GEOTECHNICAL ENGINEERING LAB

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DETERMINATION OF SPECIFIC GRAVITY OF SOIL SOLIDS BY PYCNOMETER METHOD

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 behigher.
- 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 1g, 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:

$$G= (W_2-W_1)/((W_2-W_1)-(W_3-W_4))$$

Where, W_1=weight of Pycnometer in grams.
W_2=weight of Pycnometer + dry soil in grams.
W_3=weight of Pycnometer + soil+ water grams.
W_4=weight of Pycnometer + water grams.

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

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 andwasher.
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 determiningG.
f) Repeat the same process for additionaltests.

Table:

Table 1: Weights of Pycnometer

Sl No	Particulars	Test No 1 (G1)	Test No 2 (G2)	Test No 3 (G3)
1	Weight of Pycnometer bottle (W_1), g			
2	Weight of Pycnometer + dry soil (W_2),g			
3	Weight of Pycnometer + soil + water, (W_3), g			
4	Weight of Pycnomerter + water (W_4), g			
5	Calculation of specific gravity, G			
6	Average G = (G1+G2+G3)/3			

Specimen calculations:

$$G = (W_2-W_1)/((W_2-W_1)-(W_3-W_4))$$

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__________.

DETERMINATION OF SPECIFIC GRAVITY OF SOIL SOLIDS BY DENSITY BOTTLE METHOD

Aim:

To determine the specific gravity of soil solids by Density bottle method.

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

Specification:

IS 2720 (Part III) – 1980 is the standard recommended to determine specific gravity of fine grained soils. The value ranges are same as the previous experiment. The average of the values obtained shall be taken as the specific gravity of the soil particles and shall be reported to the nearest 0.01 precision. If the two results differ by more than 0.03 the tests shall berepeated.

Equipments Required:

1. 50 ml capacity density bottle withstopper
2. A constant temperature water bath (27 °C)
3. Oven with a range of 105 to 110 ℃
4. Vacuum desiccators
5. Vacuum pump
6. Other accessories, such as, weighing balance accurate to 0.001g, trays, wooden mallet etc.

Theory:

Specific gravity of soil solids is defined as the weight of soil solids to weight of equal volume of water.

Equation for specific gravity, G:

$$G = (W_2-W_1)/((W_2-W_1)-(W_3-W_4))$$

Where, W_1= weight of empty bottle
W_2= weight of bottle + dry soil
W_3= weight of bottle + soil + water
W_4= weight of bottle + water

Note: This method is normally used for fine-grained soils. The method may also be used for medium and coarse grained soils, if the coarse particles are grained to pass 4.75-mm IS sieve beforeusing.

Procedure:

a) Clean and dry the density bottle and weigh it along with the stopper (W_1 in g).
b) Select about 25 gm of dry soil free of clods and put the same into the density bottle. Weigh it with brass cap and washer (W_2 in g).
c) Fill the density bottle with de-aired water up to half its height and stir the mix with a glass rod. Add more water and stir it. Place the stopper on top and take the weight (W_3 in g).
d) Remove all the contents from the density bottle, clean it thoroughly and fill it with distilled water. Weigh it (W_4 in g).
e) Use above equation for determining G.
f) Repeat the same process for additional tests.

Table:

Table 2: Weights of density bottle

Sl. No	Particulars	Test No 1 (G1)	Test No 2 (G2)	Test No 3 (G3)
1	Weight of density bottle (W_1), g			
2	Weight of bottle + dry soil (W_2), g			
3	Weight of bottle + soil + water (W_3), g			
4	Weight of bottle + water (W_4), g			
5	Specific Gravity, G			
6	Average G, (G1+G2+G3)/3			

Specimen calculations:

$$G=(W_2-W_1)/((W_2-W_1)-(W_3-W_4))$$

Result:

AVERAGE G=

.

Conclusion:

The experiment is conducted as per the procedure laid down. The specific gravity of soil solids=___________.The value falls in the range 2.6 to 2.75.The type of soil is ______as per the specification.

DETERMINATION OF WATER CONTENT OF SOIL SOLIDS 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 airtightcontainers.
b) Balance weighting to accuracy of 0.04% of the weight of the soil takenfor test.
c) Desiccators with suitable desiccatingagent.
d) Thermostatically controlled oven to maintain temperature 110 ℃± 5 ℃.
e) Otheraccessories.

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 ofsolids:

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

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

Procedure:

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

Table:

Table 3: Weights of container

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:

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

Result:

AVERAGE w=

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.

DETERMINATION OF WATER CONTENT OF SOIL SOLIDS BY PYCNOMETER METHOD

Aim:

To determine the water content of soil solids by Pycnometer bottle Method.

To determine water content by this method, the value of G should have been determined prior.

Specifications:

This test is done as per IS: 2720 (Part II) – 1973. This method is suitable for coarse grained soils from which the entrapped air can be easily removed.

Equipments Required:

1. Pycnometer of 1000 ml capacity with a brass conical cap.
2. Balance accurate to 1g.
3. Glass rod other accessories.

Theory:

A Pycnometer is a glass jar of about 1 liter capacity, fitted with a brass conical cap by means of a screw type cover. The cap has a small hole of about 6mm diameter at its apex. For many soils, the water content may be an extremely important index used for establishing the relationship between the way a soil behaves and its properties. The consistency of a fine-grained soil largely depends on its water content. The water content is also used in expressing the phase relationships of air, water, and solids in a given volume ofsoil.

Water content, w of a soil mass is defined as the ratio of mass of water in the voids to the mass of solids:

$$\text{Water content, } W\% = \left[\left(\frac{W2-W1}{W3-W4}\right)\times\left(\frac{G-1}{G}-1\right)\right]\times 100\%$$

Where, W1= Weight of empty pycnometer in grams
W2 = Weight of pycnometer + wet soil in grams
W3 = Weight of pycnometer + dry soil in grams
W4 = Weight of pycnometer + water ingrams

Procedure:

a) Clean and dry the pycnometer and weigh it (W1 in g).
b) Select a mass of wet soil of about 300 gm and place the same in pycnometer and weigh it (W2 in g).
c) Fill the pycnometer with distilled water up-to half its height and stir the mix with a glass rod. Keep on adding more water till the mix is flush with the hole in the conical cap. Dry the pycnometer outside and find the mass (W3 in g).
d) Remove the contents of PM and clean it. Fill with clean water up-to the top level of the hole in the cap weigh it (W4 in g).

e) Now use the above equation for determining water content, where, G value is taken from Experiment No 1 (Determination of specific gravity by pycnometer method) for the given soil.

Table:

Table 4: Weights of pycnometer

Sl No	**Particulars**	Test No1 (w1)	Test No2 (w2)	Test No3 (w3)
1	Weight of empty pycnometer (W1), g			
2	Weight of pycnometer + wet soil (W2), g			
3	Weight of pycnometer + soil + water (W3), g			
4	Weight of pycnometer + water (W4), g			
5	Water content, w			
6	Average water content, Avg w			

Specimen calculations:

$$w\% = [((W2-W1)/(W3-W4))\times(((G-1)/G)-1)]\times 100\%$$

Average water content, w = (w1+w2+w3)/3

Result:

Average water content,w=______%

Conclusion:

Pycnometer method is a simple method to determine the water content of a soil. Experiment is carried out using the soil specimen collected from the college itself. All foreign matters are removed, clods broken and water content we got for the soil specimenis_________.

Comparing with the oven drying method, thevalue is__________.

DETERMINATION OF IN-SITU DENSITY 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 130mm long.
2) Steel dolley, 25mm high and 100mm internal diameter.
3) Steel rammer mass 9kg, overall length with the foot and staff about 900mm.
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 dolley over the core cutter. Stop ramming when the dolley 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;

$\rho_d = \rho_t/(1+w)$ gm/cm³

Where, ρ_d = dry density in g/cm³,
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 V_c in cm³.
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 3 (*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 (ρ_d).

Observations:

Length of core cutter l=-----------------cm

Diameter of core cutter d=--------------cm

Volume of core cutter=Vc=------------cm

Table:

Table 5: Weights of core cutter

Sl.No.	Particulars	Test nos.		
		1 (ρ_{d1})	**2** (ρ_{d2})	**3** (ρ_{d3})
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) = ρ_t /(1+w)			
10.	Average density, Avg ρ_d			

Specimen calculations:

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.

DETERMINATION OF IN-SITU DENSITY 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 perIS 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 diameter at 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 report the 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, in this experiment there are two stages, namely

1. Calibration of sanddensity
2. Measurement of soildensity

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

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

OR $\square_d$ =

$\square_t/(1+w)\text{kN/m}^3$ Where,

□d = drydensity,
□d = dry unit weight,
□t = field moist density,
□t =field moist unit weight, w =water constant,
□w = unit weight of water = 9.81 kN/m³

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

$$V_h = W_s / (G \square \square_w)$$

$$\square_t = M / V_h$$

$$\square_d = \square_t/(1+w)$$

Where, 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.
$\square_t$ = moist soil in-situ density.
$\square_d$ = dry density of the soil.
G = specific gravity of the solids.
$\square_w$ = density of the water.

Procedures:

Stage1 –Determination of mass of sand that fills the cone

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

c) Keep the cylinder on a glass plate, which is kept on a horizontalsurface.
d) Open the valve and allow the sand to fill the cone completely. Close thevalve.
   Weight of sand in the cylinder +cylinder W"=-----gms

e) Determine the mass of the sand left in thecylinder.
   Weight of sand fills the conicalportion=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 beW_1.

Determination of bulk density of sand

a) Measure the internal dimensions of the calibrating container and find itsvolume.
   Length of calibrating containerl=------------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 cylinderW1=-------g

Weight of cylinder +sand in the cylinder W2=-------g

Weight of sand filled in the cylinder Wo=W2-W1=-------g

Let the weight of sand filled be Wo.

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 thecylinder
Weight of cylinder +sand after filling the calibrating container W3=-------gms.

Determine the weight of sand that fills the calibrating container Wc=W2-W3=-----

d) The bulk density of sand □sis

□s = Wc/ Vc.

Stage 2 - Determination of in-situ density:

a) Level the area where the density isrequired.

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 acontainer.
Let the weight of the soil removed = W2=----------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 thecylinder
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, $V_h = W_s/ \square_s$ where $\square_s$ = bulk density of sand.

d) Bulk density of soil in-situ, $\square_t$,is

$\square_t = W/ V_h = (W/ W_s)\square\ \square_s$

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 □d = $□_t$/(1+w)=---------g/cm^3

Result:

1) Weight of wet soil from the hole,W=________gm
2) Water content of the soil,w=_____%
3) Weight of sand that fills thehole=______gm
4) Volume of the hole Vh=Ws/□s =______cm^3
5) Bulk density of the soil □t = W/Vh =_____gm/cm^3
6) Dry density □d =□t/(1+w)=_____gm/ cm^3

a) Dry density ofsoil=____________g/cm^3
b) Water content of thesoil=__________%

Conclusion:

The dry density of thesoilis__________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.

DETERMINATION OF PARTICLE SIZE DISTRIBUTION BY SIEVING (GRAIN SIZE ANALYSIS)

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 controlledoven.
c) Trays, sieve brushes, mortar with a rubber covered pestle,etc.
d) Mechanical sieve shakeretc.

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)×100
Cumulative percentage retained = sum of percentages retained on any sieve on all coarser sieves.

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

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 500g.
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 (75µ sieve). A pan is attached to the lowest 75µ sieve to collect the portions passing #200 sieve and fit the nest to a mechanicalshaker.
d) Make sure sieves are clean. If many soil particles are stuck in the openings try to poke them out usingbrush.
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 constantvalue.
f) Determine mass of soil retained on each sieve including that collected in the pan below.

Table:

The test results obtained from a sample of soil are givenbelow.
Mass of soil taken for analysis W= ______gm

Table 7: Sieve Analysis data sheet

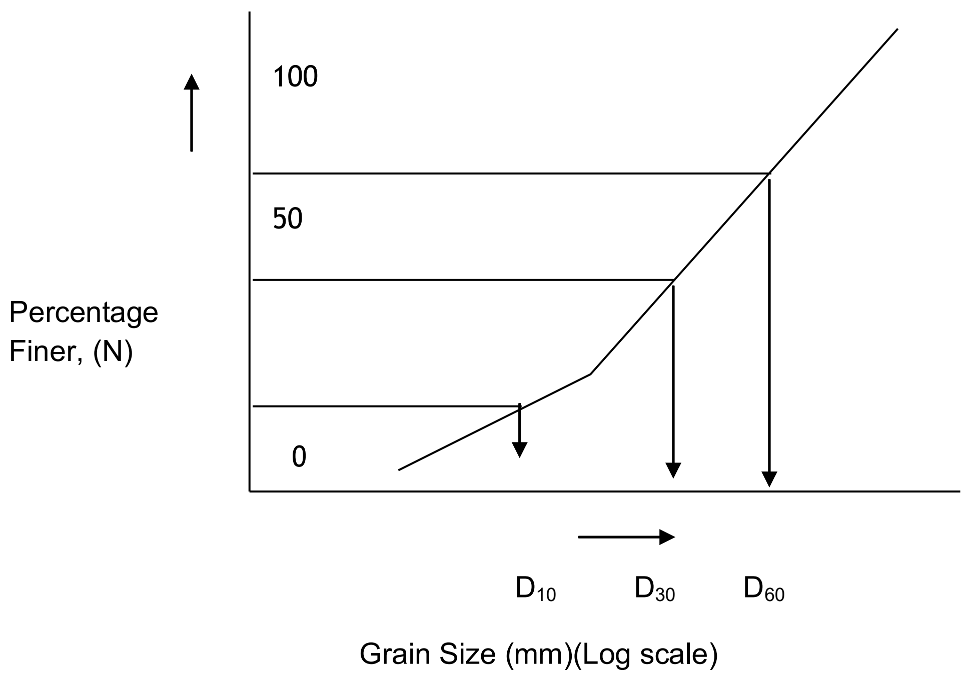
Sl No.	IS Sieves (mm)	Particle Size (mm)	Mass Retained (g)	Corrected Mass Retained (g)	Cumulative Mass Retained (g)	Cumulative % Retained	% Finer
1	4.75	4.75					
2	2.00	2.00					
3	1.00	1.00					
4	0.600	0.600					
5	0.300	0.300					
6	0.150	0.150					
7	0.075	0.075					
8	pan						

Cumulative
Massretained 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 poorlygraded.

Graph1-Grain Size in mm Vs Percentage Finer in %



<u>Result:</u>

Uniformity coefficient, Cu=

Coefficient of curvature, Cc=

Percentage gravel=

Percentage sand=

Percentage silt=

Conclusion:

The uniformity coefficient,Cu=_____and Cc=______.

The value comes in the range of well gradedsoil.

DETERMINATION OF LIQUID LIMIT OF FINESOIL

Aim:

To determine the liquid limit of fine soil by using CasagrandeApparatus

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 60^0C). 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 thistest.

Equipments Required:

a) A mechanical liquid limit apparatus (casagrande type) with groovingtools.
b) Evaporating dishes, wash bottleetc.
c) Balance accurate to 0.01g.
d) Airtight container to determine watercontent.
e) Oven to maintain temperature at 105 ℃ to 110℃.
f) Sieve (425micron).
g) Spatula
h) Desiccators 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 Atterberglimits.

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.

Procedure:

a) A representative sample of mass of about 120 gm passing through 425 µ IS sieve is taken for the test. Mix the soil in an evaporating dish with distilled water to form a uniformpaste.
b) Adjust the cup of the device so that the fall of the cup on to the hard rubber base is 10mm.
c) Transfer the portion of the paste to the cup of liquid limit device. Allow some time for the soil to have uniform distribution ofwater.
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.

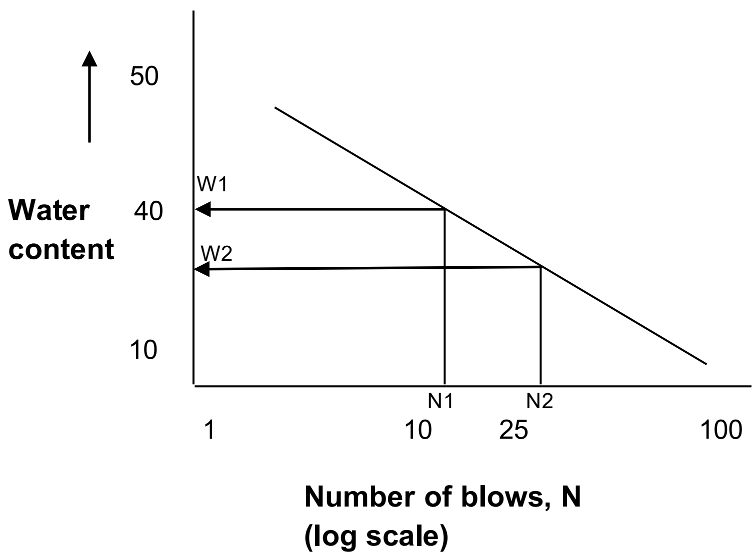
Table:

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 Vs water Content is drawn from the table data.



Result:

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

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

Conclusion:

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

DETERMINATION OF PLASTIC LIMIT OF THE SOIL

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 and leave the soil mass for 24hrs.

Equipments Required:

a) Porcelain evaporatingdish.
b) Flat glassplate.
c) Balance accurate to 0.01g.
d) Drying oven, maintained at 110 ± 5°C (230 ±9°F).
e) Weighing dishes, non-absorbent, withlids.
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.

Procedure:

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

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 watercontent.

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

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

Table:

Table 9: Water content of 3 mm soil

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				

Result:

The Plastic limit of soil (average water content)is________________.

Plasticity index = $w_p - w_L$

Conclusion:

The plastic limit of the soil=______and plasticity index= _____

The type of soil is______.

DETERMINATION OF SHRINKAGE LIMIT

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 anddams.

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 aflat 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 mmhigh.
d) Two numbers glass plates of size 75×75×3 mm, one plate of plane glass and the other with three metalprongs.
e) Spatula balance accurate to 0.01 g, oven etc.
f) Mercury.
g) Desiccator and otheraccessories.

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. earthdams).

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.

<u>Procedure:</u>

a) Select a representative sample of soil of about 100 g passing through 425μ 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 evaporatingdish.
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 thecup.
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 p at Vd is

Vd = Mm/ 13.6.

Where, 13.6 is the density of mercury in g/cm^3

Calculation of shrinkage limit, Ws

Mass of wet soil = M_o =(M_1-M_3)=-------------g

Mass of dry soil = M_s =(M_2–M_3)=-------------g

Volume of shrinkage dish = Volume of wet soil = V_o = ---------------

Volume of dry soil = V_d = ---------------

V_d = M_m / 13.6 where, 13.6 g/cm^3 is the density of mercury.

 Srinkage limit,W_s is

$W_s = ((M_o-M_s)-(V_o-V_d)\times\rho_w)/M_s$

Shrinkage ratio, $S_r = ((V_o-V_d)/V_o)\times 100$

Shrinkage limit of undistributed soil

In this case G is known in advance. The equation to be used for determining Ws is $W_s=[(V_d/M_s)-(1/G)]\times 100$

For the undistributed soil we need to know only the volume of anundistributed 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 sampleinitially 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

$$Ws = [(V_d/M_s)-(1/G)]\times 100.$$

Result:

The shrinkage limit W_s=------------------

Verification/Validations:

Value of shrinkage limit varies from 13 to 26.

Conclusion:

The shrinkage limit of soilis_________.

DETERMINATION OF MAXIMUM DRY DENSITY AND OPTIMUM MOISTURE CONTENT BY STANDARD PROCTOR COMPACTION METHOD

Aim:

To determine moisture content –DRY DENSITY RELATIONSHIP BY STANDARD PROCTOR TEST.

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

Specifications:

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

Equipment Required:

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

Theory:

The objectives of compaction are:
a) To increase soil shear strength and therefore its bearing capacity.
b) To reduce subsequent settlement under working loads.
c) To reduce soil permeability making it more difficult for water to flow through

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

1. Bulk density Yt =(M2-M1)/V
2. Dry density ρd = ρt/(1 +w)

3. Dry density ρd for zero air voidsline.

$$\rho d = G\rho w/(1 + (wG/S))$$

Where, M1 = mass of mould used for proctor test

M2 = mass of mould + compacted soil.

M = mass of wet soil.

V = volume of mould.

ρw = density of water.

G = Specific gravity of soils.

W = water content.

S = degree of saturation.

Procedure

a) Select a representative soil sample of about 25 kg. The material used for the test must be finer than 20 mm sieve. Air-dry sample.
b) Add sufficient water to the sample (about 7 % for sandy soils and 10 % for clay soils), which will be less than the estimated optimum moisture content. Mix the soil thoroughly and keep this in an airtight container for a period of 20hours.
c) Fix the mould to the base plate after cleaning its inside surface. Find the mass of the mould with the base plate (M1).
d) Attach the extension collar to the mould.
e) Take about 2.5 kg of soil in an air tight container and compact it in the mould in three equal layers each layer is compacted by giving 25 blows by the hammer weighing 2.6 kg and dropping from a height of 310 mm. The compaction must be uniform over the whole area, and a spatula scratches each layer before adding another layer. The filling must be such that the last layer projects into the collar by about 5 mm. After the completion of compaction, remove the collar and remove the excess soil with the help of a straight edge. Find the mass of the mould with the base plate and the soil (M2). Remove the soil from the mould by making use of an ejector and take a representative sample for water content determination.
f) Carry out the tests 3 to 4 times by repeating the steps from (e) onwards. Each time use a fresh soil sample.

Observations and tabulation:

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

The test results are tabulated below.

Table 15: Weight of Soil for varying water content

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

Note: Plot dry density vs. moisture content and find out the max dry density and optimum moisture for the soil. Also, mark the 100 % and 80 % saturation lines.

Result:

Maximum dry density ρd __= g/cm3

Optimum moisture content, w= ___ %

Conclusion:

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

DETERMINATION OF PERMEABLITY OF A SOIL SAMPLE BY CONSTANT- HEAD METHOD

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 seepage force which has direct effect on the safety of hydraulic structures. The rate of settlement of compressible clay layer under load depends on its
permeability. The quantity of water escaping through and beneath the earthen dam depends on the permeability of the embankments and its foundations respectively. The rate of discharge through wells and excavated foundation pits depends on the coefficient of permeability of the soils. Shear strength of soils also depends indirectly on permeability of soil, as dissipation of pore pressure is controlled by itspermeability.

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 1000ml
2. The mould shall be fitted with a detachable base plate and removable extension counter.
3. Compacting equipment: 50 mm diameter circular face, weight 2.76 kg and height of fall 310 mm as specified in I.S 2720 part VII1965.
4. Drainage bade: A bade with a porous disc, 12 mm thick which has the permeability 10 times the expected permeability ofsoil.
5. Drainage cap: A porous disc of 12 mm thick having a fitting for connection to water inlet oroutlet.

6. Constant head tank: A suitable water reservoir capable of supplying water to the permeameter under constanthead.

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 ofspecimen.

Theory:

The knowledge of this property is much useful in solving problems involving yield of water bearing strata, seepage through earthen dams, stability of earthen dams, and embankments of canal bank affected by seepage, 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:

$k = (Q \times L)/(A \times h \times t)$ 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 areused
    i. Internal diameter of the mould = 100mm.
    ii. Effective height of the mould = 127.3mm.
    iii. Detachable collar: 100 mm diameter and 60 mm height.
    iv. Drainage base, having a porousdisc.
- Weighing balance, and other accessories.

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 making use 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 intervalt.
i) Measure the head h, length of sample L, and calculate the cross sectional area A of 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

0 Sl.No	Quantity of water Q=------ml	Time t=----sec	k=(QL)/(Ath) (cm/sec)
1			
2			
3			
4			

Result:

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

Conclusion:

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

FALLING HEAD PERMEABILITY TEST FOR FINE GRAINED SOILS

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 seepage. A material with continuous voids is called a permeable material. Hence permeability is a property of a porous material which permits passage of fluids through inter connecting 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 stand pipe reaches a given lower limit. The time required for the water in the stand pipe to drop from the upper to the lower level is 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

(t2-t1) = 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 same water head reference

Procedure:

a) Open the valves in the standpipe and the bottom outlet. Ensure that the soil sample is fully saturated without any entrapping of air bubble before startingthe test.
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 thevalves.
c) Select in advance the heights h1 and h2 for the water to fall and determinethe height □h1h2 and mark this height on the standpipe.
d) Open the valves and fill the standpipe with water up to height h1 and start the stopwatch.
e) Record the time intervals for water to fall from height h1 to □h1h2 and from □h1h2 to h2. These two time intervals will be equal if a steady flow condition has been 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:

Table 12 (a): Observations

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

Table 12(b): Computation of coefficient of permeability

Sl.No	Initial Head (h1) cm	Final Head (h2) cm	Time t In seconds	k=((2.3×a×L)/(A×t))×log10(h1/h2)
1				
2				
3				
4				

Result:

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

Conclusion:

As per the value of coefficient of permeability (______________), type of soil from the above table is____________.

DETERMINATION OF LIQUID LIMIT BY STATIC CONE PENETROMETER

Aim:

To determine Liquid Limit by Static Cone Penetrometer

The Liquid Limit is the moisture content at which the soil passes from the plastic to the liquid state as determined by the Cone Liquid Limittest

Specifications:

This test is conducted as per IS : 2720(Part 5)-1985- Methods of test for soils : Determination of liquid and plastic limit. 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.

Equipment Required:

Static Cone Penetrometer

Theory:

The cone penetration test "CPT" is one of the most commonly used site investigation tools in the field of geotechnical engineering for the classification and characterization of soils. The liquid limit of the soil corresponds to the water content of a paste which would give 20 mm penetration of the soil.

Procedure:

1) Take 200 gm of soil, add 5 percentage water and make a paste
2) Mix the soil thoroughly and fix the mould in such a way that it should touch the surface
3) Release the cone and note down the depth of the penetration.
4) Repeat experiments with different values of watercontent
5) Draw a graph of water content vs penetration. The one with 20 mm penetration would give the liquid limit of the soil.

Table:

Table18: Depth of Penetration for various water contents

Trial No	**1**	**2**	**3**	**4**
Depth of penetration (mm)				
Weight of Container (W1)				
Weight of Container + Wet soil (W2)				
Weight of Container + dry soil (W3)				
Water content w=(W2-W3)/(W3-W1)%				

Result:

The liquid limit w_l = %

Conclusion:

The liquid limit of the soil is________.

Post-Viva Questions: (Refer page 36)

DETERMINATION OF SHEAR PARAMETERS BY 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. One kg 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. If 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

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

For sand

$$S=\sigma\tan\emptyset$$

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)

$\emptyset$=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 advantage of 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.

Procedure:

a) Place the sample of soil into the shear box, determine the water content and dry density of the soil compacted.
b) Make all the necessary adjustments for applying vertical load, formeasuring vertical and lateral movements and measurement of shearing force,etc.
c) Apply a known load on the specimen and then keep it constant during the course of the test (for consolidation keep it for a long time without shearing, and quick tests apply the shearing without consolidation soon after placing the vertically 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 shearing

operation.
e) Remove the specimen from the box at the end of the test, and determine the final watercontent.
f) Repeat the tests on three or four identical specimens.

Table:

The test sample of cohesionless soil with a little cohesion is given in tabular form below.

(1) Soil density ρd = 1.62g/cm³

Data sheet for sample 1: (for sample 2, 3, and 4 similar data sheets are to be prepared)

Initial area = Ao = 6×6 = 36 cm². Initial thickness = 2.4 cm. seating pressure = 0.5 kg/cm²

Table 13: Data Sheet for Direct Shear Test

Horizontal dial gauge reading	Horizontal displacement (mm)	Corrected area(cm^2)	Proving ring reading	Force (kg)	ζ (kg/ cm^2)	Vertical Dial reading	Vertical Displacement (mm)	Ht(cm)
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 $\sigma(kg/cm^2)$	Shear stress at failure $\zeta(kg/cm^2)$
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 $\sigma 1$=-----------kg/cm^2

Minor principal stress $\sigma 2$=----------kg/cm^2

Inclination to major principal stress $\theta 1$=--------degrees

Inclination to minor principal stress $\theta 2$=--------degrees

<u>Result:</u>

Angle of internal friction Ǿ=-----

Unit cohesionC=---------kg/cm^2

.

Conclusion:

The given soil has angle of friction as________, showing the type of sand as densely coarse.

UNCONFINED COMPRESSION 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, Part 10: 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 grease coating).
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

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 then ecessary 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, $\epsilon\% = (\Delta L/L_o)\times 100$
   Where, ΔL = change in length of specimen.

   L_o = Initial length of specimen.

b) Corrected areaA,
   $A = A_o/(1-\epsilon)$

   Where, A_o = initial sectional area op the specimen.

c) Compressive stress, (which is the principal stress) is $\sigma_1 = P/A$ where P = axial load.
   A plot of $\sigma_1$versus Ʋ gives the maximum stress, which is the unconfined compressive strength of the soil specimen.

Observations and tabulation:

Initial data available

a) Do = cm, L = cm, Ao =cm²
b) Initial bulk density, ρt =gm/cm³
c) Initial water content,w= %

Table 14: Data Sheet for Sample 1

Strain dial reading	ΔL(mm)	Axial Strain %	Corrected area, A(cm^2)	Proving ring 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.

Result:

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

Angle of internal friction---------

Undrained cohesive strength-------------kg/cm^2

Conclusion:

Unconfined compressive strength,q_u=________.

Shear strength, S =q_u/2 =_______.

VANE SHEARTEST

Aim:

To determine Cohesion or Shear Strength ofSoil.

The structural strength ofsoil is basicallya problem ofshear strength.Vane shear test is a useful method of measuring the shear strength of clay. It is a cheaper and 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 can not be performed. The test gives the undrained strength of the soil. The undisturbed and remoulded strength obtained are useful for evaluating the sensitivity ofsoil.

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 isrequired.

It has been found that the vane gives results similar to that as obtained from unconfined compression 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 the required depth.
3. At the other end of the rod just above the surface of the ground a torsion head is used 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 round ends.
5. The first moment of these areas divided by the applied moment gives the unit shearvalue.

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= $(Px)/(2^*.\Pi^*r^2(L+2/3^*r))$

Result:

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

Conclusions:

The vane shear strength of soil is_____________.