Kallam Haranadhareddy Institute of Technology
Chowdavaram, Guntur

GEOTECHNICAL ENGINEERING LAB MANUAL

B.Tech (Civil Engineering)

Prepared

By

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GUNTUR-522019, A.P, INDIA.

KALLAM HARANADHAREDDY INSTITUTE OF TECHNOLOGY

Chowdavaram, Guntur

CERTIFICATE

Roll no.. Certified to be the bonafide Record of GEOTECHNICAL ENGG. Practical work done by Mr./Ms. .... Department of Civil Engineering, Kallam Haranadhareddy Institute of Technology during the academic year...................................

No. of Experiments done and Certified: ....

LAB-IN-CHARGE

LABORATORY INSTRUCTIONS TO THE CANDIDATES:

1. Study the experiment and read in detail aim, apparatus, and procedure of each experiment before coming to the lab. The lab teachers are instructed to take a brief written test/viva of about 5-10 minutes before the commencement of the experiment.

2. After the test, the lab teacher will give instruction to start the experiment. Do the experiment, and note the readings as a group.

3. After you complete the experiment, you have to do the calculations and discussion of results by yourself before leaving the lab.

4. Ensure that lab teacher have checked your results and get the lab mark entered in the report and get their signature.

5. Follow all the safety instructions given by the Lab staff. Kindly wear shoes inside the laboratory.

6. Absenting from the lab will be taken very seriously including fail grade as per rules. No compensatory experiments will be allowed.

7. Tests shall be done in groups. However, observation table, calculation, Discussion of the result, etc should be individual and should be completed on the same day.

8. Return the equipment after the test to the lab teacher and ensure that the lab teacher gives the mark along with his signature.

9. Lab teacher shall supervise the experiment and marks will be awarded based on the participation in the experiments, and the report.

Signature of the Student

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11.		Hydrometer Analysis.		
12.		Consolidation Test.		
13.		Determination of Relative Density of Cohesion less soils.		
14.		Vane Shear Test.		
15.		Unconfined Compression Test		
16.		Differential Free Swell Index Test		

Experiment No. **Date :**

SPECIFIC GRAVITY

Aim : To determine the specific gravity of solids by the density bottle method and pycnometer method.

Apparatus :

Density bottle method : 50ml density bottle with stopper, oven(105^{0}C to 110^{0}C), constant temperature water bath(27^{0}C), vacuum desiccator, vacuum pump, weighing balance, accuracy 0.001g and spatula.

Pycnometer method : Pycnometer of about 1 litre capacity, weighing balance, with an accuracy of 1g, glass rod, vacuum pump.

Theory :

Specific gravity of solids, G_s is defined as the ratio of the mass of a given volume of solids to the mass of an equal volume of water at 4^{0}C. Thus, the specific gravity is given by

$$G_s = \frac{\gamma_s}{\gamma_w}$$

Where, γ_s = unit weight of solids.

γ_w = unit weight of water.

The mass density of water γ_w at 4^{0}C is 1 g/ml or 1000 kg/m^3 or 9.8 kN/m^3. The specific gravity of solids for most natural soils falls in the range of 2.65 to 2.80, the smaller values are for the coarse grained soils. The presence of organic matter leads to very low values. Soils high in iron or mica exhibit high values. The specific gravity of different particles in a soil mass may not be the same. Whenever the specific gravity of a soil mass is indicated, it is the average value of all the solid particles present in the soil mass. In addition to the standard specific gravity as defined, the following two terms related with the specific gravity are occasionally used.

1. Mass Specific Gravity(G_m) – It is defined as the ratio of the mass density of the soil to the mass density of water.

$$G_m = \frac{\gamma}{\gamma_w}$$

The mass specific gravity is obviously less than the specific gravity of solids and is also known as the apparent specific gravity or the bulk specific gravity.

2. Absolute specific gravity – It is defined as the ratio of the mass density of the absolute solids to the mass density of water.

$$G_m = \frac{(\gamma_s)_a}{\gamma_w}$$

The absolute specific gravity is not of much practical use, as it is difficult to differentiate between the permeable and impermeable voids.

Formulae :

Density bottle method :

$$G = \frac{M_2 - M_1}{(M_2 - M_1) - (M_3 - M_4)}$$

Where, M_1 = mass of empty bottle.

M_2 = mass of the bottle and dry soil.

M_3 = mass of the bottle, soil and water.

M_4 = mass of the bottle filled with water only.

Pycnometer method :

$$G = \frac{M_2 - M_1}{(M_2 - M_1) - (M_3 - M_4)}$$

Where, M_1 = mass of empty pycnometer.

M_2 = mass of the pycnometer and dry soil.

M_3 = mass of the pycnometer, soil and water.

M_4 = mass of the pycnometer filled with water only.

Procedure :

Density bottle method :

1. Wash the density bottle and dry it in an oven at 105^0C to 110^0C. Cool it in the desiccator.
2. Weigh the bottle, with stopper, to the nearest 0.001g(M_1).
3. Take 5 to 10g of the oven dried soil sample and transfer it to the density bottle. Weigh the bottle with the stopper and the dry sample(M_2).
4. Add de-aired distilled water to the density bottle just enough to cover the soil. Shake gently to mix soil and water.
5. Place the bottle containing the soil and water, after removing the stopper, in the vacuum desiccator.
6. Evacuate the desiccator gradually by operating the vacuum pump. Reduce the pressure to about 20mm of mercury. Keep the bottle in a desiccator for atleast 1 hour or until no further movement of air is noticed.
7. Release the vacuum and remove the lid of the desiccator. Stir the soil in the bottle carefully with a spatula. Before removing the

spatula from the bottle, the particles of soil adhering to it should be washed off with a few drops of air-free water. Replace the lid of the desiccator and again apply vacuum. Repeat the procedure until no more air is evolved from the specimen.

8. Remove the bottle from the desiccator. Add air-free water until the bottle is full. Insert the stopper.
9. Immerse the bottle up to the neck in a constant-temperature bath for approximately 1 hour or until it has attained the constant temperature.
10. If there is an apparent decrease in the volume of the liquid in the bottle, remove the stopper and add more water to the bottle and replace the stopper. Again place the bottle in the water bath. Allow sufficient time to ensure that the bottle and its content attain the constant temperature.
11. Take out the bottle from the water bath. Wipe it clean and dry it from outside. Fill the capillary in the stopper with drops of distilled water, if necessary.
12. Determine the mass of the bottle and its contents(M_3).
13. Empty the bottle and clean it thoroughly. Fill it with distilled water. Insert the stopper.
14. Immerse the bottle in the constant temperature bath for 1 hour or until it has attained the constant temperature of the bath. If there is an apparent decrease in the volume of the liquid, remove the stopper and add more water. Again keep it in the water bath.
15. Take out the bottle from the water bath. Wipe it dry and take the mass(M_4).

Pycnometer method :

1. Clean and dry the pycnometer. Tightly screw its cap. Take its mass(M_1) to the nearest 0.1g.
2. Mark the cap and the pycnometer with a vertical line parallel to the axis of the pycnometer to ensure that the cap is screwed to the same mark each time.
3. Unscrew the cap and place about 200g of oven-dried soil in the pycnometer. Screw the cap. Determine the mass(M_2).
4. Unscrew the cap and add sufficient amount of de-aired water to the pycnometer so as to cover the soil. Screw on the cap.
5. Shake well the contents. Connect the pycnometer to a vacuum pump, to remove the entrapped air, for about 20 minutes for fine grained soils and for about 10 minutes for coarse grained soils.
6. Disconnect the vacuum pump. Fill the pycnometer with water, about three fourths full. Reapply the vacuum for about 5 minutes, till air bubbles stop appearing on the surface of the water.
7. Fill the pycnometer with water completely, up to the mark. Dry it from outside. Take its mass(M_3).
8. Record the temperature of contents.
9. Empty the pycnometer, clean it and wipe it dry.
10. Fill the pycnometer with water only. Screw on the cap up to the mark. Wipe it dry. Take its mass(M_4).

Field applications :

1. It is used for the determination of void ratio, degree of saturation, and particle size.
2. It is also used to determine the unit weight of solids, and unit weights of soil in various states.

Tabular form :

Density bottle method :

S.No.	Observations and calculations	1	2	3
	Observations			
1.	Density bottle No.			
2.	Mass of empty density Bottle(M_1).			
3.	Mass of bottle and dry soil(M_2).			
4.	Mass of bottle, soil and water(M_3).			
5.	Mass of bottle filled with water(M_4).			
	Calculations			
6.	$M_2 - M_1$			
7.	$M_3 - M_4$			
8.	$G = \frac{M_2 - M_1}{(M_2 - M_1) - (M_3 - M_4)}$			

Pycnometer method :

S.No.	Observations and calculations	1	2	3
	Observations			
1.	Pycnometer No.			
2.	Mass of empty Pycnometer (M_1).			
3.	Mass of Pycnometer and dry soil(M_2).			
4.	Mass of Pycnometer, soil and water(M_3).			
5.	Mass of Pycnometer filled with water(M_4).			
	Calculations			
6.	$M_2 - M_1$			
7.	$M_3 - M_4$			
8.	$G = \frac{M_2 - M_1}{(M_2 - M_1) - (M_3 - M_4)}$			

Model calculations :

Density bottle method :

Mass of empty bottle, M_1 =

Mass of the bottle and dry soil, M_2 =

Mass of the bottle, soil and water, M_3 =

Mass of the bottle filled with water only, M_4 =

$$G = \frac{M_2 - M_1}{(M_2 - M_1) - (M_3 - M_4)}$$

=

Pycnometer method :

Mass of empty pycnometer, M_1 =

Mass of the pycnometer and dry soil, M_2 =

Mass of the pycnometer, soil and water, M_3 =

Mass of the pycnometer filled with water only, M_4 =

$$G = \frac{M_2 - M_1}{(M_2 - M_1) - (M_3 - M_4)}$$

=

Result :

The specific gravity of solids by density bottle method =

The specific gravity of solids by pycnometer method =

Experiment No. **Date :**

CO-EFFICIENT OF PERMEABILITY
(CONSTANT HEAD & VARIABLE HEAD METHOD)

Aim : To Determine the co-efficient of permeability of the given coarse grained soil and fine grained soil.

Apparatus : Permeability meter, scale, measuring jar, stop watch and thermometer, variable head permeability, Vernier calipers.

General Discussion of test :

Soil consist of discrete particles, the void spaces between the particles are interconnected and may be viewed as a highly complex and infinite network of irregular tubes. In a two phase solid liquid system these voids are completely filled by the liquid water in these tubes is free to flow when a particle difference is created in a soil mass. Water flows from zones of high potential to low potential the resistance to flow is much less when soil have large voids i.e. more (or) less regular flow channels. The permeability of a soil is properties which describes quantitatively since permeability directly influences the rate of flow of water in soil.

Formulae :

Constant head method :

$$q = kiA$$

Where, P = hydraulic gradient = h/L.

Q = measured discharge.

t = time required for the discharge to take place.

k = coefficient of permeability.

h = head causing flow.

A = c/s area of the soil through which the flow is taking place.

L = length of the sample.

Variable head method :

$$K = \frac{2.303 \log_{10}(h_1/h_2) \times a \times L}{A(t_2 - t_1)}$$

Where, h_1 = actual head.

h_2 = Final head.

t = time interval.

A = Cross-sectional area of the specimen.

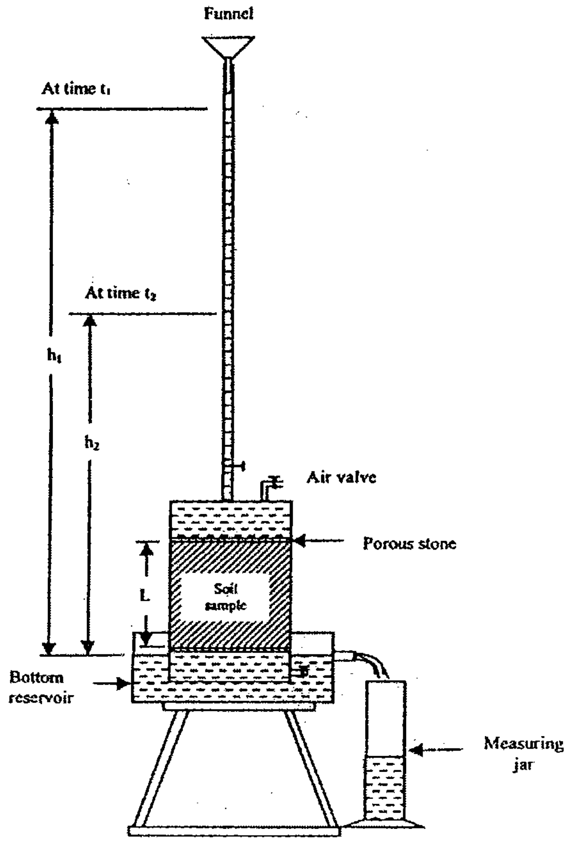
Procedure :

Constant head method :

1. Note dimensions of permeability mould and calculate its volume.
2. Take the required weight of the dry cohesion less soil into the mould to the desired dry density or void ratio. Compact the soil into the mould after fixing the base plate to the mould and place the porous stone.
3. Place a filter paper on the top of the soil and then place porous stone. Fix the top plane which is provided with an inlet valve and air cork.
4. Secure both the base plate and the top plate to the mould with suitable clamp and rubber gaskets to make the entire assembly water tight.

5. Place this assembly in a shallow metal tray with an outlet.
6. Fill the tray with water to submerge the base plate completely.
7. Ensuring that steady state flow condition, take the temperature of water. Repeat the collection of water two or three times for the same interval. Measure the hydraulic head with respect to the tail water level i.e. corresponding to the bottom of the outlet in the tray.
8. Repeat the test three or four times varying the hydraulic head for each trial.
9. Calculate the co-efficient of permeability using the formula, K = QL/hAt cm/sec

Variable Head Method :



Arrangement for variable head test

1. Note dimensions of permeability mould and calculate its volume.
2. For testing an undisturbed soil sample obtain the sample from the sample and weight the mould with the soil. Determine the water content of the sample trimmings.
3. After placing the filter paper and porous stone as mentioned earlier.
4. Attach the top cap to stand pipe tighter that bolt at permeability device to make the assembly water light. Fill the tray with water to submerge the base plate completely.
5. Fill the stand pipe to convenient height and measure hydraulic head (h_1) with respect to fall water level ponding bottom of outlet of the tray.
6. Note the time (t) for head in stand pipe to fall to a height (h_2).
7. Check the saturation of soil by nothing time for same all of head of water. Repeat same procedure until same time is obtained for equal falls in head.
8. Refill the stand pipe and allow the water to run through soil sample and take observations for different falls in head noting the corresponding elapsed times. Take at least four sets of reading with different h_1 & h_2.

<u>Field applications :</u>

1. Co-efficient of permeability is very important property used in determination through earth dams and also in determination of yield of well under confined (or) artesian conditions.
2. The constant head test is generally preferred in respect to granular soils, because it is possible to collect significant discharge in small time duration.

Limitations of test :

1. Falling head method is used for fine grained soils.
2. Constant head method is used for coarse grained soils.
3. The test is valid for undisturbed soils.

Advantages of the test :

1. From permeability test well now particle size as a co-efficient of permeability proportional to small particle size.
2. Structure of soil mass all known.
3. Void ratio of soil known as void ratio is proportional to the permeability.
4. Saturated soil has less permeability than fully saturated.

Precautions :

1. Hydraulic head should be measured with respect to the fall water level corresponding to bottom of the outlet of tray.
2. Reading should be taken without parallax error.
3. In constant method, remove all the air with the help of the air cork provided on the plate.

Code of reference :

IS:2720(xvii) – 1986 – test for soils – determination of permeability(variable head 1992).

IS:2720(xxxvi) –1987 – test for soils – determination of permeability(constant head 1992).

Tabular Form :

Variable head method :

SI. No.	Head		Readings for time (t)		Permeability (cm/min)	Permeability (cm/sec)
	Initial	Final	t_1(sec)	t_2(sec)		
1						
2						
3						
4						

Constant head method :

SI. No.	Time (seconds)	Quantity of water collected, Q (ml)	Head h (cm)	Discharge q=Q/t	Permeability k Cm/sec
1					
2					
3					
4					

Observations :

Variable head method :

Diameter of the mould, D =

Area of the mould, A = $\pi/4 \times D^2$ =

Length of the mould, L =

Volume of the mould, V =

Cross-sectional area of stand pipe, a = $\pi/4 d^2$

=

Constant head method :

Length of the mould, L =

Diameter of the mould, D =

Area of the mould, $A = \pi/4 \times D^2$ =

Volume of the mould, V =

Model Calculations :

Variable head method :

Initial head, h_1 =

Final head, h_2 =

Area of mould, A =

Cross-sectional area of stand pipe, a =

Length of mould, L =

Time elapsed, $t = t_2 - t_1$ =

Permeability $K = \frac{2.303 \log_{10} (h_1/h_2) \times a \times L}{A(t_2 - t_1)}$

K =

Constant head method :

Time elapsed =

Quantity of water collected =

Head =

Length of mould, L =

Discharge, q = Q/A=

Permeability, K =

K =

Comments :

1. Although small sample used in laboratory all assumed to be representative of the field conditions it is different to duplicate the institute structure especially of granular deposits.
2. Migration of fine is testing sand silts may be affect the measured value.
3. To determine the cross-section area of stand pipe, close the inlet tube and pour the known volume of 10cc of water exactly measured by means of pipe in a stand pipe and note the rise of water level in it. The coarse section area of the stand pipe is a volume of water.

Result :

Co-efficient of permeability of fine grained soil for Constant head method, k =

Co-efficient of permeability of coarse grained soil for variable head method, k =

Experiment No. **Date :**

DETERMINATION OF FIELD DENSITY

Aim : To determine the field density of soil by

i) core cutter

ii) method and Sand replacement method.

Apparatus :

Core cutter method : Core cutter, dolly, hammer, spatula, tray, moisture can, trowel.

Sand replacement method : Sand pouring cylinder, cylindrical calibrating can, metal tray with a circular hole, excavating tools like trowel, crow bar, plane plate, moisture cans, uniformly graded natural sand for replacement, oven, desiccator.

Formulae :

Core cutter method :

$$\rho_d \text{ (g/c.c.)} = \rho/1+w$$

Sand replacement method :

$$\rho_d \text{ (g/c.c.)} = \rho/1+w$$

Where, ρ_d = dry density of soil

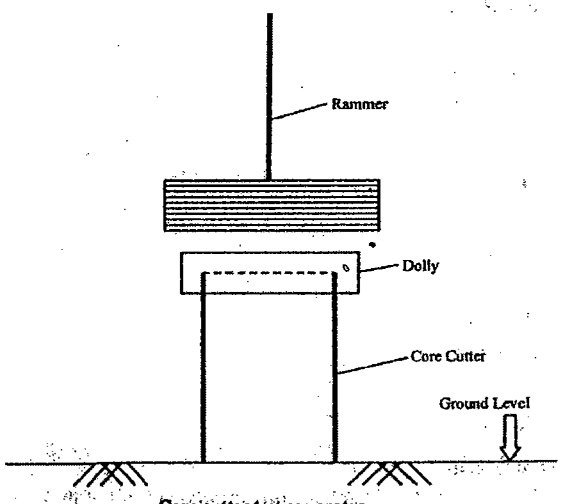
ρ = average bulk density of soil.

W = water content in soil.

Theory :

Core-Cutter Method :

1. A cylindrical core cutter is a steel tube of internal diameter 10 cm and height of 13 cm.
2. For determining the ρ_d of soil, the cutter is proceed into soil.
3. The weight of soil in the cutter is determined.



Core cutter test apparatus

4. The dry density is obtained as $\rho_d = \gamma/1+w = \frac{M/v}{1+w}$

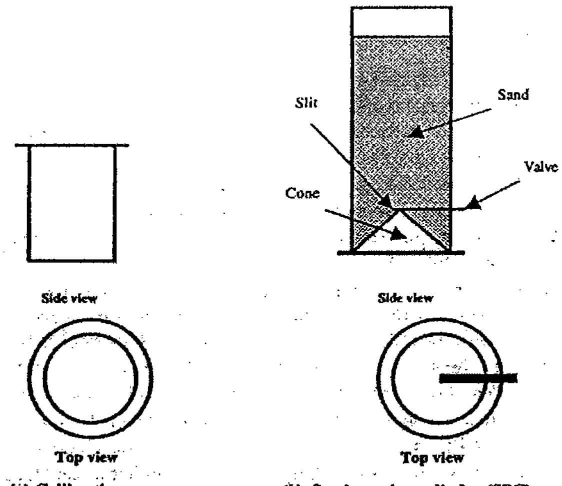
Where, M = mass of soil in the core cutter.

v = internal volume of cutter.

W = water content.

Sand Replacement Method :

1. A hole of specified dimensions if excavated in the ground and mass of excavated soil is determined.
2. The volume of hole is determined by filling it with clean, uniform land whole dry density is determined separately by calibration.



(a) Calibrating can (b) Sand pouring cylinder (SPC)

Calibrating can and sand pouring cylinder

3. The volume of the hole if equal to the mass of land filled in the hole divided by it dry density.
4. The dry density of the excavated soil is determined as

$$\rho_d = \gamma/1+w = \frac{M/v}{1+w}$$

Where, M = mass of excavated soil.

v = internal volume of the hole.

W = water content.

Procedure :

Core – cutter method :

1. Measure the dimensions of the cutter by using scale and calculated volume of core-cutter by using the $V_c = \pi d^2 h/4$
2. Now more the field and drive the core cutter into soil an uniform land.
3. The dolly is placed over the cutter while driving to prevent damage to the edges of cutter.

4. When the cutter is just at least of ground, the cutter with soil is then dugout from ground, and any soil excluding from its end is trimmed off so that the container contains volume of just equal to its internal diameter.
5. Weigh the core cutter, wet weight soil and find out the wet weight of soil.
6. By knowing the wet weight and volume of wet soil, Bulk density can be found.
7. In the field take some amount of soil into the soil and find the weight of soil.
8. Take a sample into the container and kept in oven for 24 hours and take the dry weight.
9. By subtracting the weight of container. We can get the dry weight of soil.
10. By subtracting. So we can find out the water content of soil.
11. Dry density of soil is calculated by using ,

$$\rho_d = \text{Average bulk density}/1+w$$

<u>Sand replacement method :</u>

1. The sand is used in the method is preferably a material passing through 1mm and retained on 600μ sieve.
2. Find the sand pouring cylinder with sand and weight it let it be w.
3. Keep the cylinder as the glass plate carefully. Remove the lid and open the shutter. Sand falls down and in the front of conical portion and now find the weight of the cylinder.
4. Now find the land filling in the conical portion.
5. Take calibrating can and measure its height and diameter.
6. Now we can find the volume of conical sand, $V_c = \pi d^2h/4$
7. Keep the cylinder on the calibrating can carefully remove the lid and open the shutter sand is slowly running down into can. When

land completely fills the can and conical portion it stops. Running down and its weight is determined.

8. Weight of sand filling the calibrating can

$$W_{sand} = (W_2 - W_3) - (W_1 - W_2)$$

9. Knowing weight and volume, density of calibrating sand can be calculated by using the formula.

$$\rho_{sand} = W_{sand} / V_{can}$$

10. Fill the sand into the cylinder and weigh it.
11. Make a hole of 10cm diameter and it is used to find out of the density of soil.
12. Weight of soils which is removed from hole and fills the hole with sand and it is used to find the volume.
13. Find out the volume of hole by weigh the cylinder and mass per density given the volume.
14. The bulk density of soil is calculated by

$$\gamma_b = \frac{\text{Wt. of soil excavated from pit}}{\text{Vol. of pit}}$$

15. Take a can and fill with soil and weigh it.
16. Weight of water is calculated by subtracting dry wt. to the wet weight.
17. The dry density of soil is calculated by using the formula

$$\rho_d = \rho/1+w$$

Field Applications (By both methods):

1. Estimation of amount of soil required for placing and compaction certain fills or embankment.
2. When compacted fills are constructed it is an usual practice to .

   determine the field density of soil after placement, to make sure whether the compaction applied was enough or not.

3. It is also used to avoid settlement of huge structures when density of soil was not enough to support it. This is done by increasing the density by using vibrations.

Limitations :

1. Core cutter method is suitable for soft, fine-grained soils but cannot be used on stony, gravelling soils.
2. Core cutter method finds application at places where the surface of soil is exposed and the cutter can be easily driven.
3. Core cutter method is suitable for soft cohesive soils and impracticable for stiff clays, sandy soils and soils containing gravel particles, which may damage the cutting edge.
4. In sand replacement method, for good results the sand used should be uniform, dry and clean which passes through a 600 micron sieve and retained on a 300μ sieve.
5. The sand replacement method gives accurate results in measurement of volume of hole when height of sand column in the cylinder is kept approximately same as in calibration test.
6. Depth of hole should be equal to calibrating container.

Advantages :

1. Core cutter method and sand replacement methods are made up of simple apparatus and easy to work with.
2. It does not need any type of power supply for its working expect during oven drying.
3. They give precise results as they deal with standard containers.
4. Depending on the value we get to know how dense is the soil and what load it can bear without settlement.
5. Depending on the dry density so many character determining features such as void ratio, porosity and degree of saturation can also be known.

6. Sand replacement method has a wide application for soils of various particle signs, from fine grained to coarse grained.

Scope of errors and correction of errors :

1. Bulk density varies considerably for a dry and moist sample. So, to take the dry density we should take an absolutely dry sample. This corrects the error due to presence of moisture during calculation of dry density.
2. Gradation of and has a great impact on the density. Closely graded sand gives best results.
3. The density decrease with decrease in depth of calibrating container and as level of sand decreases in cylinder so the hole excavated should be of same height and diameter as the calibrating container. This is to avoid the error due to compaction by falling from a certain height.
4. As the density of soil differs from time to time and place to place its error is made negligible by taking number of observations.

Observations :

Table-1:

Diameter of core cutter =

Depth of core cutter =

∴ Volume = π x

Weight of empty core cutter, W_1 =

Weight of soil + core cutter, W_2 =

Weight of wet soil ($W_2 - W_1$) =

Wet unit weight of soil,

$$\gamma_{wet} = \frac{\text{Weight of the soil}}{\text{Volume of soil}} =$$

Table-2 :

Moisture Content Determination :

Bin Identification No :

Empty weight of bin, W_1=

Weight of bin + wet soil, W_2=

Weight of bin + dry soil, W_3=

Weight of water (W_2- W_3) =

Moisture content, m (W_2- W_3/ W_3- W_1) =

Dry unit weight $\gamma_{dry} = \gamma_{wet} / (1+m)$ =

Weight of dry soil (r_d) (W_3- W_1) =

Void ratio, $e = (G_s \gamma_{wet} / \gamma_{dry}) - 1$ =

Degree of saturation, $S = m G_s /e$ =

Table-3 :

Calibration of Unit weight of Sand :

Volume of the calibrating container, V =

Weight of SPC + Sand, W_1 =

Weight of SPC + Sand, W_2 =

(after filling conical portion on a flat surface)

Weight of SPC + Sand, W_3 =

(after filling calibrating can)

Weight of Sand required to fill cone, $W_c = W_1 - W_2$

Weight of Sand required to fill cone & can $W_{cc} = W_2 - W_3$

Weight of Sand in calibrating can = $W_{cc} - W_c$

Unit weight of sand, $\gamma_{sand} = (W_{cc} - W_c)/v$

=

Table-4 :

Determination of Unit weight of soil :

Wt.of SPC after filling the hole & Conical portion, W_4 =

Weight of Sand in the hole and cone, (W_3-W_4) =

Weight of Sand in the pit, $Wp = (W_3-W_4)-W_c$ =

Volume of sand required to fill the pit, $V_p = W_p/\gamma_{sand}$ =

Weight of the soil excavated from the pit, W =

Wet unit weight of the soil = W/V_p =

Dry unit weight of the soil $\gamma_{dry} = \gamma_{wet} /(1+m)$ =

Void ratio of soil (e) = $\gamma_w G_s/(\gamma_{dry})-1$ =

Degree of saturation (S) = $m G_s /e$ =

Code of reference :

IS:2720(part xxix) – 1975 – methods of test for soils – determination of dry density of sand by core cutter method.

IS:2720(part xxviii) – 1974(first version) – methods of test for soils – determination of dry density of sand by sand replacement method.

Result :

Density of calibrated sand =

Bulk density of the soil =

Comments :

1. Verification of the dry density and moisture content not only for the compacted earth fills but also for natural soil.
2. In the determination of vertical over burden pressure and lateral pressure, we need field density of soil.

Experiment No. **Date :**

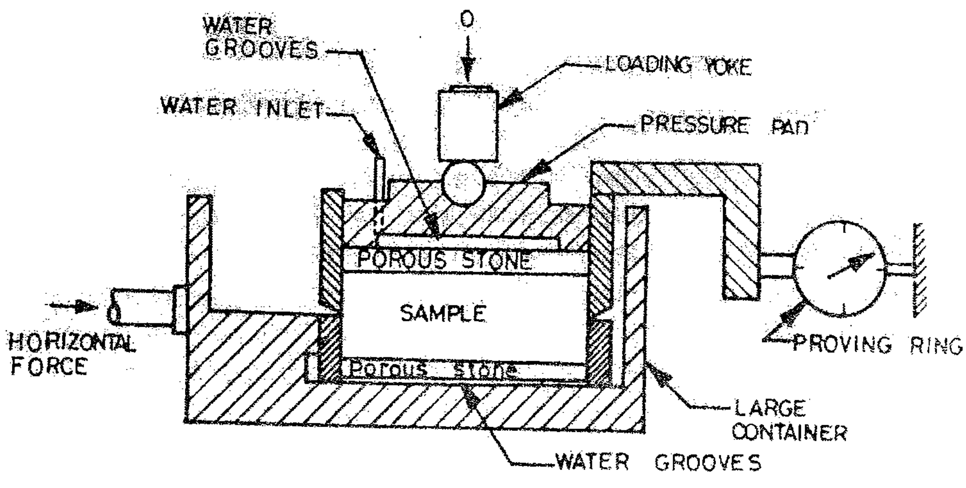
DIRECT SHEAR TEST

Aim : To determine the strength parameters of the given cohesion less soil by conducting the shear box test.

Apparatus : Shear box divided into two halves by horizontal plane and filled with locking and spacing screws, box container to hold the shear box, base plate, grid plates, porous stones, loading pad, loading yoke, loading frame, proving ring, dial gauges, static or dynamic compaction device, spatula, balance.

General discussion on test :

The apparatus consists of shear box, 6cmx6cm in size which is repeated horizontally into two halves. One half is fixed while the other half can move horizontally. A normal load is applied to the soil in the shear box through a rigid loading cap.



Direct Shear Test.

Procedure :

1. Place the gripper plate at the bottom of the box with the grooves on the specimen side and perpendicular to the direction of the movement of the movable half of the shear box. Place the pin in the shear box so, that the half in the box does not move while filling the box and compacting the soil in it.
2. Place the sample in the shear box. For this take some amount of granular soil and weight. Divide it into three parts and fill in the shear box with the soil in three layers, tamping each layer. The final thickness of the compacted specimen should be 2 cm.
3. Place the other plate with groove facing the soil specimen and in a direction perpendicular to the direction of movement.
4. Place the horizontal deformation measuring dial gauge with the spindle touching the moving half of the shear box.
5. Adjust the proving ring dial gauge to measure the shearing load. Note the initial readings of the proving ring dial gauge.
6. Shear the soil specimen after removing the pin form the shear box. Note the reading the proving ring dial gauge and the deformation dial gauge. Corresponding to different percentage strains until failure of the specimen.
7. Repeat the test with three or four normal loads every time with a different soil specimen. Compacted to the same initial dry density in dry weight and volume of the soil being kept constant.
8. Draw the stress-strain graph for samples tested under different normal stresses. The peak value of the shear stress is obtained from the graph.
9. Draw a plot between the normal stresses and the shear stress as the abscissa and the ordinate respectively. This will yield a straight line. If the soil has cohesion there will be an intercept on the shear stresses axis. This gives the magnitude of cohesion.

Importance of the test :

Safety of foundations and stability of slopes and retaining walls depending upon the shear strength of the soil. The shear strength equation of soil is known as mohr-coulomb equation that reads.

$$s = c + \sigma \tan\theta.$$

Where, s = shear strength in kg/cm^2

c = cohesion in kg/cm^2

σ = normal stress on the plane of shear in kg/cm^2

ϕ = angle of internal friction in degree.

Cohesion (c) is dependent on the water content and is due to the inner-particles forces. This is independent of the normal stress on the plane of shear or plane of failure. The angle of internal friction (ϕ) is dependent on the normal stress on the plane of failure.

This is similar to sliding friction in solids. In case of clear dry sand the cohesion term is equal to zero. Direct shear test is the simplest and the easiest test for dry cohesion less test.

Field applications :

1. Shear strength is the principal engineering property which controls the stability of a soil mass under loads.
2. It governs the bearing capacity of soils, the stability of slopes in soils, the earth pressure against retaining structures and many other problems.
3. All the problems of soil engineering are related in one way or other with the shear strength of soil.

Advantages of the test :

1. Stress conditions are known only at failure. The conditions prior to the failure are indeterminate and therefore the mohr circle can't be drawn.
2. The stress distribution on the failure plane is not uniform the stresses are more at the edges and lead to the progressive failures.
3. The area under shear gradually decreases as the test progresses. But the corrected area can't be determined and therefore the original area is taken for the computation of stresses.
4. The measurement of pore water pressure is not possible.
5. The test is not recommended for conditions other than "Fully-drained".

Disadvantages :

1. Drainage conditions cannot be controlled.
2. Pore water pressure cannot be measured.
3. It is not much use for fine-grain soils where drainage conditions play an important role influencing shear strength.
4. The test is not recommended for conditions other than "Fully-drained".

Scope and correction of errors:

1. The teeth of the grid plates should be parallel to the perforations on the porous plate.
2. The loading frame should be so arranged such that its centre should exactly coincide with the centre of the box.
3. Loads should be applied gradually.
4. Exact failure point of the soil should be identified.

Observations :

SI. No.	Normal stress kg/cm^2	Dial gauge Reading D (cm)	Shear Load (Dx0.0471)	Shear stress kg/cm^2
1				
2				
3				
4				
5				
6				

Model calculations :

Proving ring reading =

Shear load =

Area of the specimen =

Normal stress =

Shear stress = $\frac{\text{Shear Load}}{\text{Area}}$

=

Graph :

The failure envelope is obtained by plotting the points corresponding to shear strength at different normal stresses and joining them by a straight line.

The inclination of the failure envelope to the horizontal gives the angle of shearing resistance ϕ and its intercept on the vertical axis is equal to the cohesion intercept C.

From graph

According to coulomb's equation

$$S= c+\tan\phi$$

Where, S = shear strength in kg/cm^2

c = cohesion in kg/cm^2

σ = Normal stress on the plane of shear kg/cm^2

ϕ= Angle of internal friction in degrees

Eq. is in the form y =mx + c

C=cohesion in kg/cm^2, m=tanϕ.

Result from graph :-

Cohesion (c) =

Angle of internal friction (ϕ) =

Experiment No. **Date :**

TRIAXIAL COMPRESSION TEST

Aim : To Determine Shear Strength parameters of the given soil sample by conducting "Triaxial Compression Test".

Apparatus :

1. Triaxial testing machine complete with Triaxial cell.
2. Water pressure unit with hand pump.
3. Providing Ring.
4. Dial gauge.
5. Rubber Membrane.
6. Membrane Stretcher.
7. Sample trimming apparatus.
8. Bins for moisture content determination.
9. Balance and Box of weights.
10. Drying oven.

General Discussion of Test :

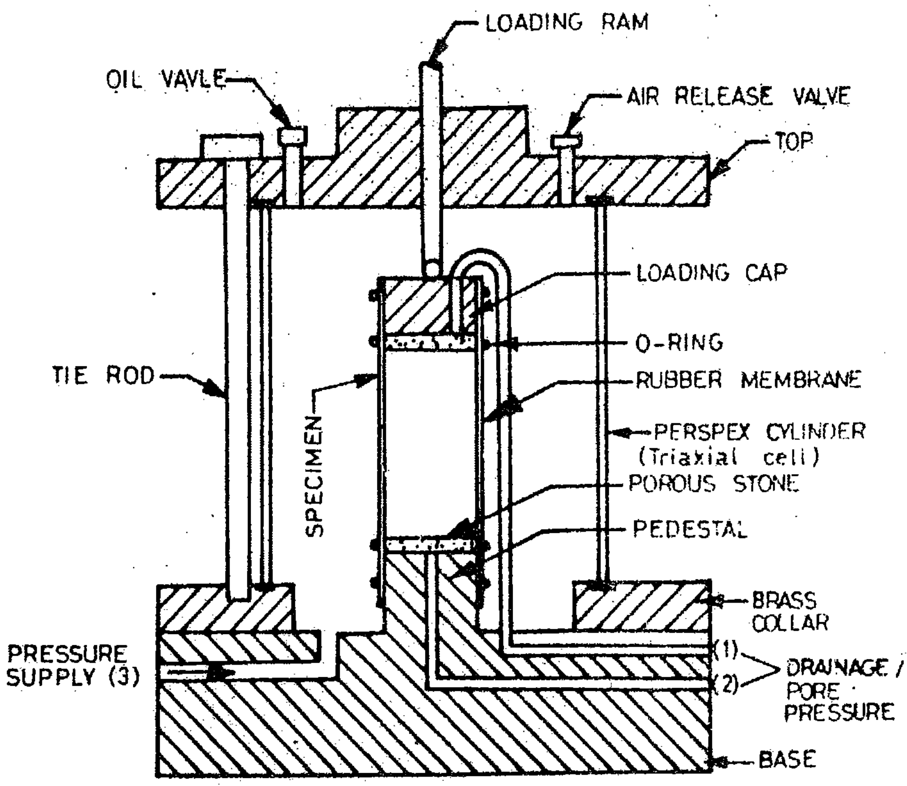
1. Casagrande developed the tri-axial test in the course of his research aimed at removing the disadvantages of direct shear test.
2. The test is carried out in a cylindrical specimen of soil, usually having a length to diameter ratio of 2.
3. The usual sizes are 76mmx38mm and 100mmx50mm. The main features of the tri-axial test assembly are shown in fig.

Theory:

1. The tri-axial compression test consists of two stages. The application of equal all round pressure on the specimen constitutes the first stage of the test.
2. Depending upon the drainage conditions permitted during the above two stages, tri-axial test can be classified as follows:
   i)Unconsolidated and undrained test(Q – test).
   ii)Consolidated undrained test(R – test).
   iii)Consolidated drained test(S – test).

Procedure :

1. Trim or prepare the soil specimen for 76.2mm long and 38.1mm in diameter. Note the weight of specimen (w_1).
2. The specimen is then enclosed in a 38.1mm diameter and about 100mm long rubber membrane using a membrane stretcher.
3. Use non porous stones on either side of specimen as neither any pressure is not to be measured nor any drainage of neither air nor water is allowed.
4. Remove the porous cylinder from its base removing the bottom fly nuts.
5. The specimen along with the non-porous plate on either side is centrally placed over the pedestal. The specimen is checked for its vertically and co-axially with the cylinder chamber.
6. The chamber along with the loading plunger is carefully placed over its base without disturbing the soil specimen. The cylinder is then attached to the base plate tightly by means of tightening the nuts.
7. The water storage cylinder is filled with water completely and its top is then closed by means of a value. Necessary pressure is built up in the cylinder by working the hand pump. The cylindrical chamber is allowed to be filled up completely.



Triaxial Tes Apparatus.

8. Adjust the deformation dial gauge reading to zero.
9. Record the initial readings of providing ring and compression dial gauge.
10. The vertical load is applied to the specimen by starting the motor at the loading frame the change in the providing ring dial gauge gives the measure of the applied load. The deformation dial gauge gives the deformation in the soil specimen which can be used to complete strain in the soil.
11. Take the readings of providing ring dial gauge at 0.5, 1.0, 1.5, 2.0% strain and every 1.0% strain thereafter up to failure or 20% strain whichever is earlier.
12. After the specimen is failed (a) stop the application of load (b) disconnect the chamber from water storage cylinder by closing the linger value (c) open the airlock knob a little (d) open the value to drain out the water in the cylinder.

13. After water is completely drained out, take out the cylinder from loading frame carefully.
14. Wipe of the rubber membrane dry and find its weight (w_2) that should be same as (w_1).
15. Repeat the test with three samples subjected to three differential lateral pressures of 0.5, 1.0 and 1.5kg/cm^2.

Field applications:

1. The purpose of tri-axial compression test is to determine the strength parameters, C and ϕ of the given cohesive soil specimen.
2. Strength parameters are very important in the calculation of safe bearing capacity of foundation analysis of stability of slopes, calculation of earth pressure, etc.
3. Safety of foundations and the stability of slopes and retaining walls depend upon the shear strength of soil.

Limitations :

1. The test is very cumbersome.
2. The test attains at different timings for different type of Soils, i.e. the time of consolidation.

Code of reference :

IS:2720(part xi) – 1993 – shear strength parameters(without pore water pressure).

Model Calculations :

For 1% of axial strain i.e., dial gauge reading =

Corrected area $A_c = \frac{A}{1 - t} =$

where A = Area of the specimen

t = % of axial strain

$A_c =$

For specimen-I

Load = Division x 0.225 = x 0.225 = kg

Stress(σd) = Load / Corrected Area = = kg/ cm^2

For specimen-II

Load = Division x 0.225 =

Stress(σd) = Load / Corrected Area =

Graph : A graph is drawn between deviator stress (on y-axis) and axial strain (on x-axis) to obtain the peak point of the stress with the maximum deviator stress for each specimen plot "Mohr's Circles" for the three test.

Results from the Graph :

For specimen-I

($\sigma 3$) =

($\sigma 1$) = $\sigma 3 + \sigma d_1$ =

For specimen-II

$(\sigma 3) =$

$(\sigma 1) = \sigma 3 + \sigma d_2 =$

Result:

For the given soil sample, cohesiveness, C =

Angle of shearing resistance =

Observations : 1. Diameter of sample = 3.81cm 2. Height of the sample = 7.2cm

3. Area of the sample = 11.39 cm^2 4. Providing ring constant = 0.225.

S. No.	Axial Strain	Dial gauge Reading	Corrected Area	Specimen-I			Specimen-II			Specimen-III		
				Divi-sion	Load (Kg)	σc Kg/ cm^2	Divi-sion	Load (Kg)	σc Kg/ cm^2	Divi-sion	Load (Kg)	σc Kg/ cm^2
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												

Experiment No. **Date :**

CALIFORNIA BEARING RATIO (CBR) TEST

Aim : To determine unsoaked California Bearing Ratio (CBR) of the given soil sample.

Apparatus :

1. Loading Frame.
2. CBR Mould (150mmϕ and 175mm height) with detachable extension collar.
3. Annular weights each of 2.5 kg.
4. Compaction hammer having wt. of 4.89kg with a drop of 450mm.
5. Spacer disc 50mm ht, 150mm Diameter.
6. Penetration plunger.
7. Tray to mix soil.
8. Calibrating measuring Jar.
9. Two dial gauges, accuracy 0.01mm.
10. Cutting collar.
11. I.S. sieves, 4.75mm and 20mm.

Formulae :

Percentage of unsoaked CBR (for 2.5mm penetration depth) $= \frac{X1}{1370} \times 100.$

Percentage of unsoaked CBR (for 5mm penetration depth) $= \frac{X2}{2055} \times 100.$

Where, X1 and X2 are the penetration loads at

2.5mm and 5mm respectively obtained from graph.

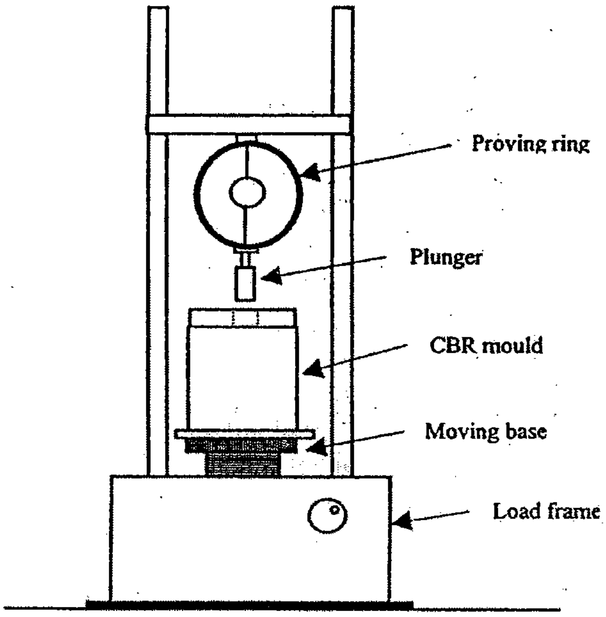
General discussion of test :

1. CBR is the Ratio of force per unit area required to penetrate a soil mass with a standard circular piston of 1875mm^2 Cross sectional Area at the rate of 1.25mm / minute to that required sample.
2. The strength of the sub grade is an important factor in the determination of the thickness required for flexible pavement. It is expressed in terms of CBR.
3. It is determined by an empirical penetration test devised by the California State Highway Department(USA).
4. The standard material is the crushed stone and the load on it which has been obtained from the test is the standard load.
5. The CBR value is usually determined for penetration of 2.5mmand 5mm. Generally, the CBR for 2.5mm penetration is high.
6. CBR test is usually carried out in the laboratory either on undisturbed samples or remoulded samples, depending upon the condition in which the sub grade soil is likely to be used.

Theory :

1. The apparatus consists of a cylindrical mould 150mm inside diameter and 175mm height.
2. It is provided with a detachable metal extension collar 50mm in height and a perforated base plate 10mm thick.

3. One annular weight and several slotted weights weighing 24.5N(2.5kg) each 147mm diameter with a central hole 53mm in diameter are used for the necessary surcharge pressure.



CBR test arrangement

4. I.S. sieves(20mm and 4.75mm) and other general apparatus such as mixing bowl, straight edge, scales soaking tank or pans are required.
5. A loading machine of capacity 50N(5000kg approximately) in which the rate of displacement of 1.25mm/min can be maintained is necessary.
6. Dynamically compacted specimens may be obtained by using standard metal rammer in accordance with IS:2720(part vii) - 1983 – determination of water content –dry density relation using light compaction (or) IS:2720 (part vii) – 1983 – determination of water content – dry density relation using heavy compaction.

7. In both the cases of compaction, if soaking of the sample is required, representative samples of the material shall be taken both before and after compaction for the determination of water content.
8. If sample is not to be soaked, representative material after the penetration shall be taken for the determination of water content.

Procedure :

1. Take 4.5kg oven dry soil sample and add required quantity of water (so as to obtain OMC) to the soil and mix it thoroughly.
2. Fit the cylindrical mould with extension collar and Base plate. Insert Spacer disc over base plate.
3. The well mixed soil is then compacted in the mould in five layers and each layer receives 55 blows.
4. Remove the collar and trim the soil to the size of the mould.
5. Place surcharge weight to produce on intensity of loading.
6. Seat the penetration piston at the centre of specimen with the smallest possible load. Apply the loads on the penetration piston so that the rate of application is 1.25mm/minute.
7. Load readings shall be recorded at plunger penetration values of 0, 0.5, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 7.5, 10.0, 12.5mm.
8. After taking the readings unload the specimen and detach the mould from the loading frame.
9. Collect about 50gm of Soil sample from the top layer of the specimen and determine moisture content.

Observations :

1. Diameter of mould $d(c_m)$ =
2. Height of the mould $h(c_m)$ =

3. Volume of the mould $V(c_m)$ =
4. Weight of the mould $w_1(g)$ =
5. Providing ring reading constant =

Tabular form :

Dial Gauge reading	Penetration mm	Proving Ring Reading	Load (Kg) P x 6.14
0			
50			
100			
150			
200			
250			
300			
350			
400			
450			
500			
550			
600			
700			
800			
900			
1000			
1100			
1200			

Calculations :

1. CBR% at 2.5mm penetration = $\frac{\text{Load at 2.5mm penetration x100}}{1370}$

=

2. CBR% at 5.0mm penetration = $\frac{\text{Load at 5mm penetration x 100}}{2055}$

=

Field applications :

1. CBR values are useful in estimating the thickness of flexible pavements.
2. Based on the CBR values of sub-grade and on the traffic volume one can design the thickness of flexible pavements.

Limitations :

1. CBR test is essentially an arbitrary strength test and hence cannot be used to evaluate soil properties like cohesion or angle of internal friction or shearing resistance.
2. Presence of coarse grained particles would result in poor results.

Graph : A load penetration curve is plotted by penetration on x-axis and load on y-axis

Correction :

Due to surface irregularities of the sample the initial portion of curve may be concave upwards a correction shall then be applied by drawing a tangent to the curve at the point of greatest slope.

Code of reference : The code of reference for laboratory determination of CBR is IS:2720(part xvi)-1965.

Result :

CBR% at 2.5mm penetration =

CBR% at 5mm penetration =

Experiment No. **Date :**

SIEVE ANALYSIS

Aim : To determine uniformity co-efficient (c_u) & co-efficient of curvature (c_c) of soil particles of given soil sample.

Apparatus : Sieves, Sieve shaker, weighing machine.

General Discussion of test :

Grain size analysis of coarse-grained soil is carried by sieve analysis. Sieves are wire screens having square openings. According to IS 460-1962, the sieve number is the mesh width expressed in mm for large sizes and in microns for small sizes. i.e., a sieve with a mesh opening of 4.75mm is designated as a 4.75mm sieve and 500μ sieve refer to a sieve with a mesh opening of 0.50mm. It must be mentioned in this test that when we say grain size or diameter of a particle which is far from being a sphere in shape. What we mean is an "Equivalent diameter" of the particles as determined by the sieve analysis.

Theory :

Grain size distribution or the percentage of various sizes of soil grains present in a given dry soil sample is an important soil grain property. In grain size analysis, we determine the relative proportions of the different grain sizes that constitute a given mass.

This is accomplished by obtaining the quantity of material passing through the apertures of a given sized sieve but retained on a sieve of smaller sized apertures. The weight of the quantity of the soil retained on any sieve with reference to the overall wt. of the soil sample taken for analysis, and is expressed as percentage is termed as percentage finer. For the purpose of determining the prop. of soil retained or passing through sieve of different apertures.

Procedure :

1. In dry sieve, a suitable quantity of pulverized dry soil of known weight (about 500gm) is taken sieved through a selected set of sieves.
2. The sieves arranged according to their sizes, with the largest aperture sieve at that the top and smallest aperture sieve at the bottom.
3. Take the following set of sieves and stack them one over the other in the order of arrangement are given 4.75mm, 2.36mm, 1.18mm, 600μ, 300μ, 150μ, 75μ.
4. Place the soil in the top sieve with the receiver lid and transfer the set of sieve with the pan at the bottom. The sieve the soil to some extent.
5. The amount of shaking depends upon the shape and no. of particles.
6. Remove the stack of sieves from the shaker and then calculate the weight of material retained on each sieves..
7. Compute the percentage retained on each sieve by dividing the weight retained on each sieve by the original weight of the soil sample taken for analysis.
8. Complete the percentage of finer by starting with 100% and subtracting the percent retained on each sieve as a cumulative.
9. Draw a graph between the percentage fineness drawn to natural scale on y-axis and the particle (aperture) size drawn to logarithmic Scale on x-axis.

Field Applications :

The grain size analysis is universally used in the engineering classification of the soils. In addition to this, test is also used for suitability criteria of soils which are used for road and air field, construction, dam and other embankment construction and design of filters for earth dams are based partly on the results of grain size analysis.

Limitations of test :

1. This test does not conducted for wet soils i.e. which are taken from the underground. This test will be conducted for such type of soils after they are kept in oven for 24 hours.
2. This test is useless in case of flaky and needle shaped particles.

Advantages of the test :

From grain size analysis, we draw a graph between the sieve size and the percentage of finer by weight. From this, we get uniformity co-efficient(C_u) and co-efficient of curvature (C_c) which is useful in construction of roads and construction of sound filters etc. And also from this test, we know that whether the soil is poorly graded (or) well graded in poorly graded soil the void content is more and in well graded soil the void content is less.

Scope of errors :

1. The finer grains of soil carry charge on their surface and have a tendency for floc formation. A floc is an accumulation of small particles. The flocs then settle. Thus, if the tendency of small particles floc formation is not prevented, the diameter measured will be the diameter of the floc and not of the individual grain.
2. And also, the error is obtained due to manual sieving without lid on top sieve from which soil particles are skipped out (or) sieve shaker also used.

Correction for error :

1. To prevent the floc formation, the soil is treated with some deflocculating agent, such as sodium hexameta phosphate or sodium oxalate.
2. Also manual sieving is done carefully.

Table: Division of soil fraction on the basis of grain sizes.

Boulder	Pebble	Coarse grained soils					Fine grained soils silts & clay size
		Gravel		Sand			
		Coarse	Fine	Coarse	Medium	Fine	
300	80	20	4.75	2.00	0.425	0.075	<0.075mm >200 microns

For well-grades samples

$C_u>4$ for gravels

$C_u>6$ for sands.

If the above criteria are not met, then the sample is termed as poorly graded.

Code of Reference :

The code of reference for grain of analysis is IS: 2720 (part 4)-1985-division of soil fraction on the basis of grain sizes.

Tabular Form :

S. No.	Sieve size	Amount of soil retained (gm)	Percentage of soil retained	Cumulative percentage of soil retained	Percentage of finers
1	4.75				
2	2.36				
3	1.18				
4	600μ				
5	425μ				
6	300μ				
7	150μ				
8	75μ				
9	Pan				

Calculations :

If we draw a graph, between % of finer and the sieve size on semi log graph, then we obtain the values of D_{10},D_{30},D_{60}.

Hence, D_{10} is the diameter of sieve size corresponding to 10% finer than that size and then

Co-efficient of Uniformity $C_u = \frac{D_{60}}{D_{10}}$

=

Co-efficient of curvature $C_c = (D_{30})^2 / (D_{10} \times D_{60})$

=

C_c =

Result from Graph :

By drawing graph between percentage finer and sieve size we get the values of D_{10}, D_{30}, D_{60}. From this we calculate C_c, C_u values. For well grades soil.

$C_u > 4$ for gravels and

$C_u > 6$ for sands also.

C_c must be in between 1&3 for both. If the above criteria are not met, the soil may be termed as poorly graded.

For air soil sample, according to C_c and C_u Values the soil may be termed as poorly graded.

Comments :

From the grain size distribution curve, grain sizes are $D_{10,}$ D_{30} and D_{60} are obtained. Here OC represents the grain size and subscript (10, 30, and 60) denotes percentage of finer. Thus D_{10} = mm, indicates the diameter of the particle corresponding to 10% finer (or) in other words 10% of the sample has grains smaller.

Result :

Co-efficient of uniformity of given sample, C_u =

Co-efficient of curvature of given sample, C_c =

Experiment No. **Date :**

CONSISTENCY LIMITS – ATTERBERG LIMITS

Aim : To determine the liquid limit and plastic limit for a given sample.

Apparatus : Casagrande's liquid limit apparatus, Grooving tools with the both sides standard and ASTM types, Oven, Evaporation dish and glass sheet, Spatula, 425µ IS sieve, Weighing balance accuracy 0.01g, wash bottle.

General discussion of test :

The liquid limit apparatus consists of a brace cup which drops through a desired height on a hard rubber base. The brace cup can be raised and lowered to fall on the rubber base with the help of a cam operated by a handle. The height of all can be adjusted with the help of adjusting groove screw. To make a standard groove in the soil. Two types of grooves are available one is "ASTM" grooving tool which is better suited for soils which are sandy or silty and have low liquid limits. The other tools is the "Casagrande" grooving tool, which has the advantage of extending to control of depth of the soil parts in the cup.

Theory :

Liquid limit is defined as the water content at which a standard groove made in a part of soil placed in the cup of a standard liquid limit device, closed area over a distance of about 13mm when the cup drops 25 times from a height of 10mm on hard rubber base.

Plastic limit may be defined as the water content at which a thread made by rolling a ball of soil crumble, when it is rolled down to a diameter of approximately 3mm. Fine grained soils are classified based on their liquid limit and plastic limit value only.

The plastic limit of a 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 diameter.

Test Procedure :

For liquid limit test :

1. Test about 200gm of air dried soil passing 425 microns sieve in a "porcelain" dish.
2. Add a small amount of water and carefully mix the soil to a uniform colour.
3. Adjust the height of fall each that it is equal to 100mm.
4. Place a portion of the paste in the cup over the spot where the cup rests on the base, squeeze down and smoother the surface of the soil part carefully. By using a grooving tool, cut a clean, straight groove that completely separated the soil part into two parts.
5. Rotate the handle at a rate of 120 revolutions per minute and count the number of blows until the two parts of the soil sample come into contact at the bottom of the groove over a distance of 3mm. Record the number of blows continue to add small amount of water until the soil attain that particular consistency at which it will take about 40 blows to close the standard groove.

6. Take about 25gm of soil from the dosed part of the groove in the cup is preweighed moisture can, place the lids on the moisture can and determine the water content.
7. Remove the reminder of the soil from the brace cup and return it to the porcelain dish, wash and dry the cup. Add a little move water to the soil in the porcelain dish and carefully mix the uniform colour and consistency. Repeat the steps. This process has to be followed each that the blow count ranges between 40" and 60" below and is obtained on a reasonably spread plot.
8. Determine the moisture content for every trail by collecting some soil generally about 25gms, out of the portion of the soil from the closed part of the groove.

Plastic Limit :

1. Take about 20gm of the air dried soil passing 425 microns IS sieve. Add water to it to obtain a consistency that enables it to be moulded into a bell.
2. Take a small portion of the ball and roll it on the glass plate with finger, using just sufficient. But uniform pressure to make it into thread of uniform diameter of the soil thread has reduced to 3mm. knead the specimen together and trail it again. Continue the process till the thread just crumbles at 3mm diameter.

Advantages :

1. The performance of the test increases the engineer's familiarity, with the various properties of the soils with a which he deals and the test results greatly increase the value of his field record.

2. We can acquire the ability to discriminate between different soils (or) different states of the same soil which previously had identical.
3. The particle size distribution and the Atterberg limits are useful index tests for classifying soils.

Limitations :

1. If the wet soil is taken for constituency test, the water present in the form of thin layer around the soil particles will effect the result. So, dried samples have to be taken.
2. If water content in the paste is high, we cannot add soil, but it must be dry to get desired blow count (or) fresh soil must be taken.
3. The particle size distribution and the Atterberg limits are useful index tests for inherently involves disturbance of the soil, they may not give a good indication of the behaviour of the insitu, undisturbed soil.

Scope of errors :

1. Use of wet soils decreases the accuracy of results.
2. The above paste may become wet due to addition of high water content.
3. The blows should not at altering speed.
4. The rolling in determination of plastic limits should be of uniform pressure.

Correction of errors :

1. Air-dried soil must be used.
2. Water content is added to soil from low rate to high rate.
3. If the paste becomes too wet the soil may be left to get dry to obtain required blow (or) fresh sample may be taken.
4. The weighing machine should be of accuracy 0.01gm.

Code of reference :

I_L = Liquidity Index

I_C = Consistency Index

I_L = Negative (or) $I_c > 1$: The soil exhibits brittle fracture $I_L > 1$ (or) I_C negative : The soil behaves as a viscous liquid when sheared.

Tabular Form :

Liquid limit:

S.No	Observations & calculations	1	2	3	4	5
	Observations:					
1.	No. of blows					
2.	Water added(ml)					
3.	Can no.					
4.	Mass of empty can, M_1					
5.	Mass of can + wet soil, M_2					
6.	Mass of can + dry soil, M_3					
	Calculations:					
1.	Mass of water(M_2-M_3)					
2.	Mass of dry soil (M_3-M_1)					
3.	Water content = $\frac{(M_2-M_3) \times 100}{(M_3-M_1)}$					

For Plastic Limit :

Water added(ml) =

Container no. =

Mass of empty can, M_1 =

Mass of can + wet soil, M_2 =

Mass of can + dry soil, M_3 =

Mass of water (M_2-M_3) =

Mass of dry soil (M_3-M_1) =

Water content = $\frac{(M_2-M_3)}{(M_3-M_1)} \times 100$ =

Model Graph :

Model Graph is plotted between the number of blows as abscissa on a logarithmic scale and corresponding water content as ordinate.

The resulting plot is called Flow Curve.

From, the flow curve, the water content corresponding to 25 blows is to be reported. The slope of flow curve is called "Flow Index".

$I_f = (w_2 - w_1)/\log(N_1/N_2)$

Model Calculations :

Weight of empty container w_1 =

Weight of container + wet soil w_2 =

Weight of container + dry soil w_3 =

Weight of water content a =

Weight of dry soil ($w_3 - w_1$) b =

% of water content = a/b x 1000 =

From Graph :

From the flow curve, the water content corresponding to 25 blows are to be repeated as the liquid limit.

The slope of the flow curve is termed as "Flow index".

$$I_f = \frac{w_2 - w_1}{\ln(N_1/N_2)} = \frac{\qquad}{\log(\quad / \quad)} =$$

Theoretical Result :

For liquid limit, water content =

For plastic limit, water content =

Experiment No. **Date :**

SHRINKAGE LIMIT

Aim : To determine the shrinkage limit of the given soil sample.

Apparatus :

1. Shrinkage dish, having a flat bottom, 45mm diameter and 15mm height.
2. Two large evaporating dishes about 120mm diameter, with a pour out and flat bottom.
3. One small mercury dish, 60mm diameter.
4. Two glass plates, one plain and one with prongs, 75mm x 75mm x 3mm size.
5. Glass cup, 50mm diameter and 25mm high.
6. IS sieve 425 microns.
7. Oven, desiccator.
8. Weighing balance. Accuracy 0.01 g.
9. Spatula, Straight edge, Mercury.

Theory :

Shrinkage limit is the smallest water content at which the soil is saturated. It is also defined as the maximum water content at which a reduction of water content will not cause a decrease in the volume of the soil mass. It can be determined from the relation

$$w_s = \frac{(M_1 - M_s) - (V_1 - V_2)\gamma_w}{M_s} \times 100$$

Where, M_1 = initial wet mass.

V_1 = initial volume.

M_s = dry mass.

V_s = volume after drying.

Procedure :

1. Take a sample of mass about 100g from a thoroughly mixed soil passing through 425 micron sieve.
2. Take about 30g of the soil sample in a large evaporating dish. Mix it with distilled water to make a creamy paste which can be readily worked without entrapping the air bubbles.
3. Take the shrinkage dish. Clean it and determine its mass.
4. Fill mercury in the shrinkage dish. Remove the excess mercury by pressing the plain glass plate over the top of the shrinkage dish. The plate should be flush with the top of the dish, and no air should be entrapped.
5. Transfer the mercury of the shrinkage dish to e mercury weighing dish and determine the mass of the mercury to an accuracy of 0.1g. The volume of the shrinkage dish is equal to the mass of mercury in grams divided by the specific gravity of mercury.
6. Place the soil specimen in the middle of the shrinkage dish, equal to about one-third the volume of the shrinkage dish.
7. Add more soil paste, approximately equal to the first portion and tap the shrinkage dish as before, until the soil is thoroughly compacted. Determine the mass of the wet soil (M_1).
8. Dry the soil in the shrinkage dish in air until the colour of the pat turns from dark to light. Then dry the pat in the oven at 105^0 to 110^0 C to constant mass.

9. Cool the dry pat in a desiccator. Remove the dry pat from desiccator after cooling and weigh the shrinkage dish to determine the dry mass of the soil(M_s).
10. Place a glass cup in a large evaporating dish and fill it with mercury. Remove the excess mercury by pressing the glass plate with prongs firmly over the top of the cup.
11. Remove the glass cup full of mercury and place it in another evaporating dish, taking care not to spill any mercury from the glass cup.
12. Take out the dry pat of the soil from the shrinkage dish and immerse in the glass cup full of mercury. Take care not to entrap air under the pat. Press the pat with prongs on the top of the cup firmly.
13. Collect the mercury displaced by the dry pat in the evaporating dish, and transfer it to the mercury weighing dish. Determine the mass of the mercury to an accuracy of 0.1g. The volume of the dry pat(V_2) is equal to the mass of the mercury divided by the specific gravity of mercury.
14. Repeat the test atleast 3 times.

Field applications :

1. The shrinkage limit is a useful parameter for the study of expansive and shrinkage behaviour of a clay soil.
2. It can be used for classifying fine-grained soils for engineering purposes.

Advantages of the test :

1. Shrinkage limit can be determined for both undisturbed and remoulded soil samples.
2. It is directly proportional to the percentage of clay size fraction present in the soil. It can be used as an indicator for the amount of clay.

Limitations of the test :

1. The water content should be greater than the liquid limit, and if it is high, soil cannot be added further.
2. It may not give a good indication of the behaviour of the insitu, undisturbed soil.

Tabular form :

S.No	Observations & calculations	1	2	3	4	5
	Observations:					
1.	Mass of empty mercury dish					
2.	Mass of mercury dish, with mercury equal to volume of shrinkage dish					
3.	Mass of mercury (2)–(1)					
4.	Volume of Shrinkage dish, V = (3)/13.6					
5.	Mass of empty shrinkage dish					
6.	Mass of shrinkage dish + wet soil					
7.	Mass of wet soil, M_1 = (6) - (5)					
8.	Mass of shrinkage dish + dry soil					
9.	Mass of dry soil, M_s = (8) –(5)					
10.	Mass of mercury dish + mercury equal in volume of dry pat					
11.	Mass of mercury displaced by dry pat = (10) –(1)					

12.	Volume of dry pat, $V_2 = (11) / 13.6$					
	Calculations:					
1.	Shrinkage limit, $w_s = \frac{(M_1 - M_s) - (V_1 V_s)\gamma_w}{M_s}$					
2.	Shrinkage ratio, $SR = M_s/V_2\ \gamma_w$					
3.	Volumetric shrinkage, $VS = \frac{(V_1 - V_2)}{V_2} \times 100$					

Result :

The shrinkage limit of the given soil sample =

Experiment No. **Date :**

PROCTOR COMPACTION TEST

Aim : To determine the moisture content and dry density relationship of a given soil under the standard proctors compaction effort.

Apparatus : Proctors compaction mould with base plate and collar, compaction rammer, moisture cans, large mixing pan, sample extruder.

General discussion of test :

1. Cylindrical mould of 10.2cm diameter and 10cm height and 817.13cc in capacity filled with detachable base plate and collar is used.
2. Rammer of 2.6kg in mass and 31cm in drop is used.
3. Balance accurate to 1g is used.
4. Palette knife, straight edge and mixing basin are used.
5. IS sieve of 4.75mm is used.
6. Apparatus for moisture content and sample extractor are also used.

Theory :

1. Soil at a site may not be often ideal for the construction of a civil engineering structure.
2. Many types of compaction of soil is necessary for 3 reasons: to decrease future settlements, to increase shear strength, to decrease permeability.

3. For construction purpose, we have to improve the soil properties. The most common and important method of soil improvement is disinfection.
4. Three methods of disinfection are: Compaction, Pre-loading and De-watering.
5. Compaction is one of the methods of making such improvement and involves densification by applying mechanical energy on a soil mixed with suitable water content.
6. To arrive at a proper amount of water to the soil in the field, the optimum moisture content, which also produces the maximum dry unit weight is determined from this test.

Test Procedure :

1. Weigh the empty proctor mould, W_1 g and also determine its volume, V. Fix the mould to the base plate and attach the collar to the mould. Apply a thin layer of oil to the inside surface of the mould and the collar.
2. Take about 2.5kg of air dried soil which is pulverized and passed through 4.75mm sieve.
3. Add to this soil, a certain initial percentage of water, say 6%, sprinkle this water uniformly on the soil and mix it carefully.
4. Divide the wet soil into 3 equal parts and fill the mould with one part of soil. Compact it with 25 equally distributed blows with standard rammer.
5. Repeat the experiment with the second and third parts of the soil.
6. The mould is thus filled with all the three soil layers. Detach the mould from the base plate, remove the collar and trim the soil on the top of the mould.
7. If there is any difficulty in removing the collar, take a spatula and trim along the bottom edge also.

8. Weigh the mould with compacted soil, W_2 g after removing the soil sticking to the mould.
9. To extrude the soil specimen from the mould, use the sample extruder. After the sample has come out, split it and take a small quantity of soil from the middle layer for water content determination.
10. After weighing the can with soil sample, keep them in the hot air oven for 24 hours.
11. Repeat the procedure by taking fresh sample of soil each time and adding water to it with 8%, 10%, 12% and 14%.
12. Then draw a graph between water content and dry density. The peak will give the optimum moisture content which will determine the maximum dry density of the soil.

Field applications :

1. Proper compaction of fills, sub grade, sub base and base course are considered essential for proper highway construction. So, this test is used to check whether The compaction achieved is the desirable limit or not.
2. The embankment may be constructed either by rolling in relative thin layers or by hydraulic fills. The former is called rolled method. In this each layer is compacted before placing the next layer. So, this test is used in the highway embankments.

Advantages :

1. It is a fast method compared to core cutter and sand replacement method.
2. Laboratory compaction tests are cheaper and quicker compared to the field tests
3. This test applies to cohesive as well as cohesion less soils.

Limitations :

1. This test is used only for light compaction.
2. This test is used to test the soil passing only through 4.75mm sieve only, but in the field various sizes of soil are present

Scope of errors :

1. If the water is not mixed homogenously, the test results may vary.
2. Mould should be placed on solid foundation. Otherwise, low density and high optimum moisture content are obtained.

Code of reference :

IS:2720(partvii) – 1974 – determination of moisture content – dry density relation using light compaction.

IS:10074 – 1982 – compaction mould assembly for light and heavy compaction(1995).

Table:

S. No.	Wt of empty mould (kg)	Wt of mould +wet soil (kg)	$\gamma_b = W/V$ (g/cc)	Wt of empty contai -ner (w_1)	Wt of conta -iner + wet soil (w_2)	Wt of contai -ner + dry soil (w_3)	% of water content $(w_2 - w_3)/(w_3 - w_1) \times 100$	$\gamma_d = \frac{\gamma_b}{1+W\%}$ (g/cc)
1								
2								
3								
4								
5								

Model calculations:

Diameter of the mould =

Height of the mould =

Volume of the cylindrical mould =

Weight of the empty mould =

Weight of the mould + wet soil =

Bulk density of soil γ_b =w/v

γ_b=

Weight of empty container =

Weight of the container + wet soil =

Weight of the container + dry soil =

% of water content = $\frac{(w_2 - w_3)}{(w_3 - w_1)} \times 100$

Dry density, $\gamma_d = \frac{\gamma_b}{1+w\%}$

Graph :

A graph is drawn taking the % of water content on x – axis and the dry density on the y – axis.

Result :

Optimum moisture content =

Maximum dry density =

Experiment No. **Date :**

CLASSIFICATION OF SOILS

HYDROMETER ANALYSIS

Aim : The object of this experiment is to determine grain size distribution of fine soils (finer than 0.075mm) i.e., silts & clays by Hydrometer analysis.

Apparatus and Materials :

1. Hydrometer
2. Dispersion cup with mechanical stirrer complete with accessories
3. Two glass jars of 1 litre capacity
4. Deflocculating agent (Sodium Hexa-metaphosphate Solution Prepared by dissolving 33g of sodium Hexa-metaphosphate and 7g of sodium Carbonate in distilled water to make one litre of Solution).

Formulae:

1. Diameter of the soil particle may be obtained from stoke's Law.

$$D = \frac{\sqrt{18\eta}}{(\gamma_s - \gamma_w)} \sqrt{\frac{H_e}{t}}$$

Where, D is the dia. of soil particle (cm).

H_e is the depth of immersion obtained from calibration curves (in cm).

t is the total elapsed time in minutes.

η is the viscosity of water at the temperature of experiment in gm sec/cm^2.

γ_w is the unit weight of water at the experiment temperature.

If the temperature during the experiment is constant, then the term within the brackets will be a constant and the above equation may be conveniently written as

$$D^2_{mm} = \frac{KH_e}{t} \quad \text{where,} \quad K = \frac{18\eta}{(\gamma_s - \gamma_w)}$$

2. The percentage finer N may be obtained form

$$N\% = \frac{GV}{(G-1)W} (r - r_w) \times 100$$

Where, V is the volume of soil suspension, (1000 cc).

W is the weight of dry soil taken for the test.

γ_w is the unit weight of water at calibration temperature of the hydrometer.

r and r_w are the hydrometer readings in soil suspension and distilled water.

G is the sp gr. of soil particles.

Since V = 1000 the above equation may be conveniently represented as follows :

$$N\% = K_1 (R_h - 1000) \times 100$$

Where, $K_1 = \frac{G}{G-1} \times \frac{1000}{W}$

R_h is the hydrometer reading

$= R_h + C_m - C_d \pm C_t$

R_h is the actually observed hydrometer reading.

C_d is the correction for dispensing agent correction.

For the combined analysis, correction for the percentage fine than

$$N1 = \frac{N \times W_1}{W_s} = N\% \text{ finer than 75 M.I.S. sieve}$$

Where W_1 = weight of dry soil passing 75 M.I.E. sieve

W_2 = Total weight of dry soil used.

Procedure :

(a) Soils containing considerable amount of fines.

1. Take about 50gms in case of clayey soil and 100gms in case of sandy soil and weigh it correct to 0.1g.
2. In case the soil contains considerable amounts of organic matter or calcium compounds pre-treatment of the soil with Hydrogen Peroxide or Hydrochloric acid may be necessary. In case of soils containing less than 20 percent of the above substances pre-treatment shall be avoided.
3. To the soil thus treated, and 100ml. of Sodium Hexa-metaphosphate solution and warm it gently for about 10mts. And transfer the contents to the cup of the mechanical mixer using a jet of distilled water to wash all traces of the soil.
4. Stir the soil suspension for about 15 minutes.
5. Transfer the suspension to the Hydrometer jar and make up the volume exactly to 1000ml. By adding distilled water.
6. Take another Hydrometer jar with 1000ml. distilled water to store the Hydrometer in between consecutive readings of the soil suspension to be recorded. Note the specific gravity (rw) readings and temperature T^0C of the water occasional.
7. Mix the soil suspension, roughly by placing the palm of the right hand over the open end and holding the bottom of the jar with left hand turning the jar is upside down and back. When the jar is upside down be sure no soil is stuck to the base of the graduated jar.
8. Immediately after shaking place the Hydrometer jar on the table and start the stopwatch. Insert the hydrometer into the

suspension carefully (avoiding circular or vertical oscillations to facilitate quick and accurate reading of the hydrometer) and take hydrometer readings at total elapsed times of 1/4 , 1/2, 1 and 2 mts.

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

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

11. Continue recording operation of the hydrometer readings until the hydrometer reads 1,000 approximately.

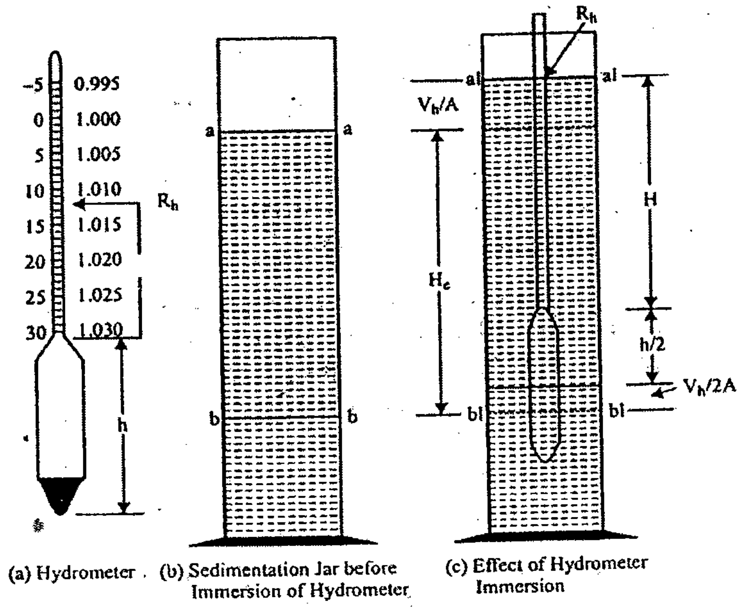


Figure 9.1 : **Hydrometer Analysis**

(b) When the Soil contains a small proportion of fines:

1. Conduct sieve analysis the soil indicated under sieve analysis.
2. Take 50gms of the oil passing 75μ sieve and run the hydrometer analysis as explained in (a). The correction to be applied for the percentage finer in the combined analysis is explained under calculations.

(c) Calibration of the hydrometer :

1. Note the mid length of the bulb.
2. Note the distances Z_r(cm) from the first and last reading and any intermediate reading also on the stem of the hydrometer to the mid length of the bulb.
3. Plot a curve (A) between the hydrometer reading Rh against depth (Z_r). This curve is applicable for readings obtained for the first two minutes with the hydrometer continuously kept inside the hydrometer jar. For all subsequent readings of the hydrometer, a correction has to be applied by subtracting the volume effect of the hydrometer from the observed value Z_r. The value of this correction is V_r 2A where V_r is the volume of the hydrometer.

(V_r) may be obtained from the volume it displaces when immersed in water. (g) the area of cross section of the jar may be obtained by dividing the volume of the jar between two marks by the distance between them.

Graph :

After determining the correction factor, plot the particle size distribution curve. This curve is used for all readings beyond the first two minutes.

Calculations :

1. Diameter of the soil particle may be obtained from stoke's Law.

$$D = \frac{\sqrt{18\eta}}{(\gamma_s - \gamma_w)} \sqrt{\frac{H_e}{t}}$$

=

2. The percentage finer N may be obtained form

$$N\% = \frac{GV}{(G-1)W} (r - r_w) \times 100$$

$$N\% = K_1 (R_h - 1000) \times 100$$

Where, $K_1 = \frac{G}{G-1} \; \frac{x\,1000}{W}$ =

R_h is the hydrometer reading

$= R_h + C_m - C_d \pm C_t$ =

For the combined analysis, correction for the percentage fine than

$$N1 = \frac{N \times W_1}{W_s} = N\% \text{ finer than 75 M.I.S. sieve}$$

=

TABLE 1

SPECIFIC GRAVITIES OF DISTILLED WATER

Temp 0_c	0	2	4	6	8
10	0.99973	0.99952	0.99927	0.99897	0.99862
20	0.99823	0.99780	0.99733	0.99681	0.99626
30	0.99568	0.9951	0.9944	0.9937	

TABLE 2

Viscosity of Water at different Temperatures in Millipoises

Temp 0_c	0	2	4	6	8
10	13.10	12.39	11.75	11.16	10.60
20	10.69	9.61	9.61	8.75	8.36
30	8.00	7.67	7.36	7.06	6.79

1000 millipoises = 1 poise

1 gram sec. per sq.cm = 980.7 poises

TABLE 3

Temperature correction (ct) for the Hydrometer analysis

Temp in ^0C	Correction	Temp. ^0C	Correction
20	Nil	27.5	0.00163
20.5	0.00009	28.0	0.00178
21.0	0.00017	28.5	0.00191
21.5	0.00037	29.0	0.00206
22.0	0.00049	30.0	0.00219
22.5	0.00058	30.5	0.00247
23.0	0.00068	31.0	0.00262
24.0	0.00081	31.5	0.00278
24.5	0.00092	32.0	0.00291
25.0	0.00102	32.5	0.00320
25.5	0.00116	33.0	0.00350
26.0	0.00127	33.5	0.00380
26.5	0.00139	34.0	0.00400
27.0	0.0150	34.5	0.00420
		36.0	0.00470

HYDROMETER ANALYSIS :

Result:

Description of Soil :

Weight of sample taken :

Specific gravity of soil :

Hydrometer No. :

Meniscus correction :

Dispersion Agent correction :

Elapsed time	Temp.	R_h Hydrometer reading $R=R_h + C_m$	Corrected Hydrometer	Depth H_e	Equivalent Dia, D	Actual $R= R_h + C_m - C_d \pm C_t$	% of particles finer than D N

Experiment No. **Date :**

CONSOLIDATION TEST

Aim : To determine the coefficient of consolidation of a given sample of clay soil.

Apparatus :

Consolidometer consisting of specimen ring, guide ring, porous stones, dial gauges. Specimen dimension are 60mm diameter and 20mm thick.

Theory and Application :

When a load is applied on a saturated soil, the load will initially transferred to the water in voids or pores of soil (called pore water). This result in development of pressure in pore water (pore pressure), which results in the escape of water from voids and bring the soil particles together. This process of escape of water under applied load, leading to reduction in volume of soil is known as consolidation. The magnitude of consolidation depends on the amount of voids or void ratio of the soil, the rate of consolidation depends on the permeability properties of soil. The two important consideration properties of soil are coefficient of consolidation (c_s) and compression index (C_c). The coefficient of consolidation reflects the behaviour of soil with respect to time under a given load intensity. Dimensional formula for C_s is L^2T^{-1}. Compression index explains the behaviour of soils under increased loads. It has no units.

Formulae :

The co-efficient of consolidation is calculated as follows :

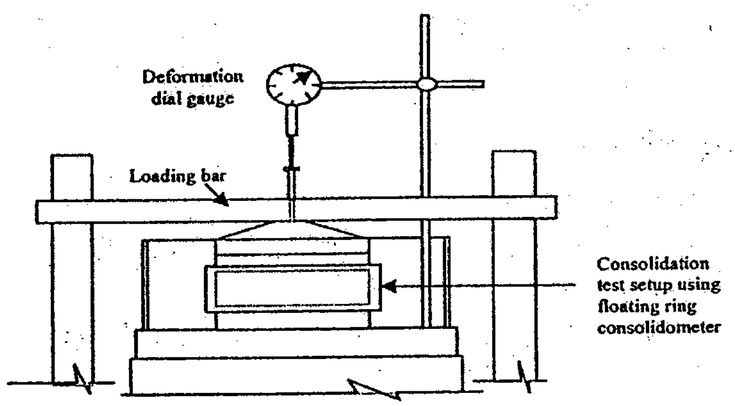
$$C_s = 0.848H^2 / t_{90}$$

Where, H = length of the drainage path.

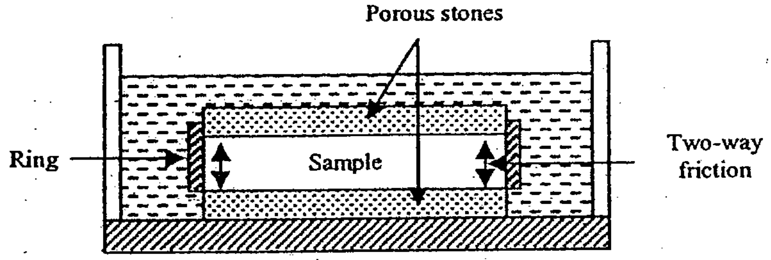
t_{90} = time for 90% consolidation.

Field applications :

Consolidation properties are required in estimating the settlements of a foundation. They provide the maximum amount of settlements under a given load and the time required for it to occur. Many times the design of foundation is carried out based on limiting settlements. The amount of consolidation will be more in clay soils hence, these properties are important for foundation resting on clay soils.



(a) Consolidometer



(b) Floating-ring consolidometer

Line diagram of a typical consolidation test apparatus

Procedure :

Preparation of specimen :

1. Sufficient thickness of soil specimen is cut from undisturbed sample.
2. The consolidation ring is gradually inserted into the sample by pressing and carefully removing the material around it. The specimen shall be trimmed smooth and flush to the ends of ring.
3. Any voids in the specimen caused due to removal of gravel or line stone pieces shall be filled back by pressing completely the loose soil in the voids.
4. The ring shall be wiped clean and weighed again with soil. This sample should be placed in the loading frame by placing wet filter paper top and bottom of the sample and two porous stones covering it.
5. Over the porous stone a perforated plate with loading ball is placed.
6. The sample is put for saturation both from top and bottom (bottom through a reservoir).
7. After allowing sufficient time for saturation the load is applied through the loading frame. The settlement in sample will be measured using a dial gauge.
8. The step wise procedure for observing reading is as follows.

   a. Apply the required load intensity (stress) at which C_s to be determined.

   b. As the loading is applied, the stop watch should be started.

   C. Take the readings of dial gauge at different time interval from the time of loading and record them in Table.

Graph :

1. Record the dial gauge readings at different time interval from the time of loading.
2. Plot a graph between $\sqrt{t}$ on X-axis and dial gauge reading on Y-axis. Where t is time in minutes.
3. The curve drawn between $\sqrt{t}$ and dial gauge reading can be divided into the three parts. Viz. (1) Immediate settlement or elastic compression. This will be reflected in the form of settlements in very small interval marked by a nearly vertical line at the initial portions of the curve. This is followed by (2) Primary consolidation curve, which will be almost a straight line with reduced slope. The majority of consolidation will be in this zone. After the primary consolidation. (3) Secondary consolidation takes place which marked by a curve.
4. Draw a straight line through the primary consolidation zone (i.e. the straight line passing through the points covered in this zone). Extend the straight line to meet Y-axis at O_c. O_c corrected zero.
5. Draw another straight line through O_c, with a slope equal to 1.15 times the slope earlier straight line.
6. The straight line so drawn (with 1.15 times the slope of primary consolidation line) will intersect the originally plotted curve at point A. The X-coordinate of this point "A" will give $\sqrt{t_{90}}$ Where t_{90} is the time required for 90% consolidation. (in minutes.

Code of reference:

The code of reference for laboratory determination of Consolidation is IS:2720(part xv) - 1965.

Observations and Calculations :

Coefficient of consolidation

Dimension of sample :

Dia = Thickness =

Unit Weight of soil :

Time (t) minutes	$\sqrt{t}$	Dial gauge Readings
0.00	0.00	
0.25	0.50	
2.25	1.50	
4.00	2.00	
6.25	2.50	
9.00	3.00	
12.25	3.50	
16.00	4.00	
20.25	4.50	
25.00	5.00	
36.00	6.00	
49.00	7.00	
64.00	8.00	
81.00	9.00	
100.00	10.00	
121.00	11.00	
144.00	12.00	
169.00	13.00	
196.00	14.00	
225.00	15.00	
256.00	16.00	

Result :

The Coefficient of consolidation for the given sample =

Experiment No. **Date :**

DETERMINATION OF RELATIVE DENSITY OF COHESIONLESS SOILS

Aim : To determine the relative density of cohesion less soil.

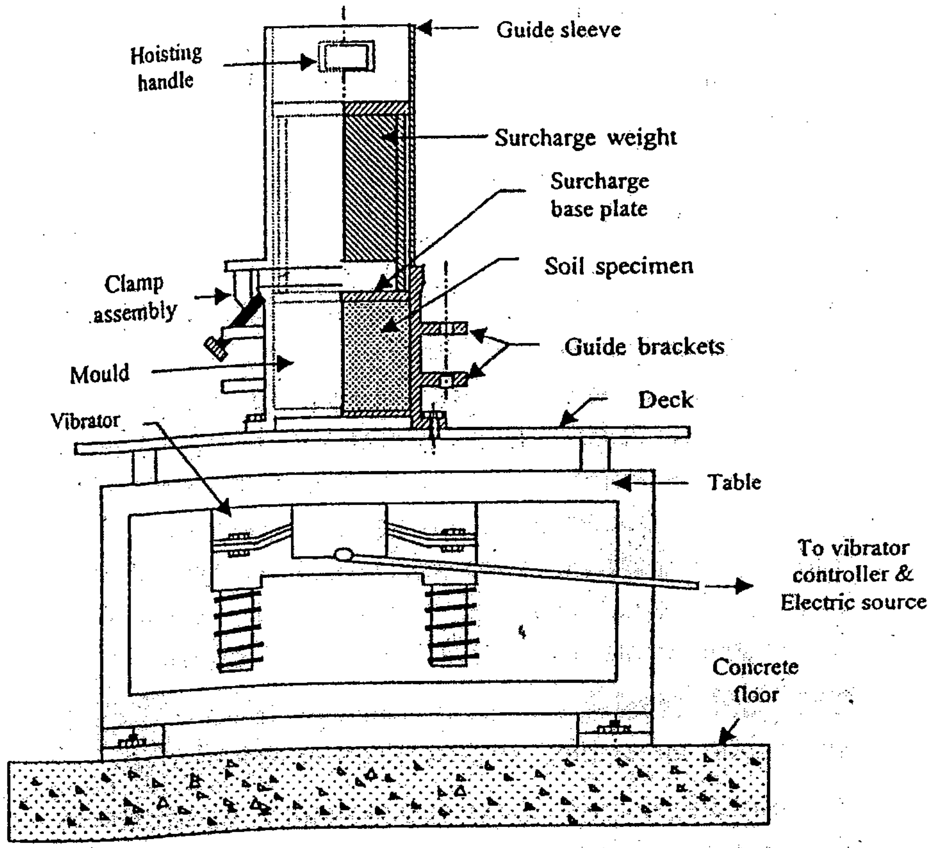
Apparatus :

1. Vibratory table : A steel table with a cushioned steel vibrating deck about 75 x 75cm the vibrator should have a net weight of over 45kg. the vibrator should have frequency of 3600 vibrations per minute, a vibrator amplitude variable between 0.05 and 0.65mm under a 115 kg load.
2. Moulds : Cylindrical metal density moulds of 3000 cc (150mm dia. and 169.77mm high) and 15000cc (280mm dia and 243.6mm high) capacity.
3. One guide sleeve with clamp assembly should be provided with lock nuts.
4. One 10mm thick surcharge base plate, with handle, for each mould.
5. Surcharge weights : One surcharge weight for each size mould. The total weight of surcharge base plate and surcharge weight shall be equivalent to $140 g/cm^2$ for the mould being used.
6. One dial gauge holder.
7. Dial gauge : A dial gauge with 50mm travel and 0.02mm least count.
8. A metallic calibration bar of size 75 x 300 x 3mm
9. Pouring devices : Consisting of funnels 12mm and 25mm in diameter and 150mm long, with cylindrical spots and lipped brims for attaching to 150mm and 300mm high metal cans.
10. Mixing pans : Two mixing pans. Suitable sizes are, one 60 x 90cm and 10 cm deep and 40 x 40 cm and 5 cm deep.

11. Weighing scale : Portable platform scale, 100kg capacity with sensitivity of 20g.
12. Hoist of atleast 135kg capacity.
13. Metal hand scoop.
14. Bristled brush.
15. Stop watch.
16. Metal straight edge 40 cm long.
17. Micrometer: 0 to 25mm with an accuracy of 0.0025mm.

Theory and Application :

Relative density is also known as density index. It is defined as the ratio of difference between the void ratio of a cohesionless soil in the loosest state and any given void ratio to the difference between its void ratios in the loosest and in the densest states. For cohesionless soils in the natural or artificially compacted states neither the actual density (nor void ratio) nor the actual density expressed as a percentage of the maximum density give an exact idea of the compactness of the soil. The concept of density index (relative density) gives a practically useful measure of compactness of such soils. The compactive characteristics of cohesionless soils and the related properties of such soils are dependent on factors like grain size distribution and shape of individual particles. Relative density is also effected by these factors and serves as a parameter to correlate properties of soils. Various soil properties, such as penetration resistance, compressibility, compaction, friction angle, permeability and California bearing ratio has been found to have simple relationships with relative density. Density index is also used to assess the possibility of a soil to fail under liquefaction.



Assembly of the relative density test apparatus

Test Procedure :

The test procedure to determine the relative density of soil involves the measurement of density of soil in its loosest possible state (γ_{min}) and densest possible states (γ_{max}). Knowing the specific gravity of soil solids (G_s) the void ratios of the soil in its loosest (e_{max}) and densest state (e_{min}) are computed. The density of soil in the field (γ) (natural state) is used to compute the void ratio (e) in the field. After obtaining the three void ratios (i.e., Minimum, maximum and natural) the relative density is computed. To measure the densities depending on the particle sizes one of the two moulds (3000cc or 15000cc) are used as presented in Table. Hence these moulds have to be initially calibrated. Then the possible minimum and maximum densities of the soil are obtained as explained below.

Calibration of Moulds :

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

Maximum size of particles (mm)	Weight of soil sample required (kg)	Pouring device to be used in the test for the determination of minimum density	Size of mould to be used (cc)
80	45	Shovel or large Scoop	15000
40	12	Scoop	3000
20	12	Scoop	3000
10	12	Pouring device (25mm dia spout)	3000
4.75	12	Pouring device (12mm dia spout)	3000

Preparation of Soil Sample :

A representative sample of soil should be selected. The weight of soil sample to be taken depends upon the maximum size of particles in the soil as given. The soil sample should be dried in an oven at a temperature of 105^0 to 110^0. The soil sample should be pulverized without breaking the individual soil particles and sieved through the required sieve.

Procedure for the determination of Minimum density :

1. The pouring device and mould should be selected according to the maximum size of particle as indicated in Table. The mould should be weighed and weight recorded. Oven-dry soil should be used.
2. Soil containing particles smaller than 10mm should be placed as loosely as possible in the mould by pouring the soil through the spout in a steady stream. The spout should be adjusted so that the height of free fall of the soil is always 25mm. While pouring the soil the pouring device should be moved in a spiral motion from the outside towards the centre to form a soil layer of uniform thickness without segregation. The mould should be filled approximately 25mm above the top and leveled with the top by making one continuous pass with the steel straight edge. If all excess material is not removed, an additional continuous pass should be made. Great care shall be exercised to avoid jarring during the entire pouring and trimming operation.
3. The mould and the soil should be weighed and the weight recorded.
4. Soil containing particles larger than 10mm should be placed by means of a large scoop (or shovel) held as close as possible to and just above the soil surface to cause the material to slide rather than fall into previously placed soil. If necessary large particles may be held by hands to prevent them from rolling off the scoop. The mould should be filled to overflowing but not more than 25mm above the top. The surface of the soil should be leveled with the top of the mould using the steel straight edge in such a way that any slight projections of the larger particles above the top of the mould shall approximately balance the large voids in the surface below the top of the mould. The mould and the soil should be weighed and the weight recorded.

Procedure for the determination of Maximum density

The maximum density of soil may be determined by either the dry or wet method.

Dry Method :

1. The guide sleeve should be assembled on top of the mould and the clamp assemblies tightened so that the inner surfaces of the walls of the mould and the sleeve are in line. The lock nuts should be tightened. The third clamp should be loosened, the guide sleeve removed, the empty mould weighed and its weight recorded.
2. The mould should then be filled with the thoroughly mixed oven dry soil in a loose state (The mould filled for the determination of minimum density may also be used for this test).
3. The guide sleeves should be attached to the mould and the surcharge base plate should be placed on the soil surface. The surcharge weight should then be lowered on to the base plate using the hoist in the case of the 15000cc mould.
4. The mould should be fixed to the vibrator deck. The assembly of mould fixed on to the vibrating table is shown in fig. The vibrator control should be set at its maximum amplitude and the loaded soil specimen should be vibrated for 8 minutes.
5. The surcharge weight and the guide sleeves should be removed from the mould. The dial gauge readings on two opposite sides of the surcharge base plate should be obtained and the average recorded. The mould with the soil should be weighed and its weight recorded.

Code of reference :

The code for relative density test is IS : 2720(Part xiv) – 1965.

Observations and Calculations :-

The minimum density test observations are recorded in Table. And the maximum density test results are tabulated in Table. Shows the computation steps for relative density.

Observations for the determination of minimum density:

Details of soil sample :

Mould No.

Weight of the mould, in g :

Volume of the mould V_c , in cc :

Method used : Funnel/Scoop Size of mould :

Test No.	1	2	3
Weight of mould, g			
Weight of soil + mould, g			
Weight of soil, W g			
Calibrated volume of mould, V_c cc			
Minimum density, $\gamma_{min} = W/V_c$, g/cc			

Observations for the determination of minimum density

Details of soil sample :

Mould No.

Weight of the mould, in g :

Volume of the mould V_c , in cc :

Dial gauge reading at left : Dial gauge reading at right :

Average dial gauge reading :

Method used : Dry / Wet Size of mould :

Test No.	1	2	3
Gauge reading : Left Right			
Average gauge reading, D_f			
Initial gauge reading, D_i			
Surface area of Soil sample, A, cm^2			
Volume of soil $V_s = V_c$ $= (D_i - D_f)A$, cc			
Weight of dry soil + mould, g			
Weight of dry soil, W, g			
Maximum density $\gamma_{max} = W/V_s$, g/cc			

Computation of relative density

Test No.	1	2	3
In-place density γ_d, g/cc			
γ_{max}, g/cc			
γ_{min}, g/cc			
$\gamma_d - \gamma_{min}$			
$\gamma_{max} - \gamma_{min}$			
Relative density, (%)			
$D_r = (\gamma_{max})(\gamma_d - \gamma_{min})) /$ $(\gamma_d (\gamma_{max} - \gamma_{min})$ x 100			
In-place moisture content of soil, (%)			

Result :-

Maximum density, g/cc =

Minimum density, g/cc =

Relative density (%) =

Experiment No. **Date :**

VANE SHEAR TEST

Aim : To determine the shearing resistance of the soft, saturated clays in the field.

Apparatus : Vertical steel rod having four stainless steel blades(vanes) fixed at its bottom, specimen of size 38mm dia and 75mm height.

Theory :

The shear vane consists of four steel blades called vanes welded at right angles to a steel rod. The vane is gently pushed into the soil up to the required depth or at the bottom of a bore hole and torque is applied to the upper end of the torque rod until the soil fails in shear, due to the rotation of the vane. The torque is measured by noting the angle of twist. Shear failure occurs over the surface and the ends of a cylinder having a diameter d equal to the diameter of the vane.

Formula :

$$s_u = \frac{T}{\pi(D^2 H/2 + D^3/6)}$$

Where, s_u = undrained shear strength of the soil sample.

T = torque applied.

D = diameter of the soil sample sheared.

H = height of the vane.

Procedure :

1. A specimen of size 38mm diameter and 75mm height is taken in a container which is fixed securely to the base.
2. The vane is gradually lowered into the specimen till the top top of the vane is at a depth of 19 to 20 mm below the top of the specimen.
3. The readings of the strain indicator and torque indicator are taken.
4. Torque is applied gradually to the upper end of the rod at the rate of about 6^0 per minute(i.e. 0.1^0 per second).
5. The torque acting on the specimen is indicated by a pointer fixed to the spring.
6. The torque is continued till the soil fails in shear and the shear strength of the soil is determined using the above formula.
7. If the top of the vane is above the soil surface and the depth of the vane inside the sample is H_1, then

$$s_u = \frac{T}{\pi(D^2 H_1/2 + D^3/12)}$$

8. After the initial test, the vane is rotated rapidly through several revolutions such that the soil becomes remoulded. The test is repeated on the remoulded soils and the shear strength in remoulded state is determined. Thus,

$$\text{Sensitivity } (S_t) = \frac{(s) \text{ undisturbed}}{(s) \text{ remoulded}}$$

Field applications :

1. The vane shear test is used to determine the sensitivity of the soil.
2. It is extremely useful in determining the in-situ shear strength of very soft and sensitive clays, for which it is difficult to obtain undisturbed samples.
3. The method can also be used for sandy soils.

Advantages of the test :

1. The test is simple and quick.
2. It is ideally suited for the determination of the in-situ undrained shear strength of non-fissured, fully saturated clay.
3. The test can be conveniently used to determine the sensitivity of the soil.

Limitations of the test :

1. The test cannot be conducted on the fissured clay or the clay containing sand or silt laminations.
2. The test does not give accurate results when the failure envelope is not horizontal.

Code of reference :

The code of reference for the Vane Shear Test is IS:2720(part xxx) – 1980 recommends that the height H of the vane should be equal to twice the overall diameter D.

Tabular form :

Diameter of the soil sample sheared =

Height of the vane =

S.No.	Torque applied		Shear strength (kg/cm^2)
	α_1	α_2	
1.			
2.			
3.			
4.			

Model calculations :

Diameter of the soil sample sheared, D =

Height of the vane, H =

Torque applied, T =

Shear strength of the soil sample,

$$s_u = \frac{T}{\pi(D^2 H/2 + D^3/6)}$$

$$=$$

Result :

The shear strength of the given soil sample of soft clays =

Experiment No. **Date :**

UNCONFINED COMPRESSION TEST

Aim : To Determination of unconfined compressive strength of a clayey soil either in undisturbed or remoulded condition.

Need and Scope Of The Experiment:

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.

Apparatus:

Compression machine, Proving ring, Deformation dial gauge, Timer, Sampling tube, Specimen extruder, Split mould, Specimen trimming tools, Vernier calipers, Balance, Apparatus for moisture content determination.

Procedure:

1. Prepare the test specimen, which may be either undisturbed, remoulded or compacted. Undisturbed specimens can be carved from a large soil block, or obtained through a sampling tube from which the specimen can be extruded to a split mould using a sample extruder.

2. Trim the two ends of the soil specimen, remove it from the mould, and measure the length, diameter and weight.

3. Place the specimen on the bottom plate of the compression machine, and adjust the upper plate to make contact with the specimen. Initialize the vertical displacement gauge and proving ring gauge to zero. Select an axial strain rate between 0.5% to 2.0% per minute and apply compression load.

4. Record the load and displacement readings at every 20 to 50 divisions of displacement gauge, or at every 15 seconds.

5. Compress the specimen till the load peaks and then falls, or till the vertical deformation reaches 20% of the specimen length.

6. Remove the specimen from the machine, and take soil samples for water content determination.

Least count of deformation dial gauge (mm/div.) =

Proving ring constant (kg/div.) =

Soil Specimen No. =

Type of specimen: Undisturbed/Remoulded

Initial length of specimen, L_0 (mm) =

Initial diameter of specimen, D_0 (mm) =

Initial area of specimen, A_0 (cm^2) =

1. Convert the dial readings to the appropriate vertical deformation and compressive load units by multiplying with respective least counts.

2. Calculate vertical strain, corrected cross-sectional area and then compressive stress.

3. Plot stress-strain curve, and show unconfined compressive strength q_u as the peak stress or the stress at 20% strain.

4. Draw a Mohr circle using q_u, and determine undrained shear strength s_u = undrained cohesion $c_u = q_u/2$

5. Compute the water content, w (%).

Table:

Elapsed time (min)	Vertical deformation (ΔL)		Vertical strain $\xi = \frac{\Delta L}{L_0}$	Corrected area $A = \frac{A_0}{1 - \xi}$ (cm^2)	Compressive load		Compressive stress (kg/cm^2)
	(div.)	(mm)			(div.)	(kg)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8) = (7)/(6)

General Remarks:

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

Results:

Water content (%) =

Unconfined compressive strength (kg/cm^2) =

Undrained shear strength (kg/cm^2) =

Experiment No. **Date :**

DIFFERENTIAL FREE SWELL INDEX TEST

Aim: To determine the free swell index of soil as per IS: 2720 (Part XL) – 1977. Free swell or differential free swell, also termed as free swell index, and is the increase in volume of soil without any external constraint when subjected to submergence in water.

Apparatus:

i) IS Sieve of size 425μm

ii) Oven

iii) Balance, with an accuracy of 0.01g

iv) Graduated glass cylinder- 2 nos., each of 100ml capacity

Procedure to determine Free Swell Index of Soil:

i). Take two specimens of 10g each of pulverised soil passing through 425μm IS Sieve and oven-dry.

ii). Pour each soil specimen into a graduated glass cylinder of 100ml capacity.

iii). Pour distilled water in one and kerosene oil in the other cylinder upto 100ml mark.

iv). Remove entrapped air by gently shaking or stirring with a glass rod.

v). Allow the suspension to attain the state of equilibrium (for not less than 24hours).

vi). Final volume of soil in each of the cylinder should be read out.

Reporting of Results:

Free swell index = $[V_d - V_k] / V_k \times 100\%$

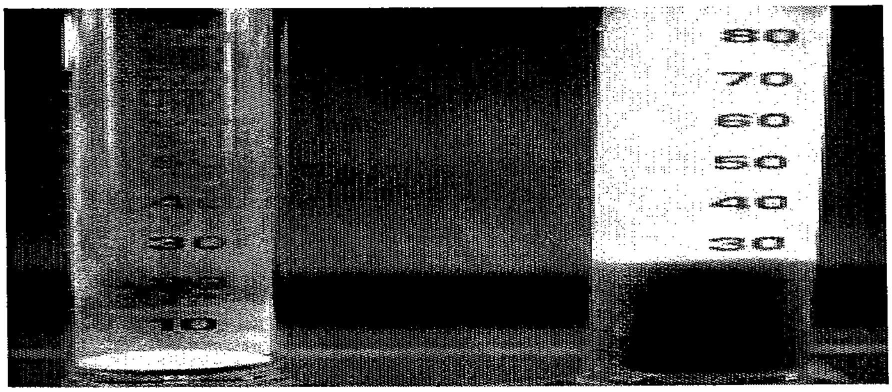
where,

V_d = volume of soil specimen read from the graduated cylinder containing distilled water.

V_k = volume of soil specimen read from the graduated cylinder containing kerosene.

Determination No	Initial Reading		Reading After 24hrs		Free Swell Index
	Kerosene	Distilled Water	Kerosene	Distilled Water	$\frac{[V_d - V_k]}{V_k} \times 100\%$

$$\text{Free swell index} = \frac{V_d - V_k}{V_k} \times 100\%$$



Free Swell Index	Degree of expansiveness	LL	PL	SL
<20	Low	0.50	0-35%	>17%
20-35	Moderate	40-60%	25-50%	8-18%
35-50	High	50-75%	35-65%	6-12%
>50	Very high	>60%	>45%	<10%

Precaution: In the case of highly expansive soils such as Sodium Betonites. The sample size may be 5 grams or alternatively a cylinder of 250ml capacity for 10 grams of sample may be used.

Result:

Differential Free Swell Index of soil =   %