APS College of Engineering

COURSE DETAILS

Course Name **:** Geotechnical Engineering Lab

Course Code **:** 18CVL77

Course Outcomes

Sl. no	Course Outcomes
1	Field identification of the soil.
2	Classify based on index properties.
3	Find OMC and MDD, and assess permeability properties of soil.
4	Shear strength and consolidation parameters to assess strength and deformation characteristics.
5	Insitu shear strength characteristics
TOTAL HOURS OF INSTRUCTION 42 Hours	

LAB INCHARGE : MURALIDHAR.A

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EXPERIMENT – 1: FIELD IDENTIFICATION OF SOIL

AIM: For field identification of soil into common types like sand, gravel, silty or clayey sand, silt, clay and organic soil.

INTRODUCTION: for identifying the soils readily in the field into common types, these are some simple tests which can be performed at the site location itself. These field tests are very helpful and can take the place of laboratory testing of classification.
The most commonly used simple field tests are based on

1. Grain size of soil particles
2. Presence of lack of plasticity
3. Dilatancy
4. Dry strength

SCOPE AND APPLICATION: the field tests are very useful in differentiating silt and clay in the field whose particle sizes are finer than 75 micron IS Sieve also, it helps to determine the consistency of clay in the field.

PROCEDURE:

I. BY GRAIN SIZE OF SOIL PARTICLES:

Sands and gravels can be identified easily by visual inspection as the diameter of fine sand particles are greater than 75 micron IS Sieve and a particle of 0.075mm will settle out of suspension in water quickly with a velocity of 0.51cm/sec. As per stokes equation **($V = (\gamma_{soild} - \gamma_w / 18\ \mu) \times D^2$)** Where D = diameter of the particle in mm and V= velocity of settlement)

STEP A: mix the sample of soil and water in the field, in a test tube or jar thoroughly.

STEP B: measure the time taken for top 10cm to become substantially clear. If it becomes clear in 20 sec the soil is said to have clean fine sand. Otherwise it is termed as silt and / or clay sizes.

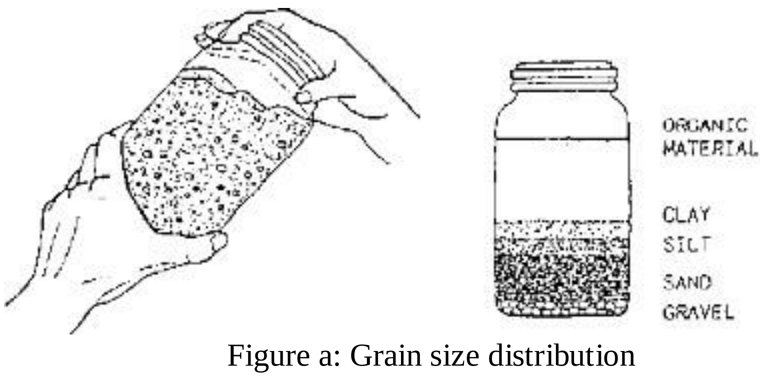


Figure a: Grain size distribution

2. PRESENCE OR LACK OF PLASTICITY: Type your text

Roll the soil into 3mm diameter threads of long length and hold by one hand.
Clay, unlike silts can support when rolled into threads of longer length than silts.
Silt, can be rolled in wet state into thin threads that can support its own weight when the length of the thread is only few cms.

The moisture content at which, soil samples starts crumbling when rolled into a thread of 3mm diameter is called plastic limit (Wp). At moisture content corresponding to this limit silts are soft and feeble, silty clays are harder, but softer than clays. The more plastic the clay the harder and tougher it will be at plastic limit. Because, silt possesses little plasticity, they usually dry after a few minutes of working with fingers.

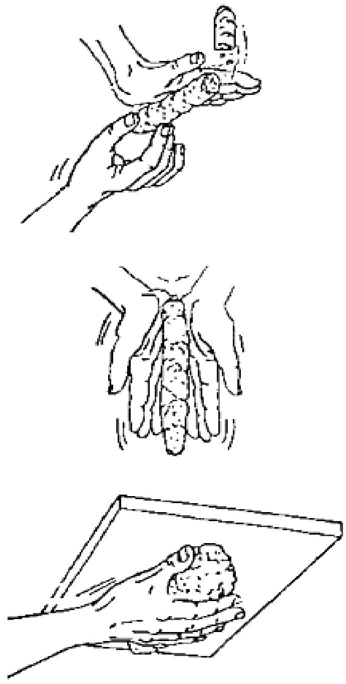


Figure b: Plasticity of Soil.

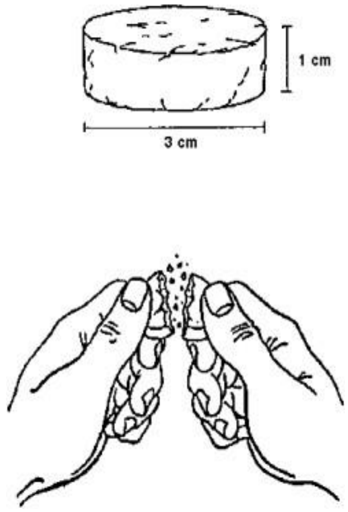


Figure c: Dry Strength of Soil.

3.DILATANCY OR SHAKING OR VOLUME CHANGE TEST:

Place a wet soil on the palm, it appears shining. If the soil is silt, the shiny looks disappear when the palm is cupped. This is because, when the palm is cupped, the soil is squeezed which causes shear deformation and since silt is non-plastic, it causes the soil to expand from low volume and hence water flows into soil to make up for the increased volume of pores.

Clay, being highly plastic and also has very low value of permeability, compared to silt, it will not loose its shiny look when the palm is cupped.

4.DRY STRENGTH TEST:

Air dried silt in lump sizes can be crushed easily by squeezing between the fingers. Dry powder of courser silt gives a gritty feeling when rubbed between fingers as shown in figure c.

Lumps of air dried clays are hard and increase with the increase in plasticity. Hence clays have appreciable dry strength than silt. Thus, soil in question is air dried and its dry strength is estimated by trying it to powder between the fingers.

After conducting these tests we can use the table given below to classify the soil as silt or clay.

Table a: Soil Classification

Typical Name	**Dry Strength**	**Dilatancy Reaction**	**Toughness of plastic thread**	**Time to settling Dispersion test**
Sandy silt	None to very low	Rapid	Weak to friable	30 sec to 60 min
Silt	Very low to low	Rapid	Weak to friable	15 to 60 min
Clayey silt	Low to medium	Rapid to slow	Medium	15 min to several hours
Sandy clay	Low to high	Slow to none	Medium	30 sec to several hour
Silty clay	Medium to high	Slow to none	Medium	15 min to several hour
Clay	High to very high	None	Tough	Several hour to days
Organic silt	Low to medium	Slow	Weak to friable	15 min to several hour
Organic clay	Medium to very high	none	Tough	Several hour to days

EXPERIMENT – 2: DETERMINATION OF MOISTURE CONTENT

AIM: To determine the natural moisture content of the given soil sample.

NEED AND SCOPE OF THE EXPERIMENT:

In almost all soil tests natural moisture content of the soil is to be determined. The knowledge of the natural moisture content is essential in all studies of soil mechanics. To sight a few, natural moisture content is used in determining the bearing capacity and settlement. The natural moisture content will give an idea of the state of soil in the field.

DEFINITION:

The natural water content also called the natural moisture content is the ratio of the weight of water to the weight of the solids in a given mass of soil. This ratio is usually expressed as percentage.

APPARATUS REQUIRED:

1. Non-corrodible air-tight container.
2. Electric oven, maintain the temperature between 1050 C to 1100 C.
3. Balance of sufficient sensitivity.

PROCEDURE:

1. Clean the containers with lid dry it and weigh it (W1).
2. Take a specimen of the sample in the container and weigh with lid (W2).
3. Keep the container in the oven with lid removed. Dry the specimen to constant weight maintaining the temperature between 105^0 C to 110^0 C for a period varying with the type of soil but usually 16 to 24 hours.
4. Record the final constant weight (W3) of the container with dried soil sample. Peat and other organic soils are to be dried at lower temperature (say 60^0) possibly for a longer period.

OBSERVATIONS AND RECORDING:

Data and observation sheet for water content determination

Sl.No.	Sample No.	1	2	3
1	Weight of container with lid W_1 gm			
2	Weight of container with lid +wet soil W_2 gm			
3	Weight of container with lid +dry soil W_3 gm			
4	Water/Moisture content $W = [(W_2 - W_3)/(W_3 - W_1)] \times 100$			

INTERPRETATION AND REPORTING

RESULT

The natural moisture content of the soil sample is _________

GENERAL REMARKS

1. A container without lid can be used, when moist sample is weighed immediately after placing the container and oven dried sample is weighed immediately after cooling in desiccators.

2. As dry soil absorbs moisture from wet soil, dried samples should be removed before placing wet samples in the oven.

EXPERIMENT – 3: DETERMINATION OF SPECIFIC GRAVITY DENSITY BOTTLE

AIM:

Determine the specific gravity of soil fraction passing 4.75 mm I.S sieve by density bottle.

NEED AND SCOPE:

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

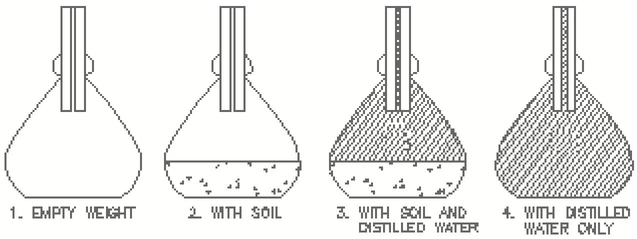
DEFINITION:

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

THEORY:

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

Specific gravity of soil is an important parameter used in calculating void ratio, degree of saturation, unit weight & other properties of soil. Specific gravity of soil solids is determined by 50 ml density bottle in the case of fine grained soils & 500 ml or 1000 ml Pycnometer in the case of coarse grained soils.



APPARATUS REQUIRED:

1. Density bottle of 50 ml with stopper having capillary hole.
2. Balance to weigh the materials (accuracy 10gm).
3. Wash bottle with distilled water.
4. Alcohol and ether.

PROCEDURE:

1. Clean and dry the density bottle
   a. Wash the bottle with water and allow it to drain.
   b. Wash it with alcohol and drain it to remove water.
   c. Wash it with ether, to remove alcohol and drain ether.
2. Weigh the empty bottle with stopper (W_1)
3. Take about 10 to 20 gm of oven soil sample which is cooled in a desiccator. Transfer it to the bottle. Find the weight of the bottle and soil (W_2).
4. Put 10ml of distilled water in the bottle to allow the soil to soak completely. Leave it for about 2 hours.
5. Again fill the bottle completely with distilled water put the stopper and keep the bottle under constant temperature.

6. Take the bottle outside and wipe it clean and dry note. Now determine the weight of the bottle and the contents (W_3).
7. Now empty the bottle and thoroughly clean it. Fill the bottle with only distilled water and weigh it. Let it be W_4.
8. Repeat the same process for 2 to 3 times, to take the average reading of it.

OBSERVATIONS

Sl. No.	Description	1	2	3
1	Weight of density bottle (W_1 g)			
2	Weight of density bottle + dry soil (W_2)			
3	Weight of bottle + dry soil + water at temperature T_x ^{0}C (W_3 g)			
4	Weight of bottle + water (W_4 g)			
5	Specific gravity G = w_2-w_1 / (w_2-w_1)-(w_3 – w_4)			
6	Average specific gravity			

CALCULATIONS

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

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

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

INTERPRETATION AND REPORTING:

Unless or otherwise specified specific gravity values reported shall be based on water at 27^0C. So the specific gravity at 27^0C = K Sp. gravity at T_x^0C.

$$where \quad K = \frac{\text{Density of water at temperature } T_x^0 C}{\text{Density of water at temperature } T_x^0 C}$$

The specific gravity of the soil particles lie within the range of 2.65 to 2.85. Soils containing organic matter and porous particles may have specific gravity values below Soils having heavy substances may have values above 3.0

VIVA QUESTIONS:

1) Define specific gravity?
2) What are the typical values of specific gravity for sandy soil used in the lab?
3) How do you convert the specific gravity at room temperature to the standard temperature 27°C?
4) When do you use Kerosene instead of distilled water for determining specific gravity of the soil?
5) What will happen to the soils kept in the oven at a temperature much higher than 110°C?

Additional Information

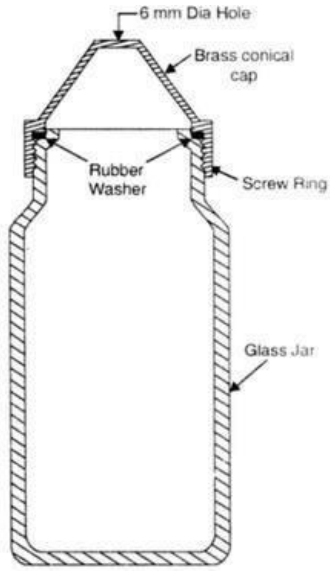
Sand particles composed of quartz have a specific gravity ranging from 2.65 to 2.67. Inorganic clays generally range from 2.70 to 2.80. Soils with large amounts of organic matter or porous particles (such as diatomaceous earth) have specific gravities below 2.60. Some range as low as 2.00.

EXPERIMENT - 3: DETERMINATION OF SPECIFIC GRAVITY BY PYCNOMETER

AIM: To determine the specific gravity of the given soil sample.

APPARATUS:

Balance (capacity not more than 3 Kg), weight box, pycnometer of 500 ml capacity, distilled water and oven



PYCNOMETER

THEORY:

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

PROCEDURE:

Specific Gravity:

1. Take the empty weight of the pycnometer, (W_1)
2. Take sample of fine aggregates for which specific gravity has to be found out (sample must be saturated and free from surface moisture) and transfer that to the empty pycnometer and then it is weighed, W_2
3. The flask with sample is filled with water up to a mark made on the flask and its weight is taken. W_3
4. Then the flask is emptied and thoroughly washed. After washing, the flask is filled with the water up to the mark made on the pycnometer and its weight is taken. The pycnometer should be completely dry on the outer face, W_4
5. Calculate the specific gravity of the fine aggregate sample by formula
6. Specific Gravity = Dry weight of aggregates/weight of equal volume of water

$$= (W_2 – W_1) / [(W_2 – W_1) - (W_3 – W_4)]$$

OBSERVATION AND CALCULATIONS:

	DISCRIPTION	Trial1	Trial 2	Trial 3	Average
Specific Gravity	Mass of empty pycnometer (W_1) gm				
	Mass of pycnometer + fine aggregates (W2) gm				
	Mass of pycnometer + fine aggregates + water, (W3) gm				
	Mass of pycnometer + water, (W_4) gm				

Bulk specific Gravity = Dry weight of aggregates / weight of equal volume of water

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

=

Apparent Specific Gravity = Dry weight of aggregates / (Weight of equal volume of water excluding air voids in aggregates)

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

=

RESULT:

Specific Gravity of given soil sample =

EXPERIMENT – 4: GRAIN SIZE DISTRIBUTION
I. SIEVE ANALYSIS

AIM: To determine the particle size distribution of coarse grained soil, as per **IS: 2720 (Part IV) – 1965.**

OBJECTIVE

(a) Select sieves as per *I.S* specifications and perform sieving.
(b) Obtain percentage of soil retained on each sieve.
(c) Draw graph between log grain size of soil and % finer.

NEED AND SCOPE OF EXPERIMENT

The grain size analysis is widely used in classification of soils. The data obtained from grain size distribution curves is used in the design of filters for earth dams and to determine suitability of soil for road construction, air field etc. Information obtained from grain size analysis can be used to predict soil water movement although permeability tests are more generally used.

APPARATUS

1. Balance
2. I.S sieves
3. Mechanical Sieve Shaker

The grain size analysis is an attempt to determine the relative proportions of different grain sizes which make up a given soil mass.

PROCEDURE

1. Take 1 kg of soil sample by quartering and breaking if any lumps are present.
2. Arrange the sieves in the order of I.S. Sieve size 4.75 mm, 2.36 mm, 1.18 mm, 600 microns, 425 microns, 300 microns, 150 microns and 75 microns by keeping the 4.75 mm size sieve at top and 75 micron at the bottom.
3. Fix them in the sieve shaking machine with the pan at the bottom and cover at the top.
4. Keep the sample in the top sieve, Carry out the sieving in the set of sieves as arranged before for not less than 5 minutes.
5. Weigh the mass retained on each sieve.
6. The grain size of size greater than 75 micron is determined by sieving set sieves of

decreasing order; sieve placed one below the other and separating out the different size ranges. Two methods of sieve analysis are as follows:

1. wet sieving applicable to all soil and
2. Dry sieving applicable only to soil which has negligible proportion of clay and silt.

Fineness Modulus = Cumulative percentage weight retained in sieves / 100 =

OBSERVATIONS AND RECORDING

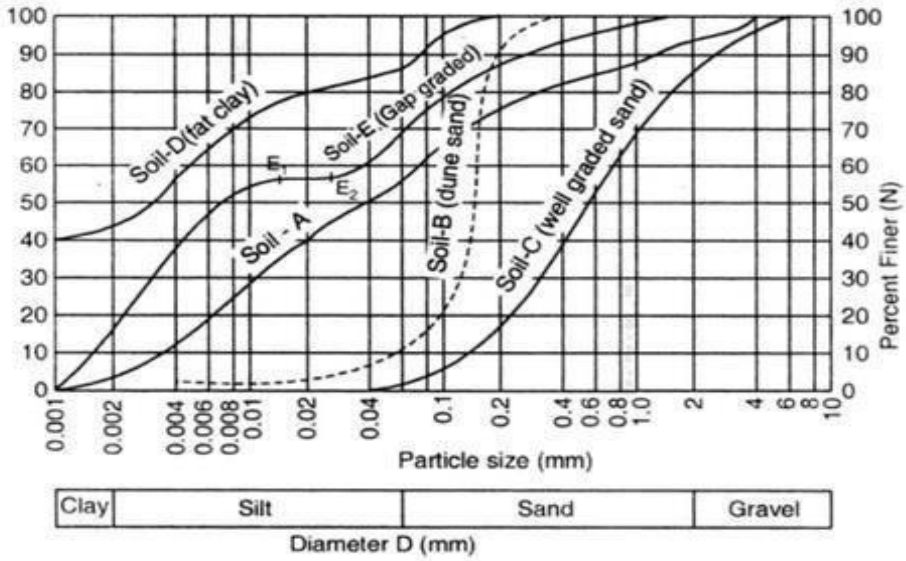
Weight of soil sample =

Moisture content =

I.S sieve number or size in mm	Wt. Retained in each sieve (gm)	Percentage on each sieve	Cumulative % retained on each sieve	% finer	Remarks
4.75					
2.36					
1.18					
600					
425					
300					
150					
75					
			$\sum$C =		

GRAPH

Draw graph between log sieve size vs % finer. The graph is known as grading curve. Corresponding to 10%, 30% and 60% finer, obtain diameters from graph are designated as D_{10}, D_{30}, D_{60}.



Particle Size Distribution Graph

$C_u = (D_{60}/D_{10})$

=

$C_c = (D_{30}^2 / (D_{60} X D_{10}))$

Co-efficient of Permeability $K = C\,(D_{10})^2$

$= 100\,(D_{10})^2$ ………………… cm/sec

(Paste the Graph Sheet Here)

CALCULATION

1. The percentage of soil retained on each sieve shall be calculated on the basis of total weight of soil sample taken.
2. Cumulative percentage of soil retained on successive sieve is found.

VIVA QUESTIONS:-

1) What do you understand by well graded soil, poorly graded soil, gap graded soil and uniformly graded soil?
2) How can you determine the gradations of fine grained soils?
3) Define Uniformity coefficient.
4) What do you understand by coefficient of curvature/gradation?
5) How can you arrive at coefficient of permeability of filter sands using D_{10} of the soil?
6) Explain the following notations / designations of the soil: GW, GP, SW, SP,GM,GC,SM,SC, MH, ML, OL

Additional Information:

- What is wet sieve analysis?

Wet sieving is a procedure used to evaluate particle size distribution or gradation of a granular material. It's also used to prepare a granular material for particle size **analysis** by removing fines that may impede the separation process.

EXPERIMENT – 5: 5.1. DETERMINATION OF CONSISTENCY LIMITS LIQUID LIMIT TEST BY CASAGRENDE'S

AIM: To determine the liquid limit of a given soil sample

OBJECTIVE

1. Prepare soil specimen as per specification.
2. Find the relationship between water content and number of blows.
3. Draw flow curve.
4. Find out liquid limit.

NEED AND SCOPE

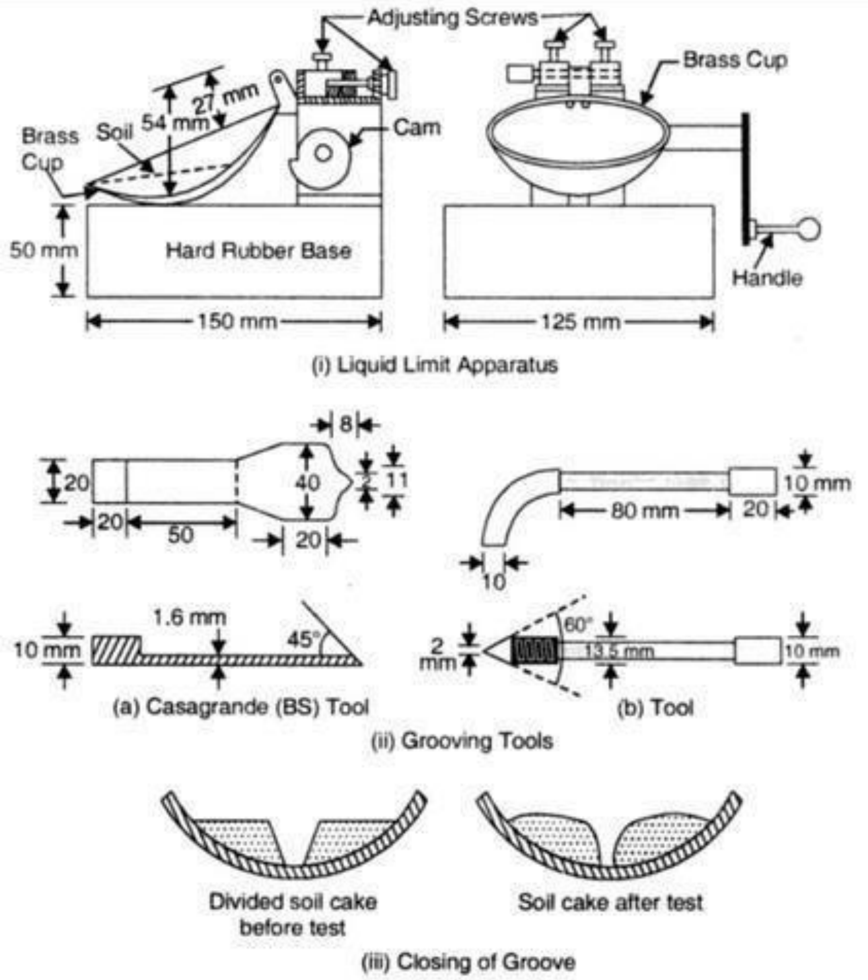
Liquid limit is significant to know the stress history and general properties of the soil met with construction. From the results of liquid limit the compression index may be estimated. The compression index value will help us in settlement analysis. If the natural moisture content of soil is closer to liquid limit, the soil can be considered as soft if the moisture content is lesser than liquids limit, the soil can be considered as soft if the moisture content is lesser than liquid limit. The soil is brittle and stiffer.

THEORY

The liquid limit is the moisture content at which the groove, formed by a standard tool into the sample of soil taken in the standard cup, closes for 10 mm on being given 25 blows in a standard manner. At this limit the soil possess low shear strength.

APPARATUS REQUIRED

1. Balance
2. Liquid limit device (Casagrande's)
3. Grooving tool
4. Mixing dishes
5. Spatula
6. Electrical Oven



Liquid Limit Apparatus

PROCEDURE

1. About 120 gm of air-dried soil from thoroughly mixed portion of material passing 425 micron I.S sieve is to be obtained.
2. Distilled water is mixed to the soil thus obtained in a mixing disc to form uniform paste. The paste shall have a consistency that would require 30 to 35 drops of cup to cause closer of standard groove for sufficient length.
3. A portion of the paste is placed in the cup of liquid limit device and spread into portion with few strokes of spatula.
4. Trim it to a depth of 1cm at the point of maximum thickness and return excess of soil to the dish.
5. The soil in the cup shall be divided by the firm strokes of the grooving tool along the diameter through the centre line of the follower so that clean sharp groove of proper dimension is formed.
6. Lift and drop the cup by turning crank at the rate of two revolutions per second until the two halves of soil cake come in contact with each other for a length of about 1 cm by flow only.
7. The number of blows required to cause the groove close for about 1 cm shall be recorded.

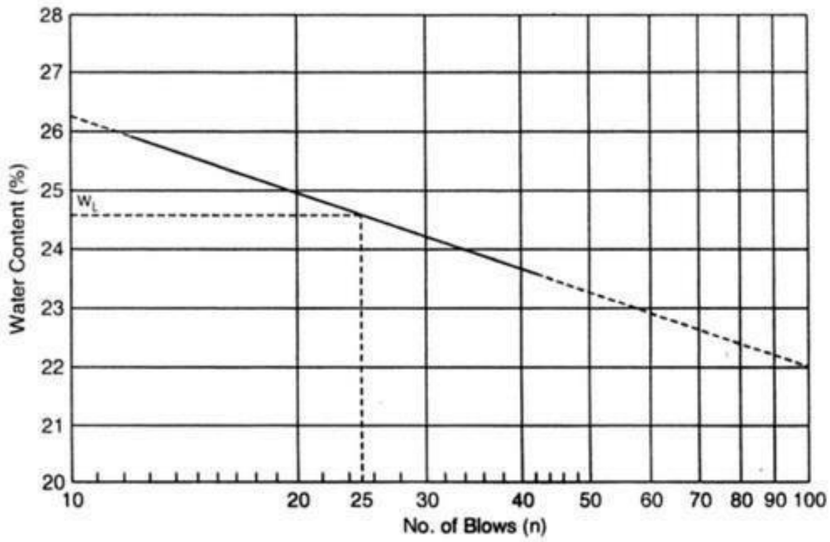
8. A representative portion of soil is taken from the cup for water content determination.
9. Repeat the test with different moisture contents at least three more times for blows between 10 and 40.

OBSERVATIONS

Determination Number	1	2	3	4
Container number				
Weight of container (W_1)				
Weight of container + wet soil (W_2)				
Weight of container + dry soil (W_3)				
Weight of water $W_w = (W_2 - W_3)$				
Weight of dry soil $W_d = (W_3 - W_1)$				
Moisture content (%) = $(W_W/W_D)100$				
No. of blows				

GRAPH

Draw a graph showing the relationship between water content (on y-axis) and number of blows (on x-axis) on semi-log graph. The curve obtained is called flow curve. The moisture content corresponding to 25 drops (blows) as read from the represents liquid limit. It is usually expressed to the nearest whole number.



Specimen Graph: Flow Curve

RESULT: liquid limit of a given soil sample = …………

Flow index (I_F) = W_1-W_2/log (n_2/n_1) = …………………

(Paste the graph sheet here)

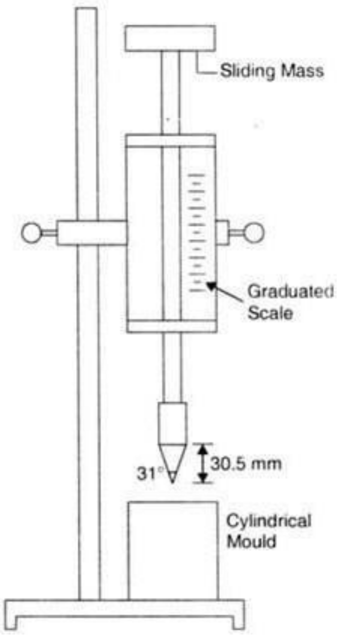
LIQUID LIMIT BY CONE PENETRATION METHOD

THEORETICAL DISCUSSIONS:

The basic principle is to observe depths of penetration of the soil at various moisture content of a metal cone of certain weight and apex angle with a point just touching the surface is allowed to drop into the surface of the soft clayey soil.

APPARATUS/EQUIPMENTS:

Cone penetration device, Balance, Water content cups, oven etc.



Cone Penetration Apparatus

PROCEDURE:

1. Take about 150gm of soil passing through 425micron sieve in a porcelain dish mix with distilled water into a uniform paste.
2. The wet soil paste should be transferred to the cylindrical cup of cone penetration device, ensuring that no air is trapped in this process. Finally level the paste up to the top of the cup and place it on the base of the cone penetration device.
3. Adjust the penetrometer such that the cone point just touches the surface of the soil paste in the cup clamp the device in this position. The initial reading should be adjusted to zero. Release the vertical clamp of the cone to penetrate into the soil paste under its own weight.
4. Record the penetration of the cone after five seconds to the nearest mm. Test should be repeated at least to have 4 sets of penetration values in the range of 14-28 mm.
5. Find out the moisture content of the soil paste for each trail.

OBSERVATIONS:-

Trial	Penetration in (mm)	Cup no	Weight of empty cup (w1)	Wt. Of cup + wet soil (w2)	Wt. Of cup + dry soil (w3)	Water content (w2- w3) / (w3- w1)

GRAPH:

A graph representing water content in the Y-axis and the cone penetration on the X-axis (using semi log sheet) shall be prepared the best fitted line is drawn. The moisture content corresponding to cone penetration of 20 mm shall be taken as the liquid limit of the soil.

(Paste the graph sheet here)

RESULTS:-

Liquid Limit by Cone Penetration Method = _____________

Additional Information

Liquid limit values for types of soil.

Type of soil	Liquid limit
sand	20
silts	27
clay	100

5.2. PLASTIC LIMIT TEST

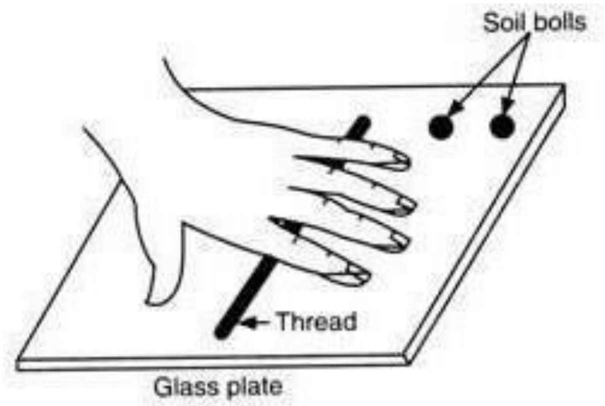
AIM: To determine the plastic limit of a given soil sample.

NEED AND SCOPE:

Soil is used for making bricks, tiles, and soil cement blocks in addition to its use as foundation for structures.

APPARATUS REQUIRED

1. Porcelain dish.
2. Glass plate for rolling the specimen.
3. Air tight containers to determine the moisture content.
4. Balance of capacity 200gm and sensitive to 0.01gm
5. Oven thermostatically controlled with interior of non-corroding material to maintain the temperature around 105^0 and 110^0C.



PROCEDURE

1. Take about 20gm of thoroughly mixed portion of the material passing through 425 micron I.S. Sieve obtained in accordance with I.S. 2720 (part 1).
2. Mix it thoroughly with distilled water in the evaporating dish till the soil mass becomes plastic enough to be easily moulded with fingers.
3. Take about 10gms of this plastic soil mass and roll it between fingers and glass plate with just sufficient pressure to roll the mass into a threaded of uniform diameter throughout its length. The rate of rolling shall be between 60 and 90 strokes per minute.
4. Continue rolling till you get a threaded of 3 mm diameter.
5. Kneed the soil together to a uniform mass and re-roll.
6. Continue the process until the thread crumbles when the diameter is 3 mm.
7. Collect the pieces of the crumbled thread in air tight container for moisture content determination.

8. Repeat the test to at least 3 times and take the average of the results calculated to the nearest whole number.

OBSERVATION AND REPORTING

Compare the diameter of thread at intervals with the rod. When the diameter reduces to 3 mm, note the surface of the thread for cracks.

PRESENTATION OF DATA

Container No.		
Wt. of container + lid, W_1		
Wt. of container + lid + wet sample, W_2		
Wt. of container + lid + dry sample, W_3		
Wt. of dry sample $= W_3 - W_1$		
Wt. of water in the soil $= W_2 - W_3$		
Water content (%) $= (W_2 - W_2) / (W_3 - W_1) \times 100$		

Average Plastic Limit=

Plasticity Index (Ip) = $(W_L - W_P)$ =

Toughness Index =Ip/I_F

Flow index $(I_F) = W_1 - W_2/\log(n_2/n_1)$

Consistency index $I_C = W_L - W/ I_P$

Graph:

Semi log graph is used and plasticity index is taken in the ordinary scale (Y-axis) and Liquid Limit (X-axis).

(Paste the graph sheet here)

VIVA QUESTIONS:-

1) What are the practical applications of liquid limit, plastic limit and plasticity index of soils?
2) Why do you use the soil passing from 425µ IS sieve to determine L.L., P.L. & S.L.?
3) If a thread of 5mm is made instead of 3mm, then what is the effect of P.L.?
4) What is the degree of saturation of a soil at P.L.?
5) What is the degree of saturation of a soil at S.L.?
6) Does volume increase on addition of water at S.L.?
7) What are the factors affecting the value of S.L.?
8) What is the effect of air bubbles on S.L.?
9) Why do you use mercury to determine the volume of wet and dry soil pat? Can you use any other material?

5.3 SHRINKAGE LIMIT TEST

OBJECTIVE:
To determine the shrinkage limit and calculate the shrinkage ratio for the given soil.

THEORY:

As the soil loses moisture, either in its natural environment, or by artificial means in laboratory it changes from liquid state to plastic state, from plastic state to semi-solid state and then to solid state. Volume changes also occur with changes in water content. But there is particular limit at which any moisture change does not cause soil any volume change.

NEED AND SCOPE:

Soils which undergo large volume changes with change in water content may be troublesome. Volume changes may not and usually will not be equal.

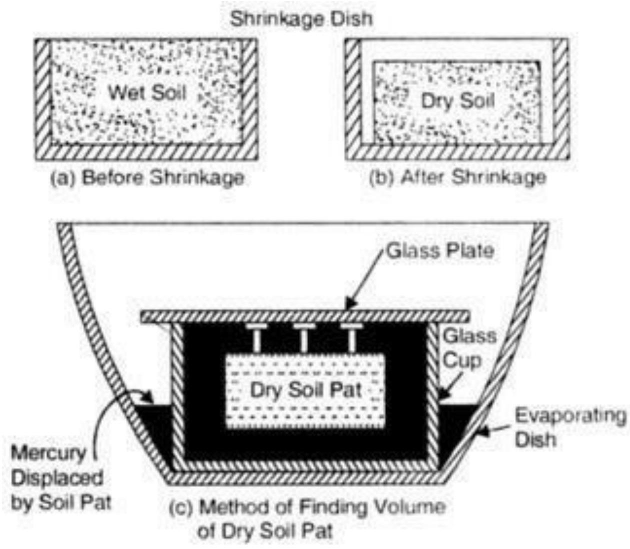
A shrinkage limit test should be performed on a soil.

1. To obtain a quantitative indication of how much change in moisture can occur before any appreciable volume changes occurs
2. To obtain an indication of change in volume.

The shrinkage limit is useful in areas where soils undergo large volume changes when going through wet and dry cycles (as in case of earth dams)

APPARATUS:

1. Evaporating Dish. Porcelain bowl about 12cm diameter with flat bottom.
2. Spatula
3. Shrinkage Dish. Circular, porcelain or non-corroding metal dish (3 nos) having a flat bottom and 45 mm in diameter and 15 mm in height internally.
4. Straight Edge. Steel, 15 cm in length.
5. Glass cup. 50 to 55 mm in diameter and 25 mm in height , the top rim of which is ground smooth and level.
6. Glass plates. Two, each 75X75 mm one plate shall be of plain glass and the other shall have prongs.
7. Sieves. 2mm and 425- micron IS sieves.
8. Oven-thermostatically controlled.
9. Graduate-Glass, having a capacity of 25 ml and graduated to 0.2 ml and 100 cc one mark flask.
10. Balance-Sensitive to 0.01 g minimum.
11. Mercury. Clean, sufficient to fill the glass cup to over flowing.
12. Wash bottle containing distilled water.



Shrinkage Limit Apparatus

PROCEDURE

Preparation of soil pat

1. Take about 100 gm of soil sample from a thoroughly mixed portion of the material passing through 425-micron I.S. sieve.
2. Place about 30 gm the above soil sample in the evaporating dish and thoroughly mixed with distilled water and make a creamy paste. Use water content somewhere around the liquid limit.

Filling the shrinkage dish

3. Coat the inside of the shrinkage dish with a thin layer of Vaseline to prevent the soil sticking to the dish.
4. Fill the dish in three layers by placing approximately 1/3 rd of the amount of wet soil with the help of spatula. Tap the dish gently on a firm base until the soil flows over the edges and no apparent air bubbles exist. Repeat this process for 2nd and 3rd layers also till the dish is completely filled with the wet soil. Strike off the excess soil and make the top of the dish smooth. Wipe off all the soil adhering to the outside of the dish.
5. Weigh immediately, the dish with wet soil and record the weight.
6. Air- dry the wet soil cake for 6 to 8hrs, until the colour of the pat turns from dark to light. Then oven-dry the constant weight at 105^0C to 110^0C say about 12 to 16 hrs.

7. Remove the dried disk of the soil from oven. Cool it in a desiccator. Then obtain the weight of the dish with dry sample.
8. Determine the weight of the empty dish and record.
9. Determine the volume of shrinkage dish which is evidently equal to volume of the wet soil as follows. Place the shrinkage dish in an evaporating dish and fill the dish with mercury till it overflows slightly. Press it with plain glass plate firmly on its top to remove excess mercury. Pour the mercury from the shrinkage dish into a measuring jar and find the volume of the shrinkage dish directly. Record this volume as the volume of the wet soil pat.

Volume of the Dry Soil Pat

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

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

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

CALCULATION

First determine the moisture content

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

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

V = Volume of wet soil pat in cm3

$V0$ = Volume of dry soil pat in cm3

$W0$ = Weight of oven dry soil pat in gm.

CAUTION

Do not touch the mercury with gold rings.

TABULATION AND RESULTS

Sl.No	Determination No.	1	2	3
1	**W.C OF WET SOIL PAT**			
	1. Wt. of container in gm,W_1			
	2. Wt. of container + wet soil pat in gm,W_2			
	3. Wt. of container + dry soil pat in gm,W_3			
	W.C= (W2-W3/ W3-W1) x 100			
2	**VOLUME OF WET SOIL PAT (Vw)**			
	1 Wt. of Shrinkage dish only(w4)			
	2 Wt. of dish + Mercury(W5)			
	3. Wt. of mercury only (W_M)= (W5-W4)			
	Volume of wet soil pat = W_m/13.6 cc			
3	**By mercury displacement method**			
	VOLUME OF DRY SOIL PAT(Vd)			
	1 Weight of Porcine bowl only (W6)			
	2 weight of bowl + displaced mercury (W7)			
	3.Weight of mercury only (W_m)= W7-W6			
	Volume of dry soil pat = W_m/13.6 cc			
4	**Weight of dry soil pat** Wd = ... gm			

5	**Shrinkage limit** (Ws) Ws = [WC – {(Vw –Vd) / Wd}] x 100			
6	**Shrinkage ratio** (S_R) SR = [Wd / (Vd x γw)] x 100 γw = 1 g/cm3			
7	**Volumetric shrinkage** (Vs) Vs = (WC – Ws) x SR			
8	**Linear shrinkage** (LS) LS = 100[1 – {100/(Vs + 100)}1/3]			

RESULT: Shrinkage limit of a given soil sample ………………………………

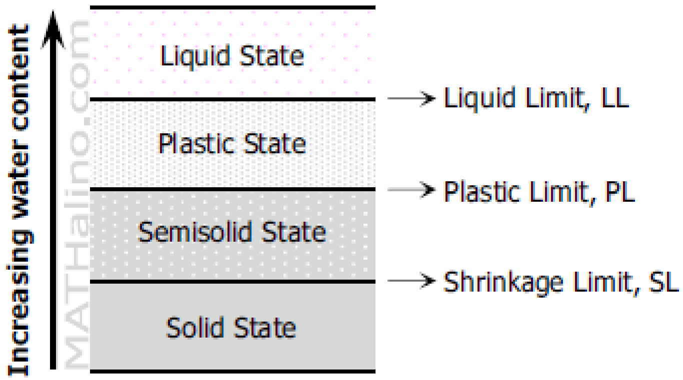


Figure: Atterber limits

EXPERIMENT – 6: IN SITU DENSITY BY CORE CUTTER AND SAND REPLACEMENT METHOD

OBJECTIVE:

Determination of field density of soil by

I. Core cutter method
II. Sand replacement method

CORE CUTTER METHOD.

APPARATUS /EQUIPMENTS:

Cylindrical core cutter made of steel (100mm dia approximately 130mm height), steel dolly 25mm height and 100mm dia, hammer with steel rod, knife, and balance container for water content determination.

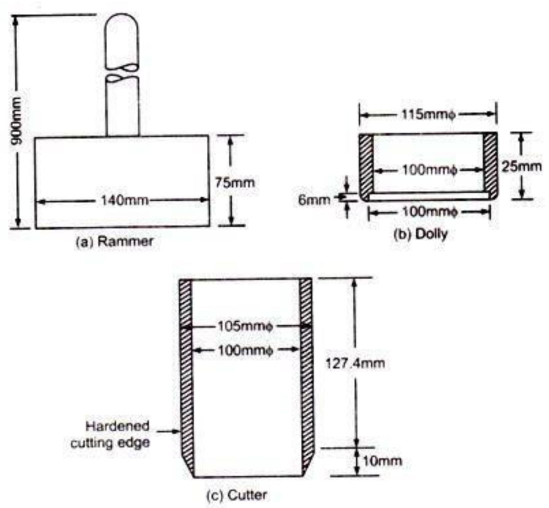
THEORETICAL DISCUSSIONS:-

For quality control of earth constructions like embankments, roads, air fields' etc.measurements of In situ density is essential. In the core cutter method the weight of the soil in the core cutter when divided by the volume of the core cutter gives the density of soil in situ.

Core Cutter method – is used to determine the field density of soft soils like clay soils or other cohesive soils which are placed as fills. This method cannot be used for **coarse grained soil** since the core cutter does not penetrate through them due to high resistance at the tip of the instrument.

PROCEDURE:

1) Inner diameter of core cutter is measured and weighed.
2) Small area of about 30sq.cm is chosen and levelled. Dolly is fixed on top of the core cutter and the whole assembly is driven into the soil until the top of dolly protrudes about 1.5cm above the surface.
3) With the help of straight edge the cutter is dugout from soil and the end of cutter is trimmed flat .Other end of the dolly is removed and trimmed off.
4) Cutter full of soil is weighed.
5) The soil sample is kept in oven for 24hrs to determine the water content.
6) The average wet and dry density values are obtained by repeating the test at 2 or 3 nearby locations.



Core Cutter

OBSERVATIONS:

1	Weight of core cutter(W1)			
2	Weight of core cutter + soil(W2)			
3	Weight of wet soil (W3)			
4	Diameter of core cutter (d)			
5	Height of core cutter (h)			
6	Volume of core cutter V =[(π D^2 / 4) H]			
7	Bulk Density γb = (W3 / V) g/cm^3			
8	Container number			
9	Weight of Empty container (w4)			
10	Weight of container + wet soil (w5)			
11	Weight of container + dry soil (w6)			
12	Water content WC = [W5 – W6 / W6 – W4] X 100			
13	Dry Density γd = (γb/ 1+ WC) g/cm^3			

RESULT

Bulk density = _____________

Dry density = ______________

SAND REPLACEMENT METHOD

OBJECTIVE:

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

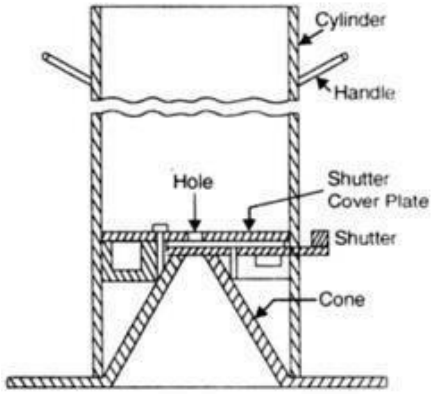
NEED AND SCOPE:

The in situ density of natural soil is needed for the determination of bearing capacity of soils, for the purpose of stability analysis of slopes, for the determination of pressures on underlying strata for the calculation of settlement and the design of underground structures.

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

1. **APPARATUS REQUIRED**:

1. Sand pouring cylinder of 3 litre/16.5 litre capacity mounted above a pouring come and separated by a shutter cover plate.
2. Tools for excavating holes; suitable tools such as scraper tool to make a level surface.
3. Cylindrical calibrating container with an internal diameter of 100 mm/200 mm and an internal depth of 150 mm/250 mm fitted with a flange 50 mm/75 mm wide and about 5 mm surrounding the open end.
4. Balance to weigh unto an accuracy of 1g.
5. Metal containers to collect excavated soil.
6. Metal tray with 300 mm/450 mm square and 40 mm/50 mm deep with a 100 mm/200 mm diameter hole in the centre.
7. Glass plate about 450 mm/600 mm square and 10mm thick.
   8. Clean, uniformly graded natural sand passing through 1.00 mm I.S.sieve and retained on the 600micron I.S.sieve. It shall be free from organic matter and shall have been oven dried and exposed to atmospheric humidity.
8. Suitable non-corrodible airtight containers.
9. Thermostatically controlled oven with interior on non-corroding material to maintain the temperature between 105^0C to 110^0C.
10. Desiccators with any desiccating agent other than sulphuric acid.



THEORY

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

$$\gamma_d = \gamma_b /(1+w)$$

γ_d = Dry Density

γ_b = Bulk Density

W = Water Content

PROCEDURE

Calibration of the Cylinder

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

2. Allow the sand of volume equal to that of the calibrating container to run out of the cylinder by opening the shutter, close the shutter and place the cylinder on the glass sand takes place in the cylinder close the shutter and remove the cylinder carefully. Weigh the sand collected on the glass plate. Its weight (W_2) gives the weight of sand filling the cone portion of the sand pouring cylinder.

Repeat this step at least three times and take the mean weight (W_2) Put the sand back into the sand pouring cylinder to have the same initial constant weight(W_1)

Determination of Bulk Density of Soil

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

4. Place the sand poring cylinder centrally on the of the calibrating container making sure that constant weight (W_1) is maintained. Open the shutter and permit the

sand to run into the container. When no further movement of sand is seen close the shutter, remove the pouring cylinder and find its weight (W_3).

Determination of Dry Density of Soil in Place

5. Approximately 60 Sqcm of area of soil to be tested should be trimmed down to a level surface, approximately of the size of the container. Keep the metal tray on the level surface and excavate a circular hole of volume equal to that of the calibrating container. Collect all the excavated soil in the tray and find out the weight of the excavated soil (W_w).

6. Remove the tray, and place the sand pouring cylinder filled to constant weight so that the base of the cylinder covers the hole concentrically. Open the shutter and permit the sand to run into the hole. Close the shutter when no further movement of the sand is seen. Remove the cylinder and determine its weight (W_3).

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

OBSERVATIONS AND CALCULATIONS

SL. No.	**Sample Details** / **Calibration**	**1**	**2**	**3**
	Weight of sand in cone			
	Weight of sand + cylinder before pouring W_1 gm			
	Weight of sand + cylinder after pouring W_2 gm			
	Weight of sand in cone portion $C_{one} = (W1 – W2)$			
	Bulk density of standard sand			
	Volume of calibrating container (V) in cc			
	Mean weight of cylinder + sand after filling the container W3			
	Weight of the sand filling the calibrating container $W^1 = (W1 – W3 - W_{cone})$			
	Bulk density of sand $\gamma_s = W^1 / V$ gm/cc			
Sl. No.	**Bulk Density of Soil**	**1**	**2**	**3**
	Weight of wet soil from hole W_{SOIL} gm			
	Weight of sand + cylinder after pouring W_4 gm			
	Weight of sand in hole $W^{II} = (W_1 - W_4 - W_{CONE})$ gm			
	Volume of the hole (Vh) = W^{II} / γ_s			
	Bulk density of soil $\gamma_b = (W_{soil}/Vh) \} \gamma_s$ gm/cc			
	Water content determination			

	Container number			
	Weight of container only (W1)			
	Weight of container + wet soil (W2)			
	Weight of container + dry soil (W3)			
	Moisture content (%) = W2 – W3 / W3- W1			
	Dry density $\gamma_d = \gamma_b / (1+w)$ gm/cc			

GENERAL REMARKS

1. While calibrating the bulk density of sand great care has to be taken.
2. The excavated hole must be equal to the volume of the calibrating container.

VIVA QUESTIONS:

1) What are the advantages & disadvantages between the core cutter method and sand replacement method?
2) Which method is better suited for determination of In situ density?
3) What do you understand by the notations γ_t, γ_{d}, γ_{sat} and γ_b?
4) What is the role of standard sand in sand replacement method?

EXPERIMENT 7: STANDARD PROCTOR COMPACTION TEST

DEFINITION:

The Proctor compaction test is a laboratory method of experimentally determining the optimal moisture content at which a given soil type will become most dense and achieve its maximum dry density.

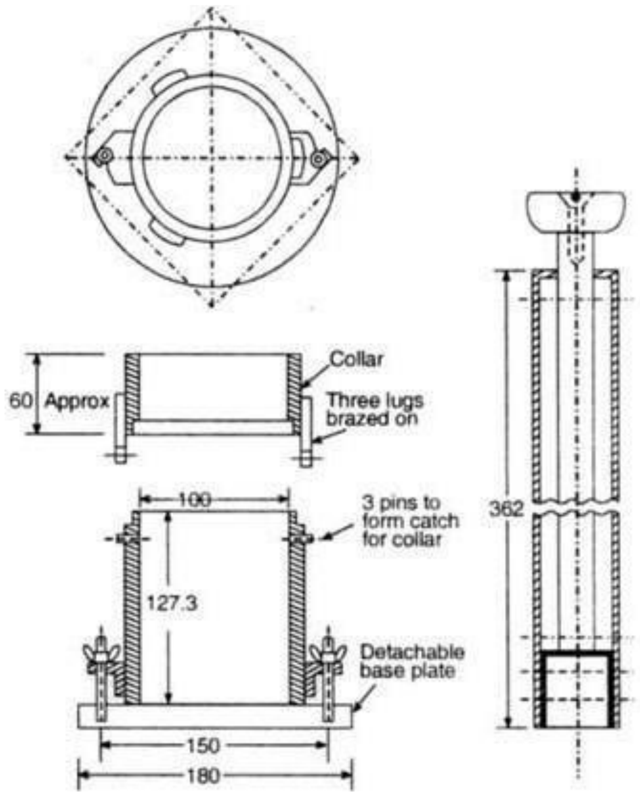
OBJECTIVE:

Compaction can be applied to improve the properties of an existing soil or in the process of placing fill. The main objectives are to:

- Increase shear strength and therefore bearing capacity
- Increase stiffness and therefore reduce future settlement
- decrease voids ratio and so permeability, thus reducing potential frost heave

APPARATUS/EQUIPMENTS:

Standard Proctor mould, Modified Proctor mould, Sample extruder, Balances-one with capacity 10Kg sensitive to 1g & other with capacity 200g sensitive to 0.01g,oven,water content containers, steel straight edge,4.75 mm IS sieve, Metallic rammers, Mixing Tools such as big tray, spoon, trowel, spatula etc.



Standard Proctor Test

THEORETICAL DISCUSSIONS:

Compaction of soil can be achieved by rolling, vibrating and damping of the soil which is essential during the construction of earth dams, embankments etc;The factors which affect the compaction of soil are the type of soil, method of compaction, energy inputs and the water content. Proctor demonstrated that for a given soil and comp active energy, the dry density attained is a maximum at a particular water content called Optimum Moisture Content (OMC).

PROCEDURE:-

1) Measure the internal dimensions of the Proctor mould and thus calculate its volume (V).
2) Weigh the weight of the empty mould & base plate (W_1).Smear with a thin layer of oil the inner surface of the base plate, Proctor’s mould and its collar.
3) Take 3 Kg of soil passing through 4.75mm IS sieve in a large tray. Add enough water to bring its water content up to 7 %(sandy soil) or 10 %(clayey soil) less than the probable OMC of the soil.
4) Attach the collar and base plate to the Proctor’s mould.
5) Mix the matured wet soil thoroughly. Take about 3 Kg of soil and compact it in the Proctor’s mould in 3 equal layers, each layer being given 25 blows from the rammer weighing 2.6Kg, dropping from a height of 310mm in the case of Standard Proctor mould. In the case of Modified Proctor mould a bigger mould of capacity 2250ml is used. In case of Modified Proctor test 5 Kg of soil should be taken and should be compacted in 5 equal layers. The base plate is detached and the mould is weighted with compacted soil (W_2). Each layer given 56 blows from the rammer weighing 2.6 Kg dropping from a height of 310mm.
6) Remove the collar and cut the excess soil with the help of straight edge. Clean the mould from outside and weigh to the nearest gram. Take out the soil from the mould. Cut it in the middle and keep a representative soil specimen for Water content determination.
7) Repeat the steps 5 & 6 for about 5 or 6 times using a fresh part of soil by adding a higher Water content than the preceding specimen.

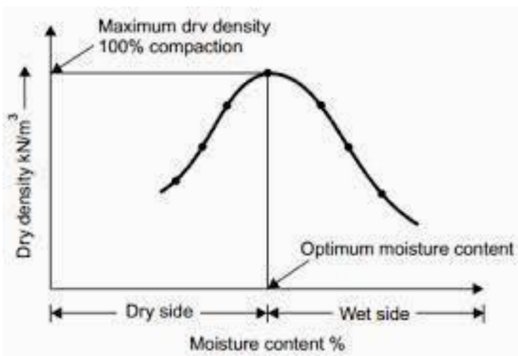
OBSERVATION AND CALCULATION

Weight of soil =
Weight of mould + base plate =
Height of the mould (H) =
Diameter of the mould =
Volume of the mould (π d^2 / 4) H

Bulk Density			
Water to be added (percent)			
Weight of mould only (W1)			
Weight of Mould + compacted soil (W2) gms			
Weight of soil only (Ws)			
Bulk density of soil: γb = Ws / V (gm /cc)			
Water content			
Container No.			
Weight of cup only (W1)			
Wt. Of container + wet soil gms.(W2)			
Wt. Of container + dry soil gms (W3)			
WATER CONTENT W = W2 – W3 / W3 – W1 (%)			
Dry Density of Soil			
γd = (γb / 1 + W) gm /cc			

Graph:

Plot the graph of dry density along Y- axis v/s water content along X- axis to determine Max Dry Density (MDD) and Optimum Moisture Content (OMC).



VIVA QUESTIONS:-

1) On what factors would OMC depend for a given soil? Explain.
2) What are the different types of rollers that are used for compaction work in the field?
3) How do you control the quality of work done in field compaction projects?
4) Distinguish clearly between compaction & consolidation.

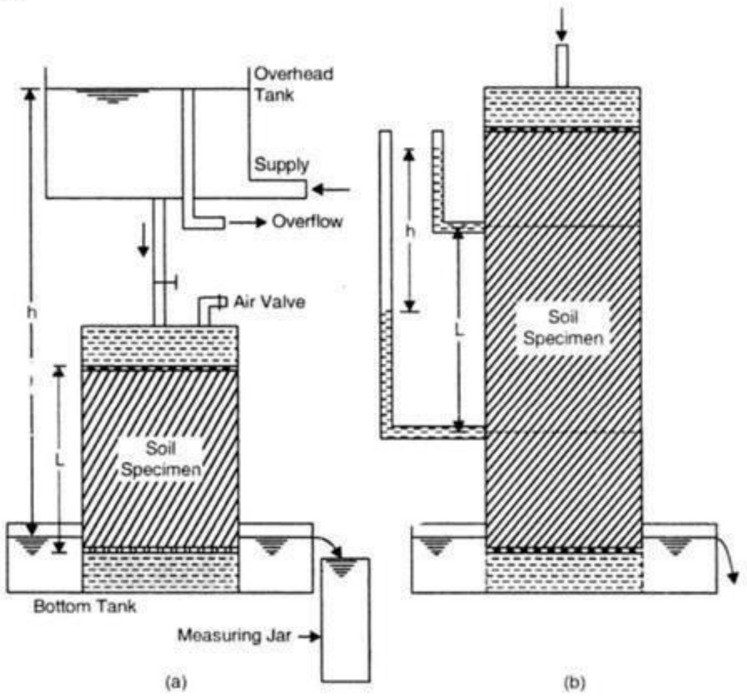
EXPERIMENT – 8: CO-EFFICIENT OF PERMEABILITY BY CONSTANT HEAD AND VARIABLE HEAD METHODS

OBJECTIVE:

To determine the co-efficient of permeability of coarse grain soils by the constant head method and the co-efficient of permeability of fine grained by the variable head methods.

APPARATUS / EQUIPMENTS:

A suitable water reservoir for supplying constant head, a set of stand pipe for variable head test permeameter, mixing tank, balance, stopwatch, water content cans.



Constant Head Apparatus

THEORETICAL DISCUSSIONS:

The property of the soil which permits water to percolate through its voids is called permeability according to Darcy's law in the laminar range; the velocity of flow is proportion to the hydraulic gradient.

CONSTANT HEAD PERMEABILITY TEST:-

$V \propto i$

$V=Ki$

$AV=KAi$

$AV=$ flow rate $= Q = KAi$

$K = QL/hAt$ m / sec

$i =$ hydraulic gradient $= h/L$

A = cross section of soil mass perpendicular to the direction of flow,
V = velocity of flow,
h = head loss in a distance L along the flow path.

PROCEDURE:

I. CONSTANT HEAD METHOD:

a) Preparation Of Specimen:

1) Take about 800-1000gm of soil and mixed with water so that its water content rises to optimum water content.
2) Grease the mould. Assemble the dynamic permeameter. Place the mould upside down on the dynamic compaction base and weigh the assembly. Put 3cm collar to the other end.
3) Compact the wet soil in 2-layers by applying 15 blows to each layer with 2.5kg ramming rod. Remove the collar and trim off the excess soil and weigh the assembly filled with soil and determine the weight of the soil,(W).
4) Place the filter paper or fine wire mesh on the top of specimen and fix the perforated base plate on it.
5) Turn the specimen upside down. Remove the compaction plate and place the porous stone on the top of the specimen and fix up the sealing a top cap.

b) Saturation of compacted specimen:

Place the permeameter mould in the vacuum desiccators at the open air valve. Fill the desiccators with desired water such that it reaches the well above the top cap. Apply the vacuum and increase gradually to about 70cm of Hg.

TESTING:-

1) Place the mould in the bottom tank and fill it with water up to its outlet. Connect the outlet of constant head tank to the inlet of permeameter.
2) Adjust the head by either adjusting the Relative height of mould and constant head tank or by rising or by lowering the air intake tube within the head tank.
3) Run the test for some convenient time interval.
4) Note the duration of test by stop watch. Collect the water (V-cc) in a beaker flowing from outlet of bottom tank and measure it.

OBSERVATIONS:-

h = head causing flow.
L = Internal length of permeameter
t = time in seconds
Q= total volume of water collected in t, sec
D = Internal dia of permeameter
A = Internal area of permeameter

V = Internal volume of permeameter

$\frac{W_S}{V}$ = Bulk unit weight (γb)

w= water content

Dry unit weight (γd) = $\frac{(\gamma b)}{1+w}$

Hydraulic gradient, i= h /L

Coefficient of Permeability of soil, K = Q / h At

Seepage velocity (Vs) = (1+ e/e)

Void ratio e = $(G\ \gamma_W / \gamma d) - 1$

Porosity (n) = **e / (1+e)**

Co efficient of percolation Kp = k / n

Head causing flow (h)	Time taken to collect water (t)	Discharge Q = Volume of water / t (cc / sec)	Coefficient of permeability K = (cc / sec)	Average value K (cc / sec)

RESULT:-

K =

VARIABLE HEAD PERMEABILITY TEST:-

According to Darcy's law

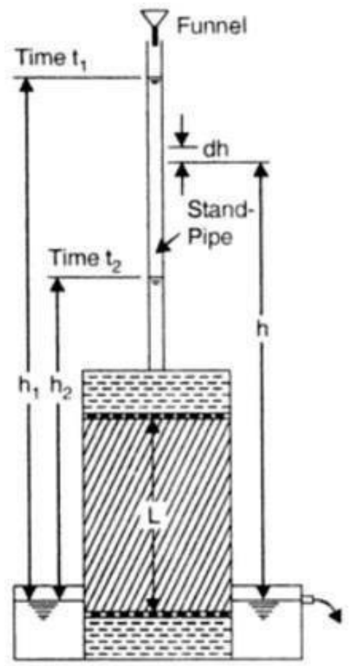
K = 2.303 [(aL / At) $\log_{10}$ (H1/H2)]

Where a = cross section area of stand pipe,

t = time of flow, = $t_2 - t_1$

H_1 = initial head, H_2 = final head.

II. VARIABLE HEAD METHOD OR FALLING HEAD METHOD:



Falling Head Setup

a) Preparation and saturation of specimen are same as that of constant head method**.**

b) TESTING:-

1) Keep the permeameter mould assembly in the bottom tank and fill it up to its outlet.
2) Connect inlet of mould to the stand pipe filed with water. Permit water to flow for some time until steady state of flow is reached.
3) Note the time required for water level in the stand pipe to fall from some initial value to some final value.
4) Repeat the step (3) for 2 or 3 times for same initial and head values.

c) Determination of (a):

Collect water contained in between 2 graduations [of the stand pipe] of known distance apart, weigh it and determine the inside area of stand pipe.

OBSERVATIONS:-

D = internal dia of permeameter =
A = Internal cross area of permeameter =
L = internal Length of permeameter =
V = internal volume of permeameter =
d= internal diameter of stand pipe =
a= internal area of stand pipe =
h_1= initial head in stand pipe =
h_2 = final head in stand pipe =

Weight of empty permeameter (W1) =
Weight of permeameter (W2) =
Weight of soil = W2 – W1
Dry density γd = (W2 – W1 / V)
Void ratio e = ($G \gamma_W / \gamma d$) – 1
Porosity (n) = **e / (1+e)**

CALCULATIONS:-

K_T= 2.303[(aL/A (t2 – t1) X Log_{10} (h_1/h_2)] =

RESULT:-

K =

PRECAUTIONS:-

Increase the conclusion slowly and in every increment sufficient time should be given to escape the air bubbles off the specimen without vibrating the specimen.

LIMITATIONS:-

Generally this apparatus is used for fine grained soils only.

Typical Values of K

SL.No	Soil type	Coefficient of permeability(cm/sec)
1	Gravel	1 to100
2	Sand	$10^{-3}$to 1
3	Silt	10^{-6} to 10^{-3}
4	Clay	< 10^{-6}

VIVA QUESTIONS:-

1) How does the pore affect the permeability?
2) Does cohesion of soil play any role in the determination of permeability?
3) Compare the values of permeability obtained from both the methods and state
4) The probable cause for any difference in the two values.
5) Does temperature play any significant role in computing K?

EXPERIMENT – 9: UNCONFINED COMPRESSION TEST

AIM: To determine shear parameters of cohesive soil

NEED AND SCOPE OF THE EXPERIMENT

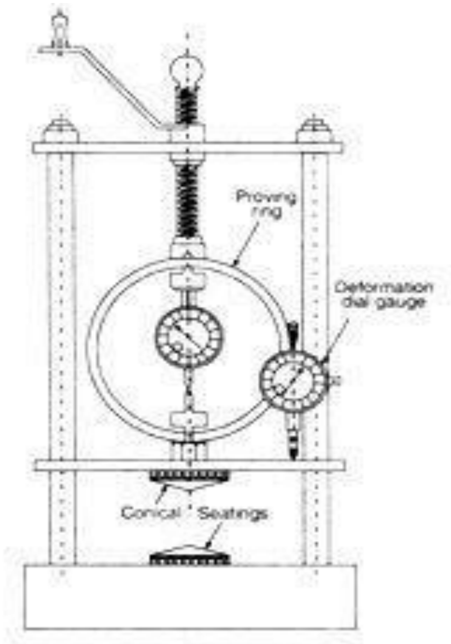
It is not always possible to conduct the bearing capacity test in the field. Sometimes it is cheaper to take the undisturbed soil sample and test its strength in the laboratory. Also to choose the best material for the embankment, one has to conduct strength tests on the samples selected. Under these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

PLANNING AND ORGANIZATION

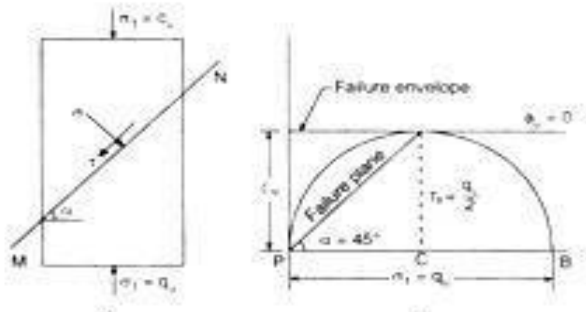
We have to find out the diameter and length of the specimen.

EQUIPMENT

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



(a) The unconfined compression tester



(b) (c)

EXPERIMENTAL PROCEDURE (SPECIMEN)

1. In this test, a cylinder of soil without lateral support is tested to failure in simple compression, at a constant rate of strain. The compressive load per unit area required to fail the specimen as called unconfined compressive strength of the soil.

PROCEDURE

1) The mould which is to be filled with sample, oiled in advance and is filled with mixture of soil and water which is to be tested .The internal diameter of the mould is same as the specimen which is to be tested .The mould is opened carefully and sample is taken out.
2) 3 identical samples are prepared for tests.
3) The initial length and diameter of the specimen is measured.
4) The specimen is placed on bottom plate of loading device and the upper plate is adjusted to make contact with the specimen and the dial gauge is set to zero.

5) The sample is compressed until cracks are developed or until a Vertical deformation of 20% is reached in the dial gauge at its peak of stress-strain curve is well passed.
6) Repeat the steps from 2 to 5 for other soil samples also.
7) The water content of each sample is determined.

OBSERVATION

Specific gravity (G_S) 2.71
Bulk density (γb) .... g/cc
Least count of dial gauge = 0.01mm
Proving ring constant = 0.4077 kg
Water content .... %
Diameter (D_o) of the sample .... mm
Area of cross-section = ... mm^2
Initial length (L_o) of the sample = ... mm

SL. No.	SAMPLE NO.	LOAD (Kg)		DEFORMATION (mm) ΔL		STRAIN (€) (%)	A= (A_0/1-€) (cm^2)	STRESS (Kg/cm^2)
		div	P= DIV x PRC	DIV	ΔL = DIV x LC	$\Delta L/L$		P / A

Interpretation and Reporting
Unconfined compression strength of the soil = q_u =
Shear strength of the soil = $q_u/2$ =
Sensitivity = (q_u for undisturbed sample)/ (q_u for remoulded sample).

General Remarks

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

VIVA QUESTIONS:-

1) Why is this test possible for cohesive soil only?
2) Why is it called quick test?
3) When do you notice a brittle failure while conducting the unconfined compressive strength test on cohesive soil?
4) When do you observe a bulging failure while conducting the UCC test on cohesive soils?

EXPERIMENT – 10 : DIRECT SHEAR TEST

AIM: To determine the shearing strength of the soil using the direct shear apparatus.

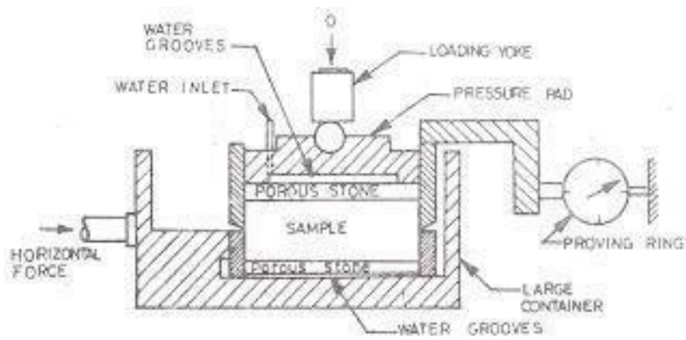
NEED AND SCOPE

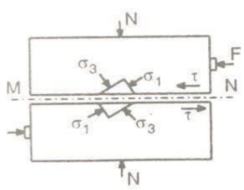
In many engineering problems such as design of foundation, retaining walls, slab bridges, pipes, sheet piling, the value of the angle of internal friction and cohesion of the soil involved are required for the design. Direct shear test is used to predict these parameters quickly. The laboratory report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

PLANNING AND ORGANIZATION

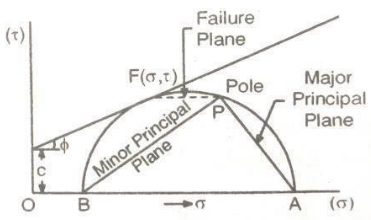
Apparatus

1. Direct shear box apparatus
2. Loading frame (motor attached).
3. Dial gauge.
4. Proving ring.
5. Tamper.
6. Straight edge.
7. Balance to weigh up to 200 mg.
8. Aluminum container.
9. Spatula.





(b) Principle of direct shear box



(c) Mohr's envelope and principal stresses during the test

KNOWLEDGE OF EQUIPMENT:

Strain controlled direct shear machine consists of shear box, soil container, loading unit, proving ring, dial gauge to measure shear deformation and volume changes. A two piece square shear box is one type of soil container used. A proving ring is used to indicate the shear load taken by the soil initiated in the shearing plane.

PROCEDURE

1) Measure the dimensions of the shear box and calculate the area of cross section (A).
2) Insert the locking keys of the shear box.
3) Weigh a dish containing dry cohesionless soil to be tested. Place the bottom grip plate. Place the soil in the shear box kept on a plane surface, tamp it gently and make a level surface. Keep the top grip plate. Weigh the dish again and get the weight of the soil used.
4) Determine the thickness of soil specimen including the thickness of grip plates by measuring the total height of the shear box and the height above the top grip plate. There shall be sufficient thickness of the soil sample above the potential horizontal failure plane.
5) Place the loading block on top of the grip plate.
6) Apply the desired normal load namely, 0.5, 1.0, 1.5 and 2.0 kg/cm^2, one after the other, in the available machine.
7) Fix the dial gauges to measure the horizontal and vertical movements. Note the initial readings.
8) Remove the locking keys of the shear box without forgetting.
9) Apply the shear stress to the sample at a specified rate of shear displacement (usually 1.25mm/min for undrained quick tests). Take the readings on the two dial gauges and the proving ring at suitable intervals of shear displacement (say at every 0.2mm horizontal displacement up to about 2mm and at every 0.5mm thereafter) continue the test up to failure.
10) Repeat the above test on three more samples of the same soil, at the same density but with different normal loads.
11) For each test, draw the shear stress v/s shear displacement graph and find the peak value $\mathbf{1}_{max}$. When there is no clear peak observed, the failure stress may be taken as that corresponding to 15% shear strain.
12) Finally plot a graph between normal stress and peak value of shear stress. Thus, find the angle of internal friction, Φ.

DATA CALCULATION SHEET FOR DIRECT SHEAR TEST

Normal load (kg) =

Loading rate (mm/min) = 1.25

Normal stress o_n (kg/cm^2) =

Proving ring constant =

Cross sectional area (Ao) = L X B = ...cm^2
Least count of dial gauge =

σ= 0.5 Kg/ cm^2

Deformation (ΔL)		LOAD		CORRECTED AREA	SHEAR STRESS
DIV	ΔL = DIV X LC	DIVISON	LOAD = DIV X PRC	AC = A$_O$ [1 – ΔL / 3]	ı = P /AC

σ= 1.0 Kg/ cm^2

Deformation (ΔL)		LOAD		CORRECTED AREA	SHEAR STRESS
DIV	ΔL = DIV X LC	DIVISON	LOAD = DIV X PRC	AC = A$_O$ [1 – ΔL / 3]	ı = P /AC

σ= 1.5 Kg/ cm^2

Deformation (ΔL)		LOAD		CORRECTED AREA	SHEAR STRESS
DIV	ΔL = DIV X LC	DIVISON	LOAD = DIV X PRC	AC = A$_O$ [1 – ΔL / 3]	ı = P /AC

PRECAUTIONS:-

1) If the sand tested is wet, there can also be a cohesion intercept in the diagram between normal stress and τ_{max}.
2) Take care to remove the locking keys before applying the shear force.

GRAPH

Plot shear stress versus normal stress as shown in fig.1 'Y" intercept gives 'C' (cohesion) and the angle made by the failure plane with the horizontal gives Ø (angle of internal friction)

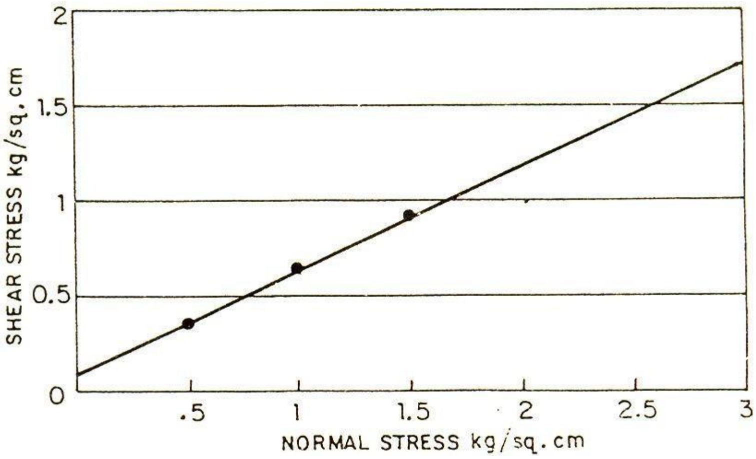


Fig 1 : Shear strength Parameters

(Paste the graph sheet here)

Results:

From the graph

1. Cohesion **C** =.......................... kg/cm
2. Angle of internal friction **Ø** =...................degrees

VIVA QUESTIONS

1) Give examples of practical engineering situations in which these forms of testing are required.
2) Enumerate the types of laboratory shear tests you would specify to be carried out in connection with the following field problems:
    a. The stability of the clay foundation of an embankment, the rate of construction being such that some consolidation of the clay occurs.
    b. The initial stability of a footing on saturated clay.

The long term stability of a slope in stiff-fissured clay. Give reasons for your choice of the test.

EXPERIMENT – 11: TRIAXIAL SHEAR TEST

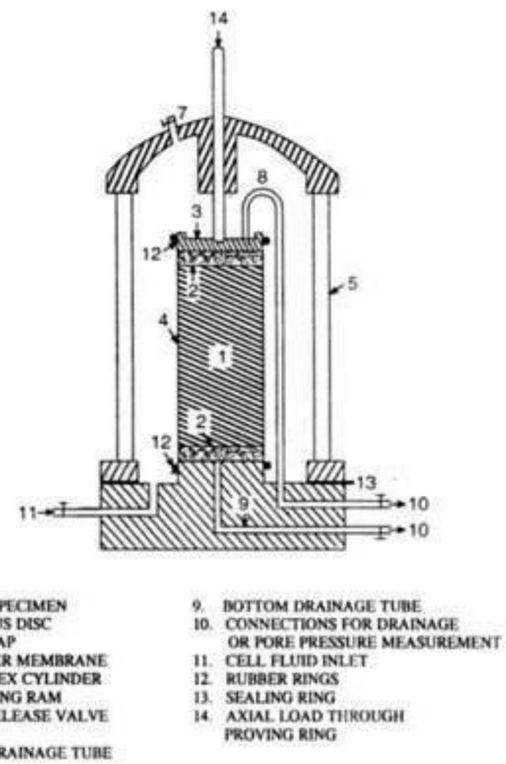
AIM: To determine the basic shear strength soil parameter Φ and C of a given cohesion- less soil using triaxial Compression testing device. The test is to be conducted under untrained unconsolidated Condition without measuring pore pressure

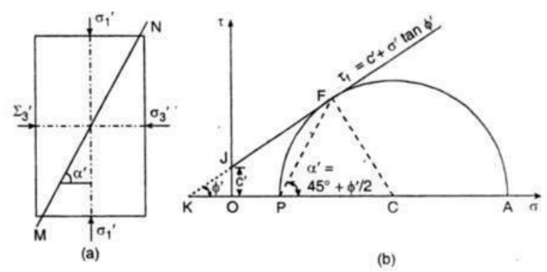
NEED AND SCOPE OF THE TEST

The standard consolidated untrained test is compression test, in which the soil specimen is first consolidated under all round pressure in the triaxial cell before failure is brought about by increasing the major principal stress.
It may be performing with or without measurement of pore pressure although for most applications the measurement of pore pressure is desirable.

APPARATUS/EQUIPMENTS:-

Strain controlled compression machine, triaxial cell, specimen mould, rubber membrane, membrane structure, porous stones, balance, stopwatch trimmer, callipers.





THEORETICAL DISCUSSIONS:

A cylindrical soil specimen is subjected to direct stresses acting in three mutually perpendicular direction and the other two principle stresses namely, intermediate and minor, act in horizontal direction. Minor principle stress is constant throughout the test and major principle circle is drawn for the stresses at failure. By Mohr's circle shear strength of soil is determined.

KNOWLEDGE OF EQUIPMENT

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

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

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

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

I. SAMPLE PREPARATION

1) Mix the soil with water at desired water (optimum) content. Compact the soil properly in the split mould which should oil properly. Trim the excess soil and takeout the specimen mould carefully.
2) Determine the water content of the soil.
3) Place the specimen on the one of end caps and put the other end cap on top of the specimen.
4) Filter paper and porous stone are kept on top as well as at the bottom of the specimen.
5) Place the rubber membrane all round the specimen with the help of membrane structure.
   Seal the rubber membrane with caps by means of rubber means

II. COMPRESSION TEST

1) Place the specimen on the pedestal in the triaxial cell.
2) Assume the cell with the loading ram.
3) Admit the operating fluid in the pressure cell and raise its pressure to the desired value.
4) Adjust the loading machine to bring the loading ram a short distance away from the seat on the top cap of the specimen.
5) Read the initial reading of load measuring Gauge (PRDG). Bring the loading ram just in contact with the seat on the top of the specimen.
6) Read the initial reading of dial gauge measuring axial compression.
7) The vertical load divided by cross sectional area gives deviator stress, which is an addition to the cell pressure that is acting in all direction.
8) Note down the failure load using proving ring dial gauge.
9) Repeat the test on three or four specimen of same water content and same soil but under different cell pressure.

Observation and Recording

Soil Specimen measurements:-

Initial Diameter, D0 =
Initial Area, Ao =
Initial Volume, V0 =
Initial length, Lo =
Initial Cell pressure o_1=
Final Cell pressure o_2=
Average cell pressure o_3= $(o_1 + o_2) / 2$
Corrected Area, Ac= $(A_0/1- €)$
Where, $€ = \Delta L/L_0$
Stress = load/corrected area = P/A

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

Size of specimen:
Length:
Proving ring constant (K) = max load / max no of divisions =.......... Kg / div
Strain dial gauge least count (const):

Deformation dial gauge ΔL		Proving ring reading (P)		Strain $€ = (\Delta L/L_0)$	Corrected area $Ac = (A_0/1- €)$ cm^2	Deviator stress $\Delta o = P / Ac$	Major principle stress $o1 = (o3 + \Delta o)$ kg / cm^2
DIV	Div x LC (mm)	DIV	Div x LC (mm)				

General Remarks

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

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

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

d) The condition of the failure of the sample is generally approximated to by a straight line drawn as a tangent to the circles, the equation of which is $\tau = C + \alpha \tan\phi$. The value of cohesion, C is read of the shear stress axis, where it is cut by the tangent to the mohr circles, and the angle of shearing resistance (ϕ) is angle between the tangent and a line parallel to the shear stress.

VIVA QUESTIONS:-

1) Is it possible to conduct triaxial compression test on dry sand? How?
2) What do you understand by UU test or CU test and CD test?
3) Give one practical example regarding the utility of UU, CU and CD test respectively.
4) What is meant by “area correction” of specimen? Did you apply this correction in your experiment?

What changes in the experiment are to be incorporated if pore pressure is also taken into consideration?

EXPERIMENT – 12 : CONSOLIDATION TEST

OBJECTIVE

Determination of consolidation properties of soil: e_i,e_f,C_v,m_v,k,a_v,C_c.

NEED AND SCOPE

The test is conducted to determine the settlement due to primary consolidation. To determine,

i. Rate of consolidation under normal load.
ii. Degree of consolidation at any time.
iii. Pressure-void ratio relationship.
iv. Coefficient of consolidation at various pressures.
v. Compression index.

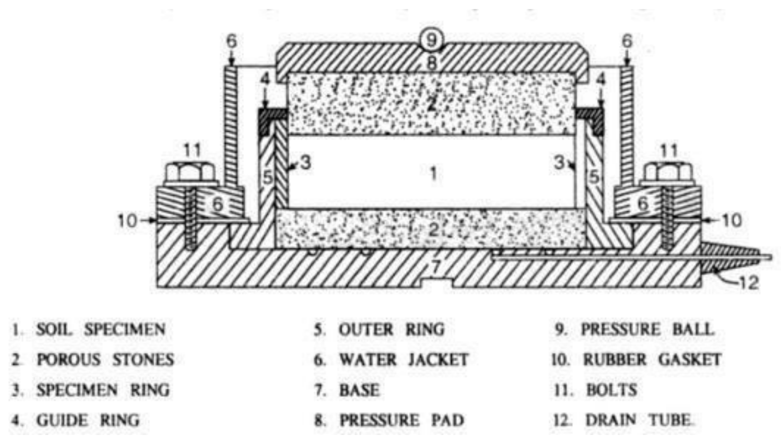
From the above information it will be possible for us to predict the time rate and extent of settlement of structures founded on fine-grained soils. It is also helpful in analyzing the stress history of soil. Since the settlement analysis of the foundation depends mainly on the values determined by the test, this test is very important for foundation design.

THEORETICAL DISCUSSIONS:-

The process of compression resulting from long term steady load and gradual reductions of pore space by escaping of pore water is termed as consolidation. The permeability of an undisturbed sample of clay is determined indirectly at several different void ratios while running a consolidation test.

APPARATUS/EQUIPMENTS:-

Fixed ring type consolidometer, suitable loading device for applying vertical loading, dial gauge, balance thermostatically controlled oven, containers, mixing basin, glass plate, filter paper, and stop watch.



Consolidation Apparatus

PROCEDURE:-

I. **Preparation of soil specimen.**

1) Preparation of specimen from undisturbed soil samples. The undisturbed sample from the field may be circular (at least 1cm diameter) or a block sample. Clean the specimen ring and weigh it empty. Cut off about 3cm to 5cm of soil specimen from one end of the sample by pressing with hands and carefully removing the material around the ring. The soil specimen so obtained should project about 1cm from either side of the ring. Trim the sample smooth and flush at top and bottom of the ring by using glass plates. Clean the ring from outside and weigh. Keep three specimens from the soil trimmings for water content determination.

2) Preparation of specimen from representative soil sample. If the consolidation properties are to be determined from a disturbed soil sample, soil is compacted at the desired water content and density, in a separate large mould and then the specimen is cut as explained in the step (1) above.
3) For the purpose of illustration, Remoulded clay specimen is used.

II. **Preparation of mould assembly and sample.**

1) Saturate the porous stones either by boiling in distilled water for about 15 minutes or by keeping them submerged in distilled water for 4 to 8 hours. Wipe away excess water. Moisture all surfaces of the consolidometer which are to be enclosed.
2) Measure the dimensions of the consolidation ring and weigh the ring accurately.
3) Fill the ring with undisturbed soil sample or remoulded sample prepared nearly at liquid limit. Trim the soil sample.
4) Note down the weight of the ring + wet sample.
5) Assemble the consolidometer with the soil specimen (in the ring) and porous stones at top and bottom of the specimen providing a filter paper between soil specimen and porous stone.
6) Mount the mould assembly on the loading frame and centre it such that the applied load is axial.
7) Position the dial gauge to measure vertical compression of the specimen. The dial gauge holder should be so set the dial is the beginning of its release run, allowing sufficient margin for the swelling of soil, if any.
8) Apply an initial seating load of 0.05 kg/cm2 to the soil sample.
9) Connect the mould assembly to the water reservoir and allow the sample to be saturated. The level of water in reservoir is at about the same level as the specimen.
10) Allow the sample for saturation for 24 hrs.(not necessary for remoulded soil sample prepared at liquid limit)

11) Apply a load of 0.25 kg/cm2and record compression dial gauge reading for the elapsed times of 0,0.25,1,2.25,4,6.25,9,12.25,25,36,49,64,81,100,121,144,169& 60x24minutes
12) Apply the next increment of pressure by doubling the load (0.5 kg/cm2). Repeat step 11. Keep doubling the pressure applied such as 0.5, 1.0, 2.0, 4.0, 8.0, 16.0 or till the anticipated pressure increase on the clay layer in the field is fully covered.
13) When the consolidation has been completed under the final load increment, unload the sample to seating load and allow the sample to freely swell or expand for 24 hours and note the dial gauge reading.
14) The specimen is then taken out and dried or keep the wet specimen along with the ring in the oven for drying.
15) Find the final water content and weight of dry soil specimen, Wd.

OBSERVATIONS:-

For pressure, compression and time

Empty weight of ring =

Dia. Of ring =

Height of ring =

Area of ring =

Volume of ring =

Sp. gravity of soil sample =

TABULAR FORMAT:-

(a) For pressure, compression and time.

Pressure intensity(kg/cm^2)		0. 1	0. 2	0. 5	1	2	4
Elapsed time(min.)	**t ^{½}**	**Dial Gauge Readings**					
0	0						
0.25	0.5						
1	1						
2.25	1.5						
4	2						
6.25	2.25						

9	3						
12.25	3.5						
25	4						
36	4.5						
25	5						
36	6						
49	7						
64	8						
81	9						
100	10						
121	11						
144	12						
169	13						
196	14						
225	15						
256	16						
289	17						
324	18						
361	19						
430	20						
500	22.4						
600	24.5						
1440	38						

Applied pressure (kg/cm^2)	Final dial reading H	Specimen height H_1= H	Drainage path $d=(H_1+H))/4$	Ht. of voids $H-H_s$	Void ratio $e+(H-H_s)/H_s$	Fitting time		C_v (cm^2/min.)		$A_v.C_c$	Remarks
						t_{50}	t_{90}	$0.197*d^2/t_{50}$	$0.848*d^2/t_{90}$		
0.1											
0.2											
0.5											
1.0											
2.0											
4.0											
8.0											
0											

(b) For pressure void ratio.

(c) For water content.

SL.No	Item	Before test	After test
1	Wt. of ring +wet soil (g)		
2	Wt. of ring +dry soil (g)		
3	Wt. of ring (g)		
4	Wt. of dry soil , W_d (g)		
5	Wt. of water (g)		
6	Water content , w		
7	Degree of saturation = (wG) / e		
8	Height of solids $H_s = W_d / (GA)$		

CALCULATIONS:-

1) Height of solids (H_s) can be calculated as $H_s=W_d/GA$.
where , G= specific gravity of soil grains.

A = C/S area of specimen

2) Voids ratio $e_i=H_i-H_s/H_s$

3) Voids ratio $e_f=H_f-H_s/H_s$

H_i = initial thickness of specimen

H_f = final thickness of specimen after compression= H_i – (change in intial & final dial gauge reading).

All of the above readings should be recorded under one specific pressure increment.

4) Coefficient of volume change, m_v from either eq 1 or 2

$m_v = -(\Delta e/1+ e_i).(1/\Delta P) = (a_v/1+e_i)$

$= (e_i - e_f/1+ e_i).(1/\Delta P)$ ---------------------- (1)

$m_v = (H_i-H_f/H_i)(1/\Delta P)\ m^2/KN$----------------- (2)

5) Coefficient of consolidation $C_v = 0.197d^2/t_{50}$ (log fitting method)

$C_v = 0.848d^2/t_{90}$ (square root fitting method)

In the log fitting method, a plot is made between dial reading and logarithm of time and the time corresponding to 50% consolidation is determined. In the square root fitting method, a plot is made between dial reading and the square root of time and the time corresponding to 90% consolidation is determined.

6) Compression index: A plot of void ratio 'e'versus log 1 is made. The initial compression curve would be found to be a straight line and the slope of this line would give you the compression index G.

7) Coefficient of compressibility (a_v) = $0.435C_c$ / o_1 where o_1 = average pressure for the increment.

Coefficient of permeability (k) = $C_v . m_v .\gamma_w$ m /sec

Where, γ_w = unit wt of water

C_v = coefficient of consolidation (m^2 /sec)

RESULTS:-

1) Coefficient of consolidation C_v (log fitting method) =
2) Coefficient of consolidation C_v (square root fitting method) =
3) Coefficient of compressibility, a_v =
4) Coefficient of permeability, K =
5) Height of voids =$H-H_s$ =

VIVA QUESTIONS:-

1) Distinguish between compaction and consolidation?
2) What do you understand by coefficient of consolidation?
3) What do you mean by corrected zero point and its significance?
4) Why the consolidation test is required?
5) Define Coefficient of compressibility.

EXPERIMENT – 13: MODIFIED PROCTOR TEST

OBJECTIVE

To determine moisture content and dry density relationship using heavy compaction or modified compaction method as per IS-2720-Part-8.

APPARATUS

- Metal mould (volume = 1000 cm3)
- Balance (capacity = 10 kg, least count = 1g)
- Oven (105 to 1100C)
- Sieve (19 mm)
- Metal rammer (weight = 4.9 kg)

PROCEDURE

1. Dry the soil sample by exposing it to air or sun light.
2. Sieve the air dried soil through 19 mm sieve.
3. Add suitable amount of water with the soil and mix it thoroughly. For **sandy and gravelly soil add 3% to 5%** of water. For **cohesive soil** the amount of water to be added should be**12% to 16% below the plastic limit**.
4. Weigh the mould with base plate attached to the nearest 1g. Record this weight as '**W1**'.
5. Attach the extension collar with the mould.
6. Compact the moist soil into the mould in five layers of approximately equal mass, each layer being given 25 blows, with the help of 4.9 kg rammer, dropped from a height of 450 mm above the soil. The blows must be distributed uniformly over the surface of each layer.
7. After completion of the compaction operation, remove the extension collar and level carefully the top of the mould by means of straightedge.
8. Weigh the mould with the compacted soil to the nearest 1 g. Record this weight as '**W2**'.
9. After weighing remove the compacted soil from the mould and place it on the mixing tray. Determine the water content of a representative sample of the specimen. Record the moisture content as '**M**'.
10. Broken up the remainder of the specimen and repeat step 5 to step 9 by adding suitable increment of water to the soil. For **sandy and gravelly soils** the increment in general is **1% to 2%**. For **cohesive soils** the increment in general is **2% to 4%.**
11. The total no. of determinations made shall be at least five, and the moisture contents should be such that the optimum moisture content, at which the maximum dry density occurs, is within that range.

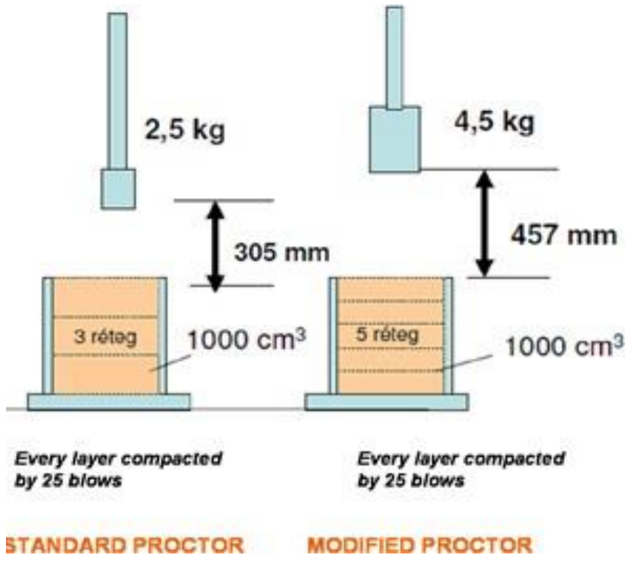


Figure: Difference between standard and modified proctor test

OBSERVATION AND CALCULATION

Weight of soil =

Weight of mould + base plate

= Height of the mould (H) =

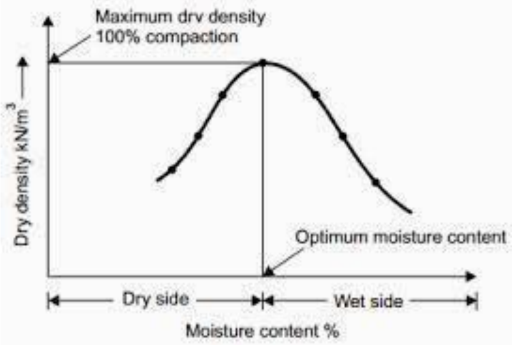
Diameter of the mould

=Volume of the mould

$(\pi\ d^2/4)H$

Graph:

Plot the graph of dry density along Y- axis v/s water content along X- axis to determine Max Dry Density (MDD) and Optimum Moisture Content (OMC).



Bulk Density			
Water to be added (percent)			
Weight of mould only (W1)			
Weight of Mould + compacted soil (W2) gms			
Weight of soil only (Ws)			
Bulk density of soil: γb = Ws / V (gm /cc)			
Water content			
Container No.			
Weight of cup only (W1)			
Wt. Of container + wet soil gms.(W2)			
Wt. Of container + dry soil gms (W3)			
WATER CONTENT W = W2 – W3 / W3 – W1 (%)			
Dry Density of Soil			
$\gamma d = (\gamma b / 1 + W)$ gm /cc			

RESULT:

Maximum dry density MDD of given soil sample is………

Optimum moisture content OMC of a given soil sample is …

EXPERIMENT 14-HYDROMETER ANALYSIS

AIM: Grain size analysis of soils by hydrometer analysis test.

OBJECTIVE

1. To determine the grain size distribution of soil sample containing appreciable amount of fines.
2. To draw a grain size distribution curve.

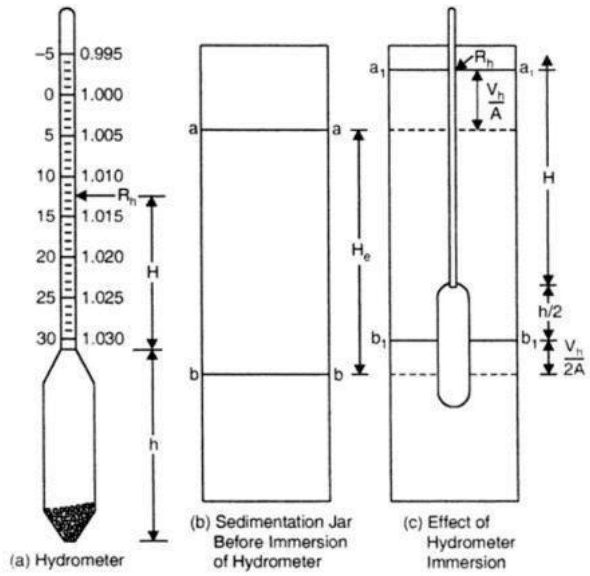
NEED AND SCOPE OF THE EXPERIMENT

For determining the grain size distribution of soil sample, usually mechanical analysis (sieve analysis) is carried out in which the finer sieve used is 63 micron or the nearer opening. If a soil contains appreciable quantities of fine fractions in (less than 63 micron) wet analysis is done. One form of the analysis is hydrometer analysis. It is very much helpful to classify the soil as per ISI classification. The properties of the soil are very much influenced by the amount of clay and other fractions.

APPARATUS

1. Hydrometer
2. Glass measuring cylinder-Two of 1000 ml capacity with ground glass or rubber stoppers about 7 cm diameter and 33 cm high marked at 1000 ml volume.
3. Thermometer- To cover the range 0 to 50^{o} C with an accuracy of 0.5 ^{o} C.
4. Water bath.
5. Stirring apparatus.
6. I.S sieves apparatus.
7. Balance-accurate to 0.01 gm.
8. Oven-105 to 110.
9. Stop watch.
10. Desiccators
11. Centimetre scale.
12. Porcelain evaporating dish.
13. Wide mouth conical flask or conical beaker of 1000 ml capacity.
14. Thick funnel-about 10 cm in diameter.
15. Filter flask-to take the funnel.
16. Measuring cylinder-100 ml capacity.
17. Wash bottle-containing distilled water.
18. Filter papers.
19. Glass rod-about 15 to 20 cm long and 4 to 5 mm in diameter.
20. Hydrogen peroxide-20 volume solution.

21. Hydrochloric acid N solution-89 ml of concentrated hydrochloric acid. (specific gravity 1.18) diluted with distilled water one litre of solution.
22. Sodium hexametaphosphate solution-dissolve 33 g of sodium hexametaphosphate and 7 gms of sodium carbonate in distilled water to make one litre of solution.



Hydrometer Analysis

CALIBRATION OF HYDROMETER

Volume

(a) Volume of water displaced: Approximately 800 ml of water shall be poured in the 1000 ml measuring cylinder. The reading of the water level shall be observed and recorded. The hydrometer shall be immersed in the water and the level shall again be observed and recorded as the volume of the hydrometer bulb in ml plus volume of that part of the stem that is submerged. For practical purposes the error to the inclusion of this stem volume may be neglected.

(b) From the weight of the hydrometer: The hydrometer shall be weighed to the nearest 0.1 gm.The weight in gm shall be recorded as the volume of the bulb plus the volume of the stem below the 1000 ml graduation mark. For practical purposes the error due to the inclusion of this stem may be neglected.

Calibration

(a) The sectional area of the 1000 ml measuring cylinder in which the hydrometer is to used shall be determined by measuring the distance between the graduations. The sectional area is equal to the volume include between the two graduations divided by the measured distance between them. Place the hydrometer on the paper and sketch it.

On the sketch note the lowest and highest readings which are on the hydrometer and also mark the neck of the bulb. Mark the centre of the bulb which is half of the distance between neck of the bulb and tip of the bulb.

b) The distance from the lowest reading to the center of the bulb is (R_h) shall be recorded ($R_h = H_L + L/2$).

(c) The distance from the highest hydrometer reading to the center of the bulb shall be measured and recorded.

(d) Draw graph hydrometer readings vs H_H and R_H. A straight line is obtained. This calibration curve is used to calibrate the hydrometer readings which are taken within 2 minutes.

(e) From 4 minutes onwards the readings are to be taken by immersing the hydrometer each time. This makes the soil solution to rise, there by rising distance of free fall of the particle. So correction is applied to the hydrometer readings.

(f) Correction applied to the R_h and H_H

$$\frac{R_h - V_h}{A} = \frac{H_L + h/2 - V_h}{2A}$$

V_h= Volume of hydrometer bulb in ml.
A =Area of measuring cylinder in cm^2.
From these two corrected readings draw graph (straight line)

Grain Size Distribution in Soil-Data and Calculation Chart

Date:
Sample No:
Total weight of dry soil taken, W =
Specific Gravity of soil, G =
Hydrometer No._______________ Wt. Of soil gone into solution, Ws =
Meniscus correction, C_n =
Dispersion agent correction =
Reading in water RW =
Temperature correction =
% finer for wt. Of soil W_s gone into solution N = [(100G)/{W_s x (G 1)}] x R

Time	Elapsed time in sec	Hydrometer reading (upper meniscus) R_h = 1000	Corrected hydrometer reading (1-lower meniscus C_m)	Z_r or Z^1_r	Velocity Cms/sec $V=Zr/K$ or z^1_r / t	Equivalent dia. Of Particle D (mm)	R	N(% finer Than for soil)	remarks

EXPERIMENT 15 -VANE SHEAR TEST

OBJECTIVE:

To find shear strength of a given soil specimen.

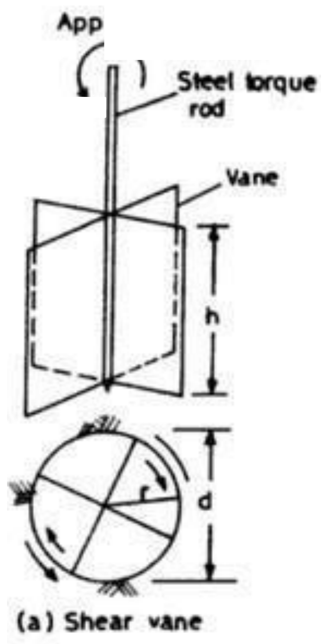
NEED AND SCOPE:

The structural strength of soil is basically a problem of shear strength. Vane shear test is a useful method of measuring the shear strength of clay. It is a cheaper and quicker method. The test can also be conducted in the laboratory. The laboratory vane shear test for the measurement of shear strength of cohesive soils, is useful for soils of low shear strength (less than 0.3 kg/cm^2) for which triaxial or unconfined tests cannot be performed. The test gives the undrained strength of the soil. The undisturbed and remoulded strength obtained are useful for evaluating the sensitivity of soil.

PLANNING AND ORGANIZATION

EQUIPMENT

1. Vane shear apparatus.
2. Specimen.
3. Specimen container.
4. Callipers.



(a) Shear vane

EXPERIMENTAL PROCEDURE

1. Prepare two or three specimens of the soil sample of dimensions of at least 37.5 mm diameter and 75 mm length in specimen.(L/D ratio 2 or 3).
2. Mount the specimen container with the specimen on the base of the vane shear apparatus. If the specimen container is closed at one end, it should be provided with a hole of about 1 mm diameter at the bottom.
3. Gently lower the shear vanes into the specimen to their full length without disturbing the soil specimen. The top of the vanes should be at least 10 mm below the top of the specimen. Note the readings of the angle of twist.
4. Rotate the vanes at an uniform rate say 0.1°/s by suitable operating the torque application handle until the specimen fails.
5. Note the final reading of the angle of twist.

Find the value of blade height in cm.

7. Find the value of blade width in cm.

CALCULATIONS:

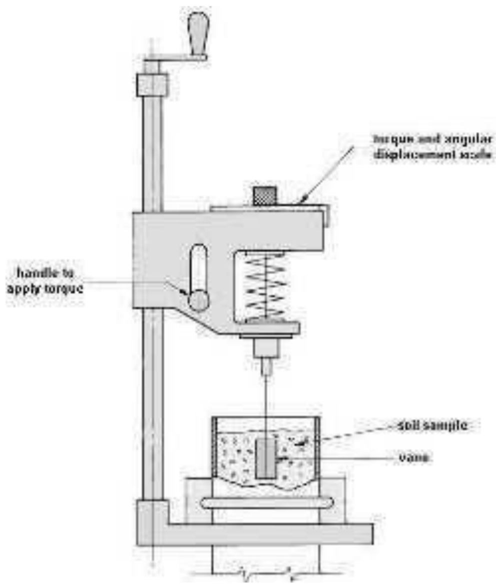
Shear strength, $S = T / \pi(D^2 H / 2 + D^3)$

Where S = shear strength of soil in kg/cm2

T = torque in cm kg

D = overall diameter of vane in cm

T = spring constant / 180o x difference in degrees.



OBSERVATION:

Sl. No	Initial Reading (Deg)	Final Reading (Deg.)	Difference (Deg.)	T=Spring Constant/180 x Difference Kg-cm	$G = 1/\pi(D^2H/2 + D^3/6)$	S=TxG Kg/cm^2	Average 'S' Kg/cm^2	Spring Constant Kg-cm

GENERAL REMARKS:

This test is useful when the soil is soft and its water content is nearer to liquid limit.

SUMMARY OF COMMON SHEAR STRENGTH TESTS			
Test Type	**Applicability**	**Advantages**	**Disadvantages**
Direct Shear Test	a. Effective strength parameters for coarse grained and fine grained soils	a. Simple and inexpensive b. Thin sample allows for rapid drainage of fine grained soils	a. Only for drained conditions b. Failure plane forced to occur at joint in box c. Non-uniform distribution of stress and strain d. No stress-strain data

Triaxial Shear Test	a. Effective and total strength parameters for coarse-grained and fine-grained soils b. Compared to direct shear tests, triaxial tests are preferred for fine-grained soils	a. Easy to control drainage b. Useful stress-strain data c. Can consolidate sample hydrostatically or to *in situ* *Ko* state of stress d. Can simulate various loading conditions	a. Apparatus more complicated than other types of tests b. Drained tests on fine grained soils must be sheared very slowly
Unconfined Compression Test	a. Undrained shear strength of 100% saturated samples of homogenous, unfissured clay b. Not suitable as the only basis for design on critical projects	a. Very rapid and inexpensive	a. Not applicable to soils with fissures, silt seams, varves, other defects, or less than 100% saturation b. Sample disturbance not systematially accounted for
Lab Vane Shear Test	a. Undrained shear	a. Very rapid and	a. Not applicable to soils

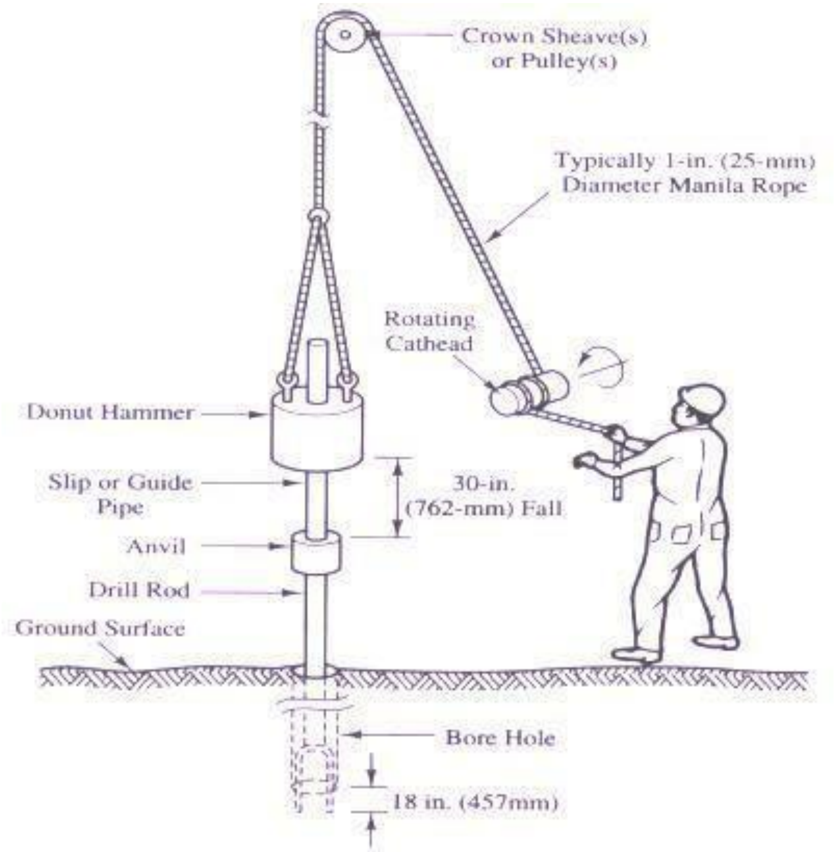
	strength of 100% saturated samples of homogenous, unfissured clay b. Not suitable as the only basis for design on critical projects	inexpensive	with fissures, silt seams, varves, other defects, or less than 100% saturation b. Sample disturbance not systematially accounted for

DEMONSTRATION 1: STANDARD PENETRATION TEST

AIM: To perform standard penetration to obtain the penetration resistance (N-value) along the depth at a given site.

EQUIPMENT & APPARATUS:

- Tripod (to give a clear height of about 4 m; one of the legs of the tripod should have ladder to facilitate a person to reach tripod head.)
- Tripod head with hook
- Pulley
- Guide pipe assembly
- Standard split spoon sampler
- A drill rod for extending the test to deeper depths
- Heavy duty post hole auger (100 mm to 150 mm diameter)
- Heavy duty helical auger
- Heavy duty auger extension rods
- Sand bailer
- Rope (about 15 m long & strong enough to lift 63.5 kg load repeatedly)
- A light duty rope to operate sand bailer
- Chain pulley block
- Casing pipes
- Casing couplings
- Casing clamps
- Measuring tapes
- A straight edge (50 cm)
- Tool box



SPT TEST SET UP

PROCEDURE

1. Identify the location of testing in the field
2. Erect the tripod such that the top of the tripod head is centrally located over the testing spot. This can be reasonably ensured by passing a rope over the pulley connected to the tripod head and making the free end of the rope to come down and adjusting the tripod legs such that the rope end is at the testing spot. While erecting and adjusting the tripod legs, care should be taken to see that the load is uniformly distributed over the three legs. This can be achieved by ensuring the lines joining the tips of the tripod legs on the ground forms an equilateral triangle. Further, it should be ensured that the three legs of the tripod are firmly supported on the ground (i.e. the soil below the legs should not be loose and they should not be supported on a sloping rock surface or on a small boulder which may tilt during testing.)
3. Advance the bore hole, at the test location, using the auger. To start with advance the bore hole for a depth of 0.5 m and clear the loose soil from the bore hole.

4. Clean the split spoon sampler and apply a thin film of oil to the inside face of the sampler. Connect an A-drill extension rod to the split spoon sampler.
5. Slip the 63.6 kg weight on to the guide pipe assembly and connect the guide pipe assembly to the other end of the A-drill rod.
6. The chain connected to the driving weight is tied to the rope passing over the pulley at the tripod head. The other end of the rope is pulled down manually or with help of mechanical winch. By pulling the rope down, the drive weight, guide pipe assembly, A-drill rod and the split spoon sampler will get vertically erected.
7. A person should hold the guide pipe assembly split spoon sampler to be vertical with the falling weight lowered to the bottom of the guide assembly.
8. Now place a straight edge across the bore touching the A-drill rod. Mark the straight edge level all round the A-drill rod with the help of a chalk or any other marker. From this mark, measure up along the A-drill rod and mark 15 cm, 30 cm and 45 cm above the straight edge level. Lift the driving weight to reach the top of the guide pipe assembly travel and allow it to fall freely. The fall of driving weight will transfer the impact load to the split spoon sampler, which drive the split spoon sampler into the ground. Again lift the drive weight to the top of travel and allow it to fall freely under its own weight from a height of 75 cm. as the number of blows are applied, the split spoon sampler will penetrate into the ground and the first mark (15 cm mark) on the drill rod approaches the straight edge.
9. Count the number of blows required for the first 15 cm, second 15 cm and the third 15 cm mark to cross down the straight edge.
10. The penetration of the first 15 cm is considered as the seating drive and the number of blows required for this penetration is noted but not accounted in computing penetration resistance value. The total number of blows required for the penetration of the split spoon sampler by 2^{nd} and 3^{rd} 15 cm is recorded as the penetration resistance or N-value.
11. After the completion of the split spoon sampler by 45 cm, pull out the whole assembly. Detach the split sampler from A-drill rod and open it out. Collect the soil sample from the split spoon sampler into a sampling bag. Store the sampling bag safely with an identification tag for laboratory investigation.
12. Advance the bore hole by another 1 m or till a change of soil strata whichever is early.

13. The test is repeated with advancement of bore hole till the required depth of exploration is reached or till a refusal condition is encountered. Refusal condition is said to exist if the number of blows required for the last 30 cm of penetration is more than 100.
14. The test will be repeated in number of bore holes covering the site depending on the building area, importance of the structure and the variation of the soil properties across the site.
15. The SPT values are presented either in the form of a table or in the form of bore log data.

DEMONSTRATION 2: SWELL PRESSURE

DEFNITION

Swelling pressure can be **defined** as the **pressure** required to keep a **soil** element. at constant volume, when boundary conditions are such as to induce a tendency to volume increase.

PROCEDURE

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, is the increase in volume of soil without any external constraint when subjected to submergence in water. The apparatus used :

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

strong>Procedure to determine Free Swell Index Of Soil
i) Take two specimens of 10g each of pulverised soil passing through 425µ m ISSieve 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 = $[V_d – V_k] / V_k$ x 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.

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%