm
Turning moment Px= ------------ kg-cm
Length of the vane L= -------- cm
Radius of the vane blades r=---------- cm

Calculations:

Undrained Shear strength of Clay Cu= $(Px)/(2*.\Pi*r^2(L+2/3*r))$

Pre-Viva Questions:

1. Is this method the direct method to determine the shear strength of soil?
2. Is it possible to determine the sensitivity of clay suing this method?
3. What is meant by sensitivity of clay?
4. What are the advantages of vane shear test?
5. What are the disadvantages of vane shear test?

Result:

Undrained Shear strength of Clay Cu=-----------------------kg/cm^2

Verification/Validations:

Where the strength is greater than that able to be measured by the vane, i.e., the pointer reaches the maximum value on the dial without the soil shearing, the result shall be reported in either of the following two ways e.g 195 + kPa or > 195 kPa.

Conclusions:

The vane shear strength of soil is____________________.

Post-Viva Questions:

1. Is this experiment an easy one?
2. What is the equation used to find the shear strength?
3. How is the torque applied to the sample?
4.

EXPERIMENT-13

Determination of shear strength of soil using unconfined compressive strength test

Aim: To determine the unconfined compression test of soil.

It is not always possible to conduct the bearing capacity test in the field. Sometimes it is cheaper to take the undisturbed soil sample and test its strength in the laboratory. Also to choose the best material for the embankment, one has to conduct strength tests on the samples selected. Under these conditions it is easy to perform the unconfined compression test on undisturbed and remoulded soil sample.

Specifications:

The test is conducted as per IS 2720-10 (1991): Methods of test for soils, Part10: Determination of unconfined compressive strength [CED 43: Soil and Foundation Engineering]. The test is performed on a cylindrical sample with a height to diameter ratio of 2: 1. The sample is placed between the plates of a mechanical load frame without any covering or lateral support. Load and deformation readings are noted until the failure of the sample or a strain of 20%, whichever is smaller.

Equipment Required:

1. Loading frame of capacity of 2 t, with constant rate of movement. What is the least count of the dial gauge attached to the provingring!
2. Proving ring of 0.01 kg sensitivity for soft soils; 0.05 kg for stiff soils.
3. Soil trimmer.
4. Frictionless end plates of 75 mm diameter (Perspex plate with silicon greasecoating).
5. Evaporating dish (Aluminum container).
6. Soil sample of 75 mm length.
7. Dial gauge (0.01 mm accuracy).
8. Balance of capacity 200 g and sensitivity to weigh 0.01g.
9. Oven, thermostatically controlled with interior of non-corroding material to maintain the temperature at the desired level. What is the range of the temperature used for drying the soil!
10. Sample extractor and split sampler.
11. Dial gauge (sensitivity 0.01mm).

Theory:

The unconfined compression test is by far the most popular method of soil shear testing because it is one of the fastest and cheapest methods of measuring shear strength. The method is used primarily for saturated, cohesive soils recovered from thin-walled sampling tubes. The unconfined compression test is in appropriate for dry sands or crumbly clays because the materials would fall apart without some land of lateral confinement.

In the unconfined compression test, we assume that no pore water is lost from the sample during set-up or during the shearing process. A saturated sample will thus remain saturated during the test with no change in the sample volume, water content, or void ratio. More significantly, the sample is held together by an effective confining stress that results from negative pore water pressures (generated by menisci forming between particles on the sample surface). Pore pressures are not measured in an unconfined compression test; consequently, the effective stress is unknown. Hence, the undrained shear strength measured in an unconfined test is expressed in terms of the total stress

Precautions:

1. Both the ends of the sample are shaped so that it should sit properly on thebottom plate of the loading frame.
2. Rate of loading of the sample should be constant.

Procedure:

a) The sample is prepared in the same way as for a triaxial test. Its natural water content and dry density are determined prior to the testing. The length (Lo) and diameter (do) are also measured.
b) Set the sample on the pedestal of the equipment and complete all thenecessary adjustments for applying on axial loads.
c) Apply the axial load at a strain of about 0.5 to 2 % per minute and continue the load till the sample fails OR the deformation reaches 20 % of axial strain.
d) Sketch the failure pattern and measure the angle of failure if possible.
e) Take a small sample of soil from the failure zone for water content determination.

Calculations:

a) The axial strain, □% =(ΔL/Lo)×100

Where, ΔL = change in length of specimen.

Lo = Initial length of specimen.

b) Corrected areaA,

A = Ao/(1-□)

Where, Ao = initial sectional area op the specimen.

c) Compressive stress, (which is the principal stress) is σ_1= P/A where P = axial load.

A plot of σ_1 versus Ꞇ gives the maximum stress, which is the unconfined compressive strength of the soil specimen

<u>Observations and tabulation</u>:

Initial data available

a) Do = cm, L = cm, Ao =cm^2
b) Initial bulk density, ρt =gm/cm^3
c) Initial water content,w= %

Table 14: Data Sheet for Sample 1

Strain dial reading	ΔL(mm)	Axial Strain %	Corrected area, A(cm^2)	Provingring reading (PR)	Axial Load P(kg)	Stress σ=P/A (kg/cm^2)

Note: Plot a graph of Compressive stress as ordinate and Axial Strain as abscissa.

Pre-Viva Questions:

1. What is the difference between unconfined compression test and triaxial test?
2. What is meant by unconfined compression strength of soil?
3. Plot roughly the Mohr circle for Unconfined Compressive Strength of soil.
4. Explain the procedure to determine the Unconfined compressive strength of soil.
5. How is sensitivity determined?

Result:

Average unconfined compressive stress qu=----------------------kg/cm^2

Angle of internal friction---------
Undrained cohesive strength ------------------------- kg/cm^2

Verification/Validations:

Minimum three samples should be tested, correlation can be made between unconfined strength and field SPT value N practically. Upto 6% strain the readings may be taken at every min (30 sec).

Conclusion:

Unconfined compressive strength,q_u=_______.Shear

strength, S =q_u/2 =_______________________.

Post-Viva Questions:

- Why we need Mohr's circle for this experiment?
- Is there any stress which cannot be determined in the case of UCC?
- Could the drainage condition be handled in UCC?

EXPERIMENT-14

Determination of shear strength of soil using Tri-axial shear test

Aim The tri-axial shear test is most versatile of all the shear test testing methods for getting shear strength ofsoil i.e. Cohesion (C) and Angle of Internal Friction (Ø), though it is bit complicated. This test can measure the total as well as effective stress parameters both. These two parameters are required for design of slopes, calculation of bearing capacity of any strata, calculation of consolidation parameters and in many other analyses. This test can be conducted on any type of soil, drainage conditions can be controlled, porewater pressure measurements can be made accurately and volume changes can be measured. In this test,the failure plane is not forced, the stress distribution of failure plane is fairly uniform and specimen can failon any weak plane or can simply bulge.

Depending upon the drainage condition, there can be three types of tri-axial tests:

(i) Unconsolidated Undrained (UU) Test: In this test, drainage is not allowed during application of cell pressure (i.e. sample remains unconsolidated) during the first stage of all round cell pressure application as well as during the second stage of additional axial pressure application.

(ii) Consolidated Undrained (CU) Test: In this test, drainage is allowed during application of cell pressure(i.e. sample gets consolidated) during the first stage of all round cell pressure application but drainageis not allowed during the second stage of additional axial pressure application.

(iii) Consolidated Drained (CD) Test: In this test, drainage is allowed during application of cell pressure (i.e. sample gets consolidated) during the first stage all round cell pressure application as well as during the second stage of additional axial pressure application.

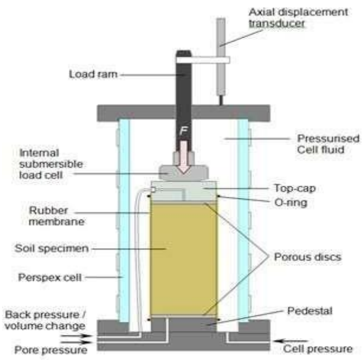


Fig. 1: Tri-axial Shear Test

Fig. 2: Tri-axial Shear Test Setup

Reference

1. IS 2720(Part 11):1993 - Determination of the shear strength parameters of a specimen tested in unconsolidated undrained tri-axial compression without the measurement of pore water pressure. Reaffirmed- 2021.
2. IS 2720(Part 12):1981 - Determination of the shear strength parameters of soil from consolidated undrained tri-axial compression with measurement of pore water pressure. Reaffirmed- 2021.

Preparation of Sample

Undisturbed Specimen

1. Note down the sample number, bore-hole number and the depth at which the sample was taken.
2. Remove the protective cover (paraffin wax) from the sampler tubes.
3. Place the sampling tube extractor and push the plunger till a small length of sample moves out.
4. Trim the projected sample using a wire saw, and push the plunger until a sample larger than requiredlength comes out.
5. Cut this sample carefully and hold it on the split sampler so that it does not fall and trim the specimensto required height.
6. Take about 10 to 15 g of soil from the tube for water content determination.
7. Measure the diameter (at top, middle and bottom of the sample and record average of the same), lengthand weight of the specimen.

Remoulded Specimen

1. Remoulded samples are prepared at the desired moisture and density by static and dynamic methods of
2. Measure the diameter (at top, middle and bottom of the sample and record average of the same), lengthand weight of the specimen.

Unconsolidated Undrained (UU) Test

Apparatus

Fig. 3: Apparatus for UU test

1. Machine capable of applying and maintaining axial compression to specimen: Capacity of 50 kN, speed of
   0.05 to 5 mm per minute and capable of applying axial compression of about one-third of the specimenheight.
2. Proving ring of 1 kN capacity with sensitivity of 2 kN for low strength soils and 10 kN capacity withsensitivity of 20 kN for high strength soils.
3. End platen of required diameter made with Perspex glass (diameter of the platen is selected according tothe diameter of the sample)
4. Dial gauge of 0.01 mm accuracy
5. Soil specimen of nominal diameter 38, 50, 70 and 100 mm and height approximately equal to twice the nominal diameter. In case of remolded samples, the ratio of diameter of specimen to maximum size of particle in the soil should not be less than 5.
6. O-rings of rubber
7. Seamless Rubber membrane: Open at both ends, with internal diameter equal to specimen diameter,length 50 mm greater than the height of the specimen and thickness of 0.2 to 0.3 mm.
8. Split mould, of length and diameter to suit the test specimen.
9. Trimming knife, piano wire saw, metal scale etc.
10. Non-corrodible metal or Plastic End Caps: Of the same diameter as the test specimen, with thickness of 20 mm for plastic or 12 mm for metal and the upper cap having central spherical seating to receive the loading ram.
11. Apparatus for Moisture Content Determination
12. Balance, with accuracy of 0.5 g.
13. Extruder, Thin-walled Tubes etc., for extruding the sample from sampler tube or from block sample.
14. Soil lathe, Meter Box etc., for preparing the test specimen.

Testing Procedure

15. Place the specimen on one of the end caps and put the other end cap on the top of the specimen.
16. Place the rubber membrane around the specimen using the membrane stretcher and seal the membraneto the end caps by means of rubber rings.
17. The specimen is now ready to be placed on the pedestal in the triaxial cell. The pedestal should be eithercovered with a slid end cap or the drainage valve should be kept closed.
18. Place the specimen on the pedestal of the triaxial cell. The cell must be properly set up and uniformly clamped down to prevent leakage of pressured water during the test.
19. Move down the loading ram and set up it on the circular groove of the top cap. Place a steel ball on the top of plunger. Adjust the center line of the specimen such that the proving ring, the steel ball, loading tram and specimen are in the same line.

20. Fill the cell with the water with inlet valve open and the confining pressure (σ_3) be raised to the desired value (for example, 50 kPa, 100 kPa and 150 kPa or 100kPa, 200 kPa and 300 kPa as per the depth where the sample is brought and the application requirements. Close the inlet valve tightly after filling the cell with water.
21. Adjust the loading machine to bring the loading ram a short distance away from the seat on the top cap. The loading machine shall then be further adjusted to bring the loading ram just in contact with the seat on the top cap and the initial reading of the gauge measuring the axial compression of the specimen shall be recorded.
22. Rate of axial compression shall be selected such that failure is produced within a period of approximately 5 to 15 minutes and readings of the load and compression measuring gauges be taken.
23. The test shall be continued until the maximum value of the stress has been passed or until an axial strain of 20 percent has been reached.
24. The cell shall be drained of fluid and dismantled, and the specimen taken out. The rubber membrane shall be removed from the specimen and the mode of failure shall be noted.
25. The specimen shall be weighed and samples for the determination of the moisture content of the specimen. The most convenient method of recording the mode of failure is by means of sketch indicating the position of the failure planes and the angle of failure plane to the horizontal.
26. At least three specimen should be tested for the UU test.

Calculations

27. The difference between the initial reading and any subsequent reading of the load measuring device is the axial load applied to specimen in addition to the cell pressure (σ_3).
28. The corrected area of specimen at any stage of test is given by:

    $A = A_0 / (1 - e)$ and $e = (L_0 - L) / L_0$

    where: A_0 = Initial are of specimen

    L_0 = Initial length of specimen

    L = Length of specimen at the given stage of test
29. The principal stress difference or deviator stress ($\sigma_1 - \sigma_3$) for any stage of test shall be determined by dividing the axial load by the corrected area.
30. A correction to allow for the restraining effect of the rubber membrane shall be deducted from the measured principal stress difference (or deviator stress) to give correct value of maximum principal stress difference (or maximum deviator stress). This correction value shall be calculated as under:

    Correction $= 4 M \times (1 - e) / D$ where:

    M = Compression modulus of the rubber membrane in kg/cm. This cannot be measure directly but may be assumed to equal to the modules measured in tension, as per the procedure given in Para 6.1.1.4 and Fig. 1 of IS:2720 (Part-11)-1983.

    e = Axial strain at the maximum value of ($\sigma_1 - \sigma_3$)

    D = Initial diameter of the sample

Results

31. Where required, the stress-strain curve of the test shall be plotted with the axial strain on X-axis and axial stress on Y-axis.
32. The type of sampler and method of sampling shall be reported.
33. The shear parameters shall be obtained from a plot of Mohr circles.

Consolidated Undrained (CU) Test

Apparatus

1. Machine capable of applying and maintaining axial compression to specimen, with Proving ring to measure the axial force being applied and Dial gauge to measure the change in length of the specimen.
2. Triaxial cell
3. Pore water pressure transducer
4. Volume change transducer

5. Data acquisition system
6. Computer with triaxial testing software
7. Specimen preparation holder for remoulded specimen
8. Coarse Porous stone of about 3 mm thickness and made of the material with particle size between 180 to150 micron.
9. Filter paper. Filter paper strips or a rectangular paper of appropriate size with parallel slits should be provided along the height of the sample at its circumference to induce radial drainage. Filter paper discs should be placed between the sample ends and the coarse porous stones.
10. O-rings of rubber, with unstretched diameter of 31 +/- 1 mm.
11. Seamless Rubber membrane: Open at both ends, with internal diameter equal to specimen diameter, length about 140 mm and thickness of about 0.2 mm.
12. End platen of required diameter made with Perspex glass (diameter of the platen is selected according tothe diameter of the sample)
13. Soil specimen of nominal diameter 38, 50, 70 and 100 mm and height approximately equal to twice the nominal diameter. The ratio of diameter of specimen to maximum size of particle in the soil should not beless than 5.
14. Split mould, of length and diameter to suit the test specimen.
15. Extruder, Thin-walled Tubes etc., for extruding the sample from sampler tube or from block sample.
16. Soil lathe, Meter Box etc., for preparing the test specimen.
17. Trimming knife, piano wire saw, metal scale etc.
18. Apparatus for Moisture Content Determination
19. Balance, with accuracy of 0.5 g.

Testing Procedure

20. Place the saturated porous stone disc, of diameter same as the sample, on top of the pedestal of triaxialtesting machine and place the circular filter paper of same size over this disc. Then place the specimen on top of the filter paper.
21. Stretch the rubber membrane, using membrane stretcher, and placed it on the soil specimen. Place the O rubber rings on top and bottom of platens of the soil specimen.
22. Place the triaxial cell over the base and tighten with the screws. Fill up the cell with water and apply a small confining pressure of about 10 kPa to hold the specimen in place.
23. The soil specimen needs to be completely saturated before consolidation phase. For this first of all watersaturation is done by supplying water from bottom of the specimen and allowing it to go out of the specimen from the top. The water used needs to be distilled & de-aired water.
24. The forced saturation is performed by applying cell pressure and the back pressure at constant incrementswith constant difference between these two pressures. The sample is allowed to saturate for some time (10-20 min) after each increment of cell pressure and the back pressure. This increase should be followed by a check for saturation value (B), also known as Skempton's pore pressure parameter. B is the ratio ofpore pressure change due to the change in cell stress ($B = \Delta u / \Delta\sigma_{cell}$). It is important to note that cell pressure always is higher than back pressure. The sample is said to be fully saturated if the B value greater than 0.95 can be acquired.
25. The consolidation stage is started by applying confining pressure. During this stage, drainage valve is keptopen and the volume change is measured until no change in volume is observed (when primary consolidation is over).
26. The machine is set in motion at an appropriate strain rate based on the soil type. The fine grained soils require to be sheared at much lower strain rate (0.05% per min – 0.2% per min) as compared to the coarse grained soils (0.5% per min – 1% per min). Fine grained soil has lower permeability (lower void space), thus pore water pressure distribution will not be uniform at higher strain in such soils (clay, silt).
27. Data acquisition system (DAQ) is attached with the computer & various transducers of triaxial system, which records the data with the help of triaxial CU software. The experiment is stopped at around 15% axial strain.
28. No drainage is allowed during shearing stage and pore pressure is measured throughout the test using the pore pressure transducer.
29. The three CU tests need to be performed at three different chosen confining pressures (σ_3).

Calculations

30. Deviator stress versus Axial strain curve and Excess pore pressure versus axial strain curves are plotted for all three CU triaxial tests.
31. The failure point of soil specimen can be defined as the point of peak stress in stress-strain relationship of each test.
32. The axial strain during consolidation is calculated by dividing the axial deformation by post-consolidationlength.
33. By subtracting each reading of pore water pressure from the initial reading of pore water pressure, changein pore water pressure is obtained.
34. By subtracting the value of load on proving ring when the loading frame was operated without the loadingram touching the sample from each value of load on proving ring, obtain the values of axial loads duringshearing.
35. By dividing post-consolidation area A, by (1 - e) where "e" is the axial strain, obtain for each e the valueof the area of the sample A_I at that strain.
36. By dividing each value of axial load, during shearing, by corresponding value of area of the sample A_I obtain values of deviator stress ($\sigma_1 - \sigma_3$).
37. Obtain values of initial cell pressure, that is cell pressure minus back pressure, which will be minor principaleffective stress (σ_3).
38. By adding values of deviator stress and minor principal stress, obtain values of major principal stress (σ_1).
39. The values of effective stresses (for both minor as well as principal stress) can be obtained by subtractingthe value of measured pore water pressure from values of measured stresses.

Results

The type of sampler and method of sampling shall be reported.

The shear parameters (total or effective) shall be obtained from a plot of Mohr circles.

Consolidated Drained (CD) Test

Testing Procedure

Same as for the CU test above except the changes:

1. Item No. 7: The CD tests are performed at much slower strain rate as compared to CU tests for the same soil.The strain rate for CD test can be chosen approx. 8-10 times lower than the CU test. It is important to have no pore water pressure generation throughout the shearing phase of CD test or in other words strain rate must be so small that pore water pressure must get dissipated quickly when specimen is subjected to compression loading in CD test.
2. Item No. 9: Drainage valves are kept open during shearing stage and volume change is measured throughoutthe test using the volume change transducer.

Calculations

3. Deviator stress versus Axial strain curve and Volumetric strain versus axial strain curves are plotted for allthree CU triaxial tests.
4. Volumetric strain = (ΔVs / Vc) x 100

   where, ΔV = Volume change due to deviator stress during shearing stage

   Vc = volume of specimen after the isotropic consolidation or before shearing stage
5. Volume of soil specimen after isotropic consolidation (Vc) can be obtained by following equation:

   $Vc = V0 - \Delta Vc$

   where, ΔVc = volume change during isotropic consolidation and V0 is initial volume of the soil specimen
6. The failure point of soil specimen can be defined as the point of peak stress in stress-strain relationship ofeach CD triaxial test.
7. Effective stress analysis is performed in CD triaxial tests as pore pressure is zero as drainage valves kept openthroughout the test. Total stress is the same as the effective stress during this test.

Results

The type of sampler and method of sampling shall be reported.

The shear parameters (total or effective) shall be obtained from a plot of Mohr circles.

EXPERIMENT-15

Determination of MDD and OMC by Standard proctor compaction test

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. 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 air fields .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
7. Spatula
8. Oven
9. Moisture bins

PROCEDURE

1. Take about 3 kg of air dried soil
2. Sieve the soil through 4.75 mm sieve. Take the soil that passes through the sieve for testing.
3. 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 21 % 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.

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) =

Observation Table

S.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 soilW = W 2 – 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					

RESULT

1. Optimum Moisture Content OMC (%) =
2. Maximum dry density (gm/cc) =

Precautions

1. If the soil has been cured add 1% water by weight in the account for evaporation losses.
2. Apply 25 blows for 1000 ml capacity mold and 56 blows for 2250 ml capacity.
3. For utmost case take two M.C rep. Samples, One near the top and other near the bottom for each trial.
4. Mix the water thoroughly.
5. Soil should be air-dried and passing through sieve No. 4.
6. Compaction should be done in specified layers, and each part should be compacted properly.
7. The Increment of water content should be 2-3 %.

EXPERIMENT-16

Determination of MDD and OMC by Modified proctor compaction test

AIM

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

Theory:

Compaction is the densification of unsaturated soil by the reduction in the volume of voids filled with air, while the volume of solids & water content remains the same. The major aim of compaction of soil is to increase shear strength, decrease compressibility, reduce permeability, & to control swelling & shrinkage of soil. The degree of compaction of soil is measured in terms of its dry density. The maximum dry density of soil occurs at optimum moisture content (OMC).The Modified Proctor Test is of great importance and is widely used in the construction of roads, highways, earth fill dams, earth filling, Airports, etc. In modified Proctor test, the soil is compacted in the given mold in Five (05) layers with a rammer of 10 lbs (4.5 kg) with a fall of 18 inches (45 cm).

Modified Proctor Test Standards:

1. AASHTO T180-90
2. ASTM D1557-91
3. BS1377 part 4; clause 4.

Apparatus.

1. Cylindrical Metal Mold, internal diameter 4″ (10.16 cm) or 6″ (15.24 cm), internal effective height of 4.6"(11.7 cm); and the mold should have detachable base plate & color 2″ (5.08 cm).
2. Rammer; weighing 10 lbs (4.5 kg) & having fall of 18 inches (45.7 cm).
3. Sensitive Balance; ranging from 1 gram to 0.I gram.
4. Thermostatically controlled oven (105°C – 110°C).
5. Steel straightedge.
6. Moisture containers.
7. Sieve No.4.
8. Tray & scoop.
9. Graduated cylinder.
10. Mixing Tools (spoon, trowel, Spatula).

Procedure:

1. Take about 4 kg of air-dried soil passing No. 4 sieve and mix it with an optimum quantity of water.
2. Weigh the empty mold without a collar, with base plate attached.
3. Place the mold With the collar attached on a solid base and compact the soil mass into the mold using standard compaction in five layers with 25 blows per layer; and with a 4.5 kg rammer dropping from a height of 45 cm. Take care to distribute the blows uniformly over the surface of each layer, and to let the rammer fall freely.
4. Remove the collar carefully strike off the projected part of the compacted soil by steel straight edge. Then weigh the mold + soil.

5. Extrude the compacted soil specimen from the mold and split it on a large tray.Take a sample for moisture content determination.

6. Break-up the specimen to No.4 sieve size, and mix it with the remainder of the original sample. Add suitable increments of water, and mix thoroughly for at least six trials. Then repeat 3 to 5 steps for each trial.

7. Draw compaction curve on a graph with dry density on ordinate and moisture contents on the x-axis. Maximum dry density shall be at the apex of the curve and optimum moisture content (OMC) at which maximum dry density is obtained.

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.

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) =

Observation Table

S.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 soilW = W 2 – 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					

RESULT

1. Optimum Moisture Content OMC (%) =

2. Maximum dry density (gm/cc) =

Precautions

1. If the soil has been cured add 1% water by weight in the account for evaporation losses.
2. Apply 25 blows for 1000 ml capacity mold and 56 blows for 2250 ml capacity.
3. For utmost case take two M.C rep. Samples, One near the top and other near the bottom for each trial.
4. Mix the water thoroughly.
5. Soil should be air-dried and passing through sieve No. 4.
6. Compaction should be done in specified layers, and each part should be compacted properly.
7. The Increment of water content should be 2-3 %.