LIST OF EXPERIMENTS

1. Atterberg's Limits (LL & PL)
2. Field density-core cutter and sand replacement method
3. Grain size analysis
4. Permeability of soil, constant and variable head test
5. Compaction test
6. CBR test
7. Consolidation test
8. Unconfined compression test
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EXPERIMENT 1

ATTERBERG'S LIMITS

(A) LIQUID LIMIT TEST

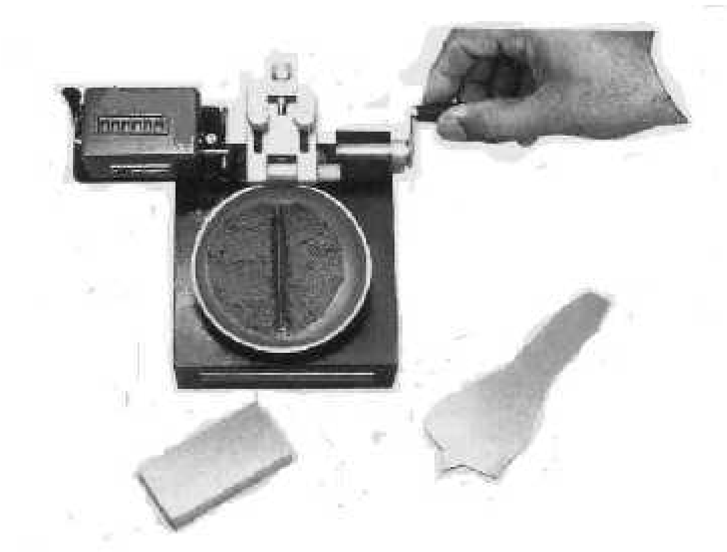
AIM: To determine the liquid limit of a soil.

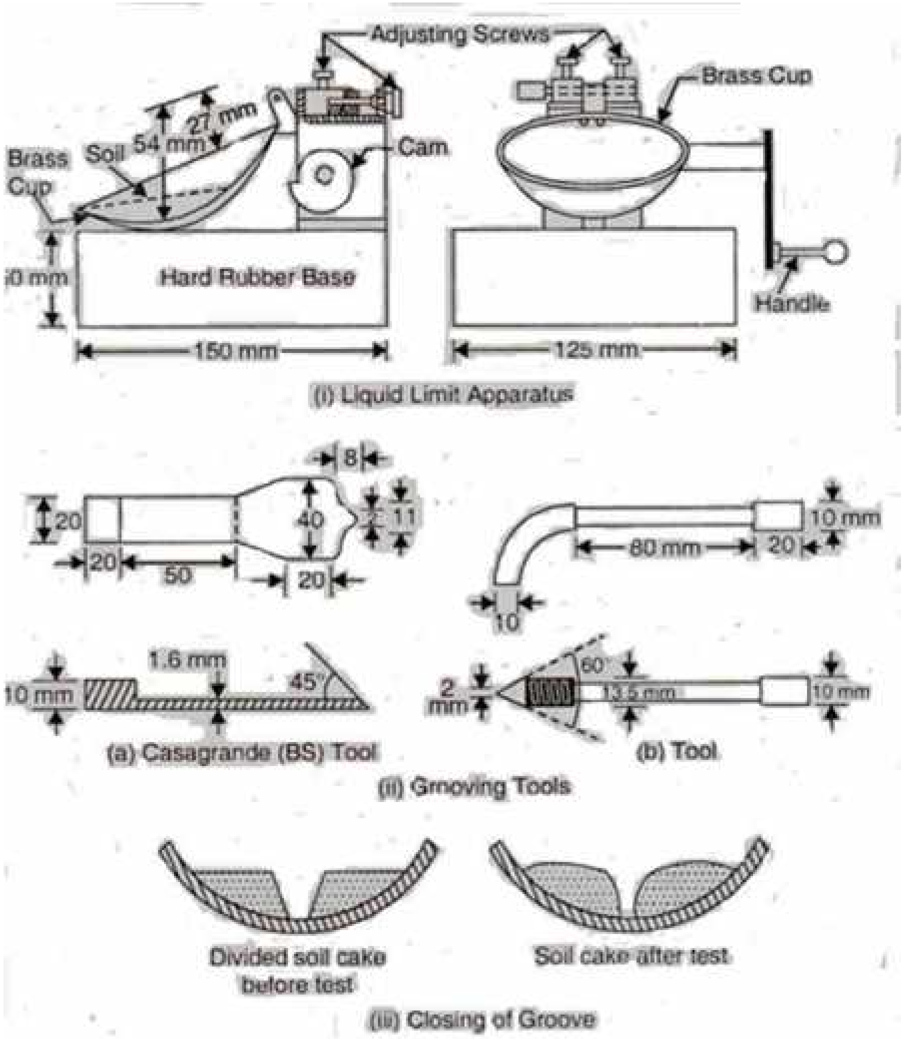
APPARATUS: 1. Balance 2. Liquid limit device (Casagrande's) 3. Grooving tool 4. Mixing dishes 5. Spatula 6. Electrical Oven

THEORY:
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.

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.

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.





LIQUID LIMIT APPARATUS

OBSERVATIONS:

Determination Number	1	2	3	4
Container number				
Weight of container				
Weight of container + wet soil				
Weight of container + dry soil				
Weight of water				
Weight of dry soil				
Moisture content (%)				
No. of blows				

COMPUTATION / CALCULATION:

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.

RESULT:

Flow index $I_f = (W_2-W_1)/(\log N_1/N_2)$ = slope of the flow curve.
Plasticity Index = $w_l - w_p$ =
Toughness Index = I_p/I_f =

(B) PLASTIC LIMIT

AIM: To determine the plastic limit of a soil.

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

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

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 molded with fingers.
3. Allow it to season for sufficient time (for 24hrs.) to allow water to permeate throughout the soil mass
4. Take about 10gms of this plastic soil mass and roll it between fingers and glass plate with just sufficient pressure to roll the mass into a threaded of uniform diameter throughout its length. The rate of rolling shall be between 60 and 90 strokes per minute.
5. Continue rolling till you get a threaded of 3 mm diameter.
6. Kneed the soil together to a uniform mass and re-roll.
7. Continue the process until the thread crumbles when the diameter is 3 mm.
8. Collect the pieces of the crumbled thread in air tight container for moisture content determination.
9. Repeat the test to 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.

Trial No.	1	2
Container No.		
Weight of empty container with lid, W_1 gm		
Weight of container + wet soil (W_2) gm		
Weight of container + dry soil (W_3) gm		
Weight of water = (W_2 – W_3) gm		
Weight of Dry soil = (W_3 – W_1) gm		
Water content, $w = \frac{(W_2 - W_3)}{(W_3 - W_1)} \times 100$		

This water content is called the plastic limit.

RESULT:
The water content is ……………

EXPERIMENT 2

FIELD DENSITY

(A) DETERMINATION OF IN-SITU DENSITY BY CORE CUTTER METHOD

AIM: To determine the in-place density of a soil using core cutter method.

APPARATUS: A core cutter of Mild steel provided with a cutting edge at its bottom and with a 25mm high dolly to fit its top; A metal rammer; a steel scale and a spaturba; A balance with a weight box.

PROCEDURE:

1. The apparatus consists of mild steel cylindrical in shape open at top and bottom and provided with a cutting edge and dolly of 25 mm in height to fit its top and a metal rammer.
2. The core cutter is 10cm in dia and 12.5 cm in height. (However these measurements must be made carefully with a steel scale and recorded). The core cutter is manufactured to give a volume of 1000cc.
3. The dolly fitted to its top is 2.5cm in height. The bottom 1 cm of the core cutter is sharpened in to a cutting edge.
4. The empty weight of the core cutter without dolly is found – W_1 gm.
5. The site where the soil's in-situ density is to be determined is cleaned and levelled. The core cutter with the dolly in position is placed on the levelled portion. It is gently driven into the soil completely with the dolly by means of a rammer.
6. After driving completely, the soil surrounding the core cutter is excavated with a small crowbar so as to enable to cut the bottom of the core cutter with a spatula and the total unit is removed from the position and kept on a plane surface.
7. The surfaces of soil at top (remove the dolly gently from its position) and bottom are then, trimmed with a spatula gently so as to be flush with the top and bottom of the core cutter.
8. The core cutter in this position is cleaned carefully from outside.
9. Now the weight of core cutter with the wet soil (without dolly) is determined as W_2 gm. Now the weight of wet soil = $W_2 - W_1$ gm
   The in-situ soil is generally assumed to be moist.

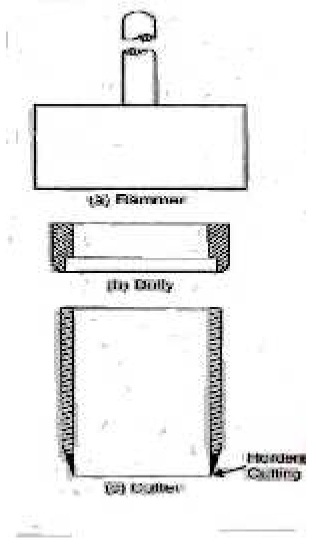
$$\text{In-situ moist density of soil} = \frac{\text{Weight of moist soil}}{\text{Volume of soil}} \text{ (gm/cc)}$$

The volume of the soil is equal to the volume of core cutter.

A small but representative sample from the core cutter is then taken and its moisture content is determined (w)

$$\text{Now the Dry Density of in-situ soil} = \frac{\text{Wet or moisture density}}{1 + w}$$

It is always preferable to express the soil density in terms of its dry density because the dry density for the soil at any given place and at any time is constant.



	Trial 1	Trial 2
Empty wt. of core cutter without dolly (gm) (w_1)		
Wt. of core cutter with soil trimmed flush with top & bottom (gm) (w_2)		
Weight of moist soil gm $W=(W_2 - W_1)$		
Height of Core cutter (cm)		
Volume of core cutter equal to volume of soil = V cc		
Bulk or moist density of soil gm/cc w/v		
Wt. of container with moist soil (gm) (w_1)		
Empty wt. of container gm (w_3)		
Weight of containing with dry soil gm (w_2)		
Weight of water $(W_2 - W_1)$ gm		
Wt. of dry soil (gm) $Ws=(W_2 - W_3)$		
Water content (%) $(W_1 - W_2)/(W_2 - W_3)$ ×100%		
Dry Density (gm / cc) Wet density/ (1 + w)		

RESULT:

Average Moist density = ………………………….. gm / cc

Average dry density = ………………………….. gm / cc

(B) DETERMINATION OF IN-SITU DENSITY BY SAND REPLACEMENT METHODS

AIM: To determine the In-place density of a soil by sand replacement method.

APPARATUS: Sand pouring cylinder, spatula, excavating tools a tray with central hole, weighing unit, scoop etc., calibrating can

PROCEDURE: The equipment in the sand replacement method consists of
i) A sand pouring cylinder mounted above a pouring cone and separated by a valve or shutter
ii) Calibrating container
iii) Tray with central circular hole and
iv) A small excavating tool, scoop, balance etc.

The procedure consists of
a] Calibration of the cylinder
b] Measurement of soil density
c] Determination of water content and dry density

a] Calibration of the cylinder :- This consists of the determination of the weight of sand required to fill the pouring cone of the cylinder and the determination of the bulk density of sand.

Uniformly graded, dry, clean sand preferably passing 600 micron sieve and retained on 300 micron sieve is used in the cylinder. The cylinder is filled up to a height (¾ the level) or 1cm below the top and its initial weight W_1 gm is recorded. The cylinder is then placed on a plane surface the valve is opened and the sand is allowed to run out to fill the conical portion below. When no further sand runs out, the valve is closed. The weight of sand pouring cylinder with the sand after filling the conical portion is determined as W_2 gm.

Now weight of sand filling the conical portion = $W_1 - W_2$ gm. Now the sand pouring cylinder with the sand (after W_2 is recorded) is placed centrally over the calibrating can such that the axis of the sand pouring cylinder coincides with the axis of calibrating can. Now release sand to fill the calibration can and the conical portion. When no sand runs out, close the valve and find the weight of sand pouring cylinder with the remaining sand after filling calibrating can the conical portion. Let this weight be W_3

Now weight of sand filling the calibrated can

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

Volume of calibrating can = V_{cc} (a known quantity)
(generally supplied by manufacturer)

$$\text{Unit weight of sand} = r_{sand} = \frac{\text{Weight of sand filling calibrated can}}{\text{Volume of calibrating can}}$$

Measurement of the unit weight of in place soil:

The site at which the in-situ unit weight is to be determined is cleaned and levelled. A square tray with a central hole in it is placed on the cleaned surface. A hole of the dia equal to the dia of the hole in the tray and a depth of about 10-15 cm is made in the ground. The excavated soil is carefully collected in to the tray and weighed. Next the sand pouring cylinder with the sand (after W_3 is taken) is placed on the hole in the tray carefully and the falling of sand is released. The excavated pit and the conical portions are filled and when no further sand falls the valve is closed and the weight of sand pouring cylinder with the remaining sand is determined and recorded as W_4 .

Now the weight of sand filling the excavated pit and conical portion = $W_3 - W_4$
Weight of sand filling the excavated pit = $(W_3 - W_4) - (W_1 - W_2)$

$$\text{Volume of sand filling the excavated pit} = \frac{\text{Weight of sand filling excavated pit}}{\text{Density of sand}}$$

This volume of sand filling the excavated pit is nothing but the volume of soil excavated from pit.

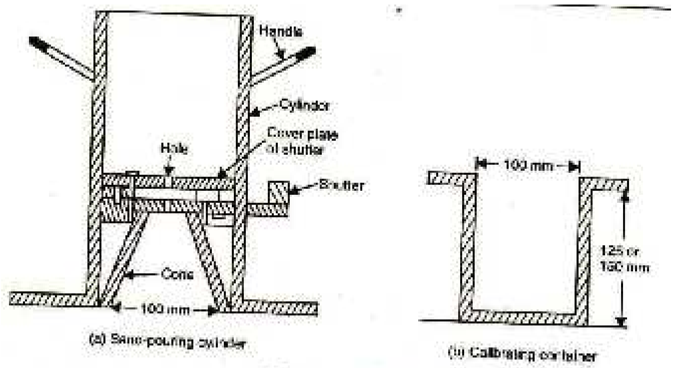
$$\therefore \frac{\text{Weight of sand filling excavated pit}}{r_{sand}} \text{ - is the volume of soil excavated from pit.}$$

$$\text{Now in-situ density soil} = \frac{\text{Wet (bulk) density (gm/cc)}}{\text{Volume of soil excavated from pit}}$$

The core cutter method for this purpose cannot be used in the case of hard or gravelly soils. Under such situations the sand replacement method is convenient.

Observation sheet for sand-replacement method for in-situ density of soil

Wt. of sand pouring cylinder + ¾ sand (gm) (W_1)	
Wt. of empty sand pouring cylinder (gm) (W_2)	
Wt. of sand pouring cylinder + remaining sand after filling conical portion (W_3) (gm)	
Wt. of sand filling conical portion (W_4) (gm) $W_4 = (W_1 - W_3)$ gm	
Wt. of sand pouring cylinder + sand after filling pit and conical portion (W_5) (gm)	
Wt. of sand filling pit and conical portion (W_6) (gm) $W_6 = (W_3 - W_5)$	
Wt. of sand filling only pit portion (gm) (W_7) $W_7 = (W_6 - W_4)$	
Volume of sand occupying pit portion (cc) $= \frac{\text{Weight of sand filling pit portion}}{\text{Density of sand}}$ This is equal to volume of soil removed from pit =V	



Sand pouring cylinder

Density of Sand Used In the Test:

Wt. of calibrated can + sand flush with top of can (gm) (W_1)	
Empty weight of calibrated can (gm) (W_2)	
Wt. of sand in calibrated can W gm $W = W_1 - W_2$	
Dia. of calibrated can (cm) (D)	
Height of calibrated can (H) (cm)	
Volume of calibrated can $V = \frac{\Pi D^2}{4} xH$ cc	
Density of sand $r_{sand} = \frac{W}{V}$ gm/cc	
Wt. of soil excavated from pit and collected in to calibrated can + wt. of can = W_3 gm	
Wt. of soil only excavated from pit = W gm $W = (W_3 - W_2)$	
In-situ density of soil = r_b $r_b = \frac{W}{V}$ gm/cc	

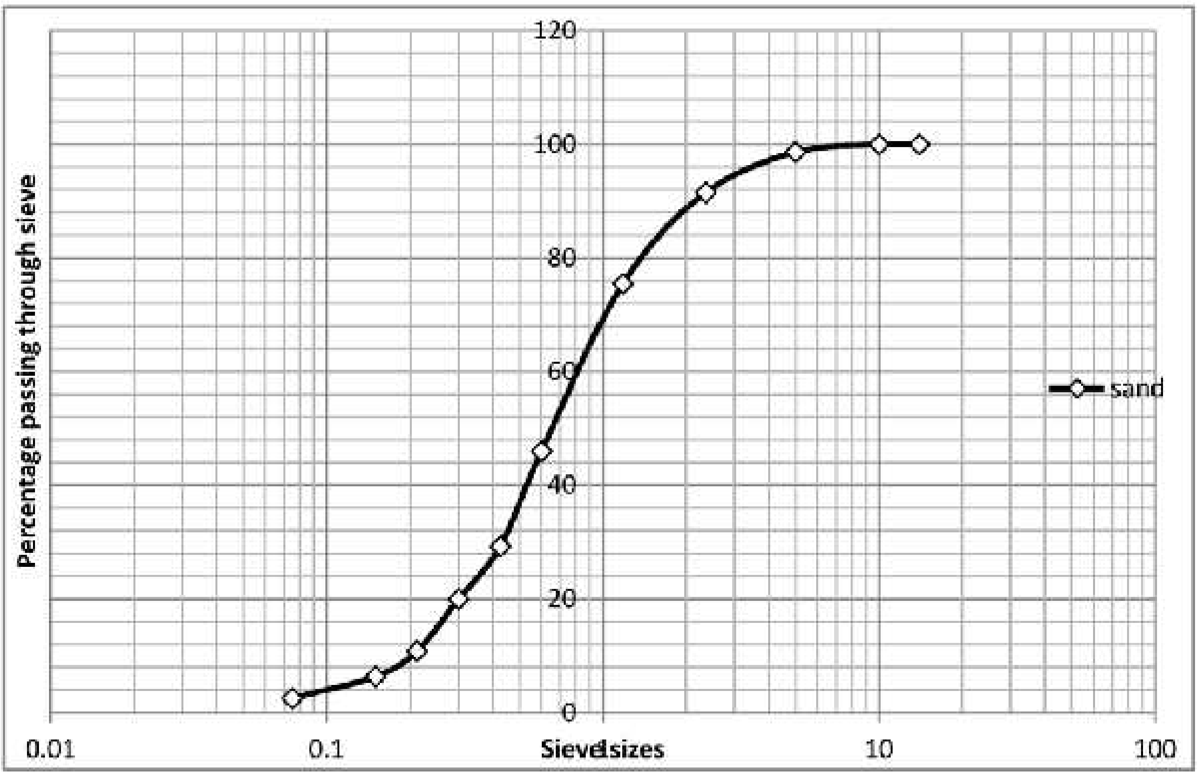
RESULT:
The dry density of the given soil sample is ……………………………….

EXPERIMENT 3

DETERMINATION OF PARTICLE SIZE DISTRIBUTION (MECHANICAL ANALYSIS) BY SIEVE ANALYSIS METHOD

AIM: To determine the particle size distribution of a coarse grained soil by a sieve analysis test and classify the soil.

APPARATUS: Set of IS:Sieves; Wire brush; balance porcelin containers to keep the soil fractions, etc.



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

1. Balance
2. I.S sieves
3. Rubber pestle and mortar.
4. Mechanical Sieve Shaker

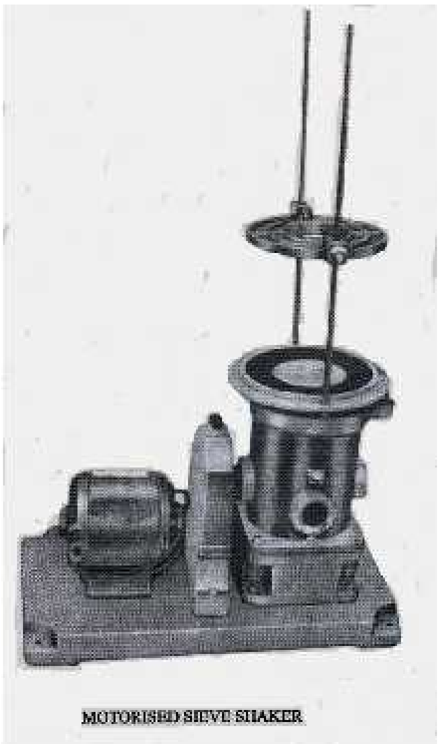
The grain size analysis is an attempt to determine the relative proportions of different grain sizes which make up a given soil mass.

KNOWLEDGE OF EQUIPMENT:
1. The balance to be used must be sensitive to the extent of 0.1% of total weight of sample taken.
2. I.S 460-1962 are to used. The sieves for soil tests: 4.75 mm to 75 microns.

PROCEDURE
1. For soil samples of soil retained on 75 micron I.S sieve

a) The proportion of soil sample retained on 75 micron I.S sieve is weighed and recorded weight of soil sample is as per I.S 2720.
b) I.S sieves are selected and arranged in the order as shown in the table.
c) The soil sample is separated into various fractions by sieving through above sieves placed in the above mentioned order.
d) The weight of soil retained on each sieve is recorded.

e) The moisture content of soil if above 5% it is to be measured and recorded.
2.No particle of soil sample shall be pushed through the sieves.



I.S sieve number or size in mm	Wt. Retained in each sieve (gm)	Percentage on each sieve	Cumulative %age retained on each sieve	% finer	Remarks
4.75					
4.00					
3.36					
2.40					
1.46					
1.20					
0.60					
0.30					
0.15					
0.075					

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.

RESULT:
The coefficient of curvature for soil sample……………………………
The coefficient of uniformity for soil sample……………………………

EXPERIMENT 4

(A) COEFFICIENT OF PERMEABILITY (CONSTANT HEAD TEST)

AIM: To determine the coefficient of Permeability of a soil by (i) Constant Head Permeability Test and (ii) Falling Head or Variable Head Permeability Test.

APPARATUS: Permeameter mould of internal dia 100mm and effective height 127.3mm, capacity 1000 ml; Detachable collar 100mm dia & 60mm high, Dummy plate 108mm diameter and 12mm thick; Drainage base having porous disc; Drainage cap having a porous disc with a spring attached to the top; Compaction equipment such as Proctor's rammer or a static compaction equipment, constant head water supply reservoir, vacuum pump; constant head collecting chamber; stop watch; large funnel; Thermometer; weighing balance; accuracy 0.1 gm; filter papers.

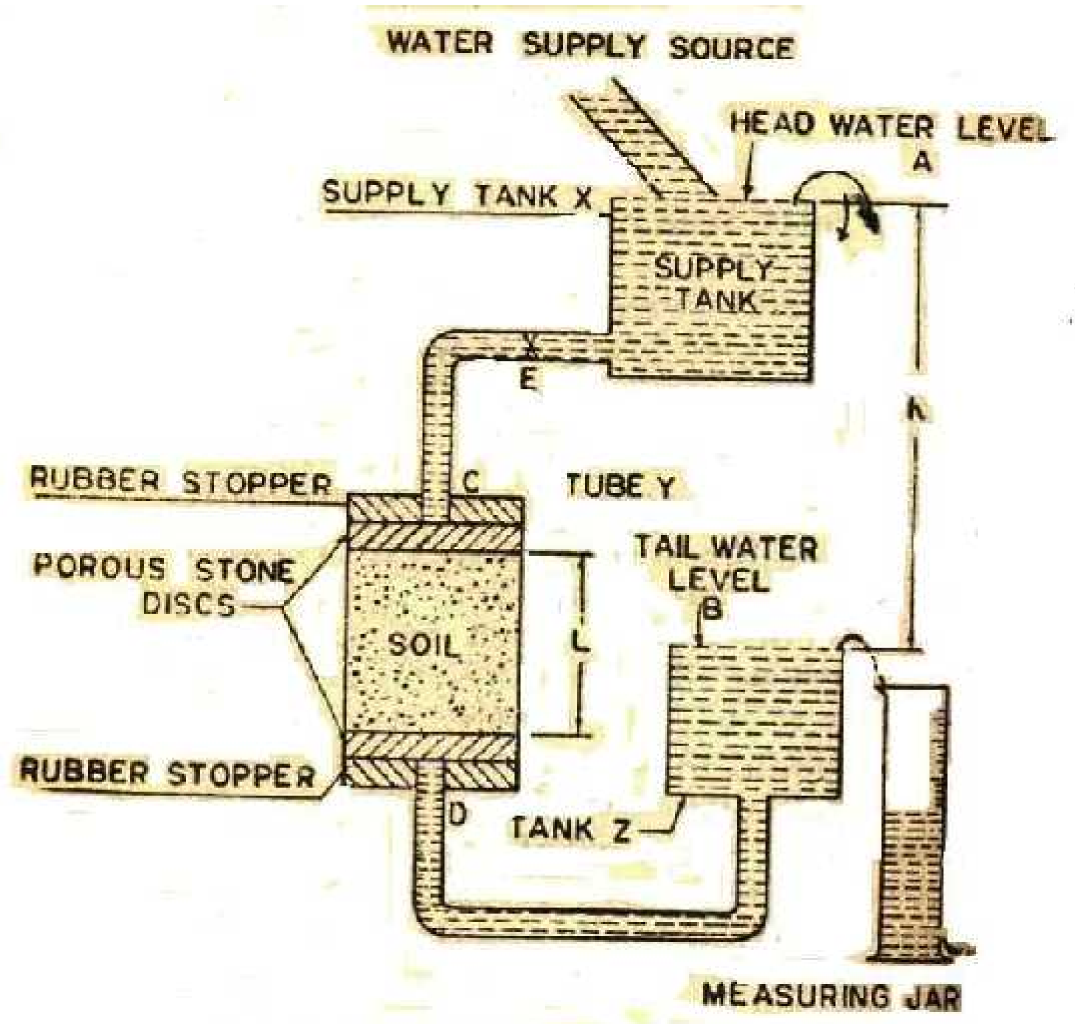
PROCEDURE:

1] Remove the collar of the mould. Measure the internal dimensions of the mould. Find the weight of the mould with dummy plate to the nearest gram.
2] Apply a little grease or oil on the inside to the mould clamp the mould between the base plate and the extension collar and place assembly on solid base.
3] Take about 2.5 kg of the soil sample from a thoroughly mixed wet soil in the mould. Compact the soil at the required dry density using a suitable compacting device.
4] Remove the collar and the base plate. Trim the excess soil and level the soil surface in level with the top of the mould.
5] Clean the outside of the mould and the dummy plate. Find the weight of soil in the mould.
6] Take a small specimen of the soil in a container and determine the water content.
7] Saturate the porous discs (stones).
8] Place a porous disc on the drainage base and place a fitter paper on the porous disc.
9] Remove the dummy plate and place the mould with the soil on the drainage base after inserting the washer in between.
10] Clean the edges of the mould. Apply grease or oil in the grooves around them.
11] Place a fitter paper on the top soil face and the porous disc on the fitter paper and fix the drainage cap using washers.
12] Connect the water reservoir to the outlet at the base and allow the water to flow upwards till it has saturated the sample. Let the free water collect for a depth of about 100mm on the top of the sample.
13] Fill the empty portion of the mould with deaired water without disturbing soil.
14] Disconnect the reservoir from the outlet at the bottom.
15] Connect the constant head reservoir to the drainage cap inlet.
16] Open the stop cock and all the water to flow downward so that all the air is removed.
17] Close the stop cock and allow the water to flow through the soil till a steady state is attained.
18] Start the stop watch and collect the water flowing out of the base in a measuring jar for some known time period (say for 1 min. or 1½ min.)
19] Repeat this thrice, keeping the interval the same. Check that quantity of water collected is approximately the same each time.
20] Measure the difference of head (h) in levels between the constant head reservoir and the outlet in the base.

The constant head permeability test is suitable for clean sands and Gravels with $K>10^{-2}$ mm/sec.
Observation (Data) sheet for Constant Head Permeameter Test :

OBSERVATIONS:

1] Weight of empty mould with base plate W_1 gm
2] Weight of mould, base & soil W_2 gm
3] Hydraulic Head causing flow, h cm
4] Trim for which discharge is collected, t sec
5] Quantity of flow or discharge (Q) ml
   a) First time in period, t
   b) Second time in period, t
   c) Third time in period, t
   Average Q (in ml x 10^3=mm^3)



Constant Head Permeameter

CALCULATIONS:

6] Weight of soil = $(W_2 - W_1)$ gr

7] Bulk density = $r_b = \dfrac{\text{Weight}}{\text{Volume}}$

8] Water content, w, determined

9] Dry Density = $r_{dry} = \dfrac{r_{wet}}{1+w}$

10] $K = \dfrac{QL}{Aht}$

Dia. of soil sample = Dia. Of mould (D) } = 100mm

Area = $\dfrac{D^2}{4}$ = 7854 mm^2

L = Length or height of sample to be measured before commencing test

RESULT:

The coefficient of permeability ………………………………

(B) COEFFICIENT OF PERMEABILITY (VARIABLE HEAD TEST)

AIM: To determine the coefficient of Permeability of a soil by variable or falling head test.

APPARATUS: Metallic mould of 100mm internal diameter, 127.3mm effective height and 1000ml capacity as per IS. The mould is provided with a detachable extension collar, 100mm diameter and 60mm high required during compaction of soil. The mould is provided with a drainage base plate with a recess for porous stone. The mould is fitted with a drainage cap having an inlet valve and an air release valve. The drainage base and cap have fitting for clamping to the mould. A vertical graduated stand pipe (½ cm; 1cm dia and 2 cm dia) is fitted to the top of permeameter, proctor's rammer, fitter papers; weighing balance, accuracy 0.1 gm; stop watch; supporting frame for stand pipe and clamping unit.

PROCEDURE: The variable read permeameter is used to measure the permeability of relatively less pervious soils such as very fine sand and silt and silty clays with $K=10^{-2}$ to 10^{-5} mm/sec.

The hydraulic head causing flow through soil sample is variable during the period of conducting the test.

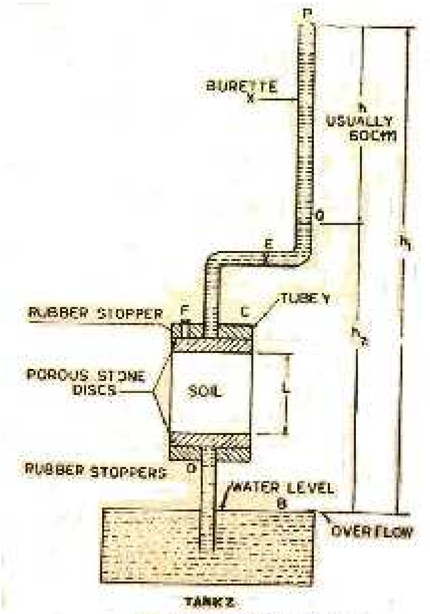
The coefficient of permeability of the soil is given by

$$K = \frac{2.303xaL}{At} \qquad \log_{10}\left(\frac{h_1}{h_2}\right)$$

Where h_1 = initial, head; h_2 = final head
t = time interval during which the head has fallen from h_1 to h_2
a = cross sectional area of stand pipe
A = cross sectional area of soil specimen
L = length or height of specimen

1] Remove the collar of the mould, measure the internal dimensions of the mould. Find the empty weight of mould (W_1 gm).
2] Apply a little grease or oil on the inside to the mould.
3] Take about 2.5Kg of soil sample, from a thoroughly mixed wet soil, in to the mould. Compact the soil at the required dry density using a suitable compacting device.
4] Remove the collar and the base plate. Trim the excess soil in level with the top of the mould.
5] Clean the outside of the mould and the dummy plate. Find the weight of mould+soil (W_2 gm).
(W_2 - W_1) = W=weight of soil in the mould
6] Take a small soil specimen and determine the water content.
7] Saturate the porous discs (stone).
Please note that the porous stones used shall be at least 10 times more pervious than the soil.
8] Place a porous disc on the drainage base and on this keep a fitter paper.
9] Remove the dummy plate and place the mould with the soil on the drainage base after inserting a washer in between.
10] Clean the edges of the mould. Apply grease or oil in the grooves around them.
11] Place a fitter paper and the porous disc and fix the drainage cap using washers.
12] Connect the stand pipe to the outlet at the base and allow the water to flow upwards till it has saturated the sample. Let the free water collect for depth of about 100mm on the top of the sample.
13] Fill the empty portion of the mould with deaired water without disturbing the sample.
14] Disconnect the stand pipe connection from the outlet at the bottom.
15] Connect the stand pipe to the drainage cap inlet. Fill the stand pipe with water.
16] Note the intial head h_1 above the centre of the outlet. Before noting h_1, open the stop cock at the top and allow the water to flow out till all the air in the mould is removed and close the stop cock. Now note h_1.
17] And allow the water from the stand pipe to flow through the soil specimen simultaneously start the stop watch.

18] After the head h_1 has fallen to a level h_2 difference in (h_1 and h_2 shall 100mm to 300mm) note final head h_2 and note the time taken for this.
It is necessary that steady state conditions shall be established.
It is fulfilled if the time for h_1 to h_2 is approximately the same as from h_2 to h_3.
19] Repeat the test for different values of h_1 and h_2 and record the time required.
20] In both the trials, the time, t, required for the head to tall from h_1 to h_2 and that from h_2 to h_3 shall be noted carefully.
Stop the flow and disconnect all the parts.
Take a small quantity of the soil specimen and determine its water content.



Variable Head Permeameter

Data sheet for variable head Permeameter Test:

OBSERVATIONS:

1] Weight of mould + base plate
2] Weight of mould + base + soil
3] Intial head, h_1
4] Final head, h_2
5] Time Interval from h_1 to h_2 =t

CALCULATIONS:

6] Weight of soil = (2) – (1)

7] Bulk density = $r_b = \dfrac{\text{Weight of soil}}{\text{Volume of soil}}$

8] Dry Density = $r_{dry} = \dfrac{r_b}{1+w}$

9] Void ratio, $e = \dfrac{Gr_w}{r_{dry}} - 1$

10] $$K = \frac{2.303 xaL}{At} \log_{10}\left(\frac{h_1}{h_2}\right)$$

(in mm/sec or in cm/sec)

<u>**RESULT:**</u>

The coefficient of permeability ………………………………

EXPERIMENT 5

COMPACTION TEST

AIM: To Determine The Compaction Characteristics Of A Soil Specimen By Proctor's Test

APPARATUS:
1. Compaction mould, capacity 1000ml.
2. Rammer, mass 2.6 kg.
3. Detachable base plate.
4. Collar, 60mm high.
5. IS sieve, 4.75 mm.
6. Oven
7. Desiccator
8. Weighing balance, accuracy 1g.
9. Large mixing pan
10. Straight edge.
11. Spatula
12. Graduated jar
13. Mixing tools, spoons, trowels, etc.

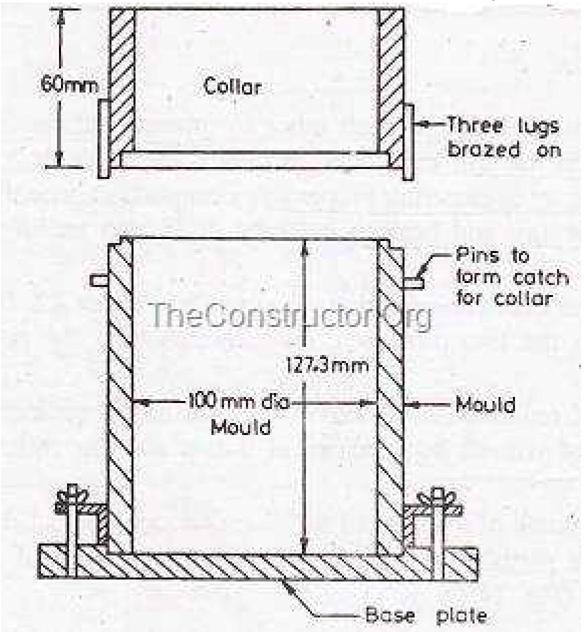
THEORY:
Compaction is the process of densification of soil by reducing air voids. The degree of compaction of a given soil is measured in terms of its dry density. The dry density is maximum at the optimum water content. A curve is drawn between the water content and the dry density to obtain the maximum dry density and the optimum water content.

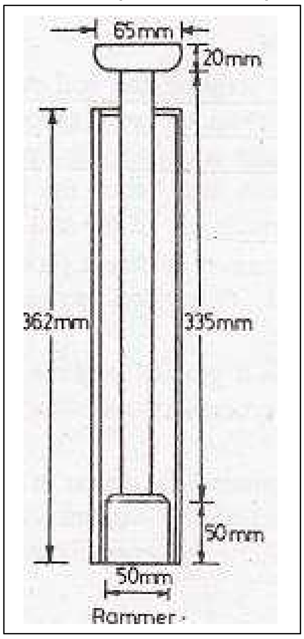
Dry density of soil: $= \frac{M / V}{1 + w}$

Where M = total mass of the soil, V= volume of soil, w= water content.

PROCEDURE:
1. Take about 20kg of air-dried soil. Sieve it through 20mm and 4.7mm sieve.
2. Calculate the percentage retained on 20mm sieve and 4.75mm sieve, and the percentage passing 4.75mm sieve.
3. If the percentage retained on 4.75mm sieve is greater than 20, use the large mould of 150mm diameter. If it is less than 20%, the standard mould of 100mm diameter can be used. The following procedure is for the standard mould.
4. Mix the soil retained on 4.75mm sieve and that passing 4.75mm sieve in proportions determined in step (2) to obtain about 16 to 18 kg of soil specimen.
5. Clean and dry the mould and the base plate. Grease them lightly.
6. Weigh the mould with the base plate to the nearest 1 gram.
7. Take about 16 – 18 kg of soil specimen. Add water to it to bring the water content to about 4% if the soil is sandy and to about 8% if the soil is clayey.
8. Keep the soil in an air-tight container for about 18 to 20 hours for maturing. Mix the soil thoroughly. Divide the processed soil into 6 to 8 parts.
9. Attach the collar to the mould. Place the mould on a solid base.
10. Take about 2.5kg of the processed soil, and hence place it in the mould in 3 equal layers. Take about one-third the quantity first, and compact it by giving 25 blows of the rammer. The blows should be uniformly distributed over the surface of each layer.
The top surface of the first layer be scratched with spatula before placing the second layer. The second layer should also be compacted by 25 blows of rammer. Likewise, place the third layer and compact it.
The amount of the soil used should be just sufficient to fill the mould ad leaving about 5 mm above the top of the mould to be struck off when the collar is removed.
11. Remove the collar and trim off the excess soil projecting above the mould using a straight edge.
12. Clean the base plate and the mould from outside. Weigh it to the nearest gram.
13. Remove the soil from the mould. The soil may also be ejected out.
14. Take the soil samples for the water content determination from the top, middle and bottom portions. Determine the water content.

15. Add about 3% of the water to a fresh portion of the processed soil, & repeat the steps 10 to 14

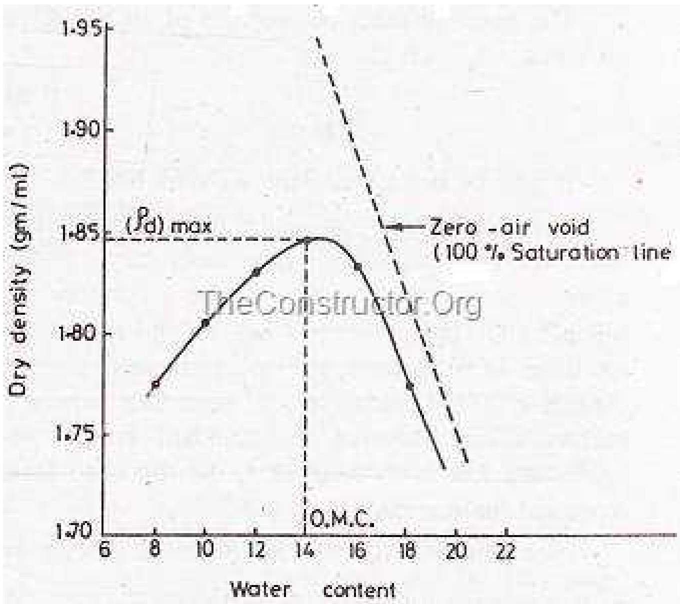




DATA SHEET FOR COMPACTION TEST:
Diameter of the mould =
Height of mould =
Volume of the mould, V=
Specific gravity of solids, G=

Sl. No.	Observations and Calculations	Determination No.		
		1	2	3
Observation				
1	Mass of empty mould with base plate			
2	Mass of mould, compacted soil and base plate			
Calculations				
3	Mass of compacted soil M = (2) - (1)			
4	Bulk Density $\rho = \frac{Mass}{Volume}$			
5	Water content, w			
6	Dry density $\rho_d = \frac{\rho}{1+w}$			
7	Void ratio $e = \frac{\rho_w G}{\rho_d} - 1$			
8	Dry density at 100% saturation (theoretical) $\rho_{d,\max} = \frac{G\rho_w}{1+wG}$			
9	Degree of saturation $S = \frac{wG}{e} \times 100$			

Plot a curve between 'w' as abscissa and ρ_d as ordinate.



RESULT:
Maximum dry density (from plot) =
Optimum water content (from plot) =

EXPERIMENT 6

CALIFORNIA BEARING RATIO TEST

AIM: To determine the California bearing ratio by conducting a load penetration test in the laboratory.

APPARATUS:
1. Cylindrical mould with inside dia 150 mm and height 175 mm, provided with a detachable extension collar 50 mm height and a detachable perforated base plate 10 mm thick.
2. Spacer disc 148 mm in dia and 47.7 mm in height along with handle.
3. **Metal rammers.** Weight 2.6 kg with a drop of 310 mm (or) weight 4.89 kg a drop 450 mm.
4. **Weights.** One annular metal weight and several slotted weights weighing 2.5 kg each, 147 mm in dia, with a central hole 53 mm in diameter.
5. **Loading machine.** With a capacity of at least 5000 kg and equipped with a movable head or base that travels at an uniform rate of 1.25 mm/min. Complete with load indicating device.
6. Metal penetration piston 50 mm dia and minimum of 100 mm in length.
7. Two dial gauges reading to 0.01 mm.
8. **Sieves.** 4.75 mm and 20 mm I.S. Sieves.
9. Miscellaneous apparatus, such as a mixing bowl, straight edge, scales soaking tank or pan, drying oven, filter paper and containers.

THEORY:
The california bearing ratio test is penetration test meant for the evaluation of subgrade strength of roads and pavements. The results obtained by these tests are used with the empirical curves to determine the thickness of pavement and its component layers. This is the most widely used method for the design of flexible pavement.

This instruction sheet covers the laboratory method for the determination of C.B.R. of undisturbed and remoulded /compacted soil specimens, both in soaked as well as unsoaked state.

DEFINITION OF C.B.R.:
It is the ratio of force per unit area required to penetrate a soil mass with standard circular piston at the rate of 1.25 mm/min. to that required for the corresponding penetration of a standard material.
C.B.R. = Test load/Standard load 100

The following table gives the standard loads adopted for different penetrations for the standard material with a C.B.R. value of 100%

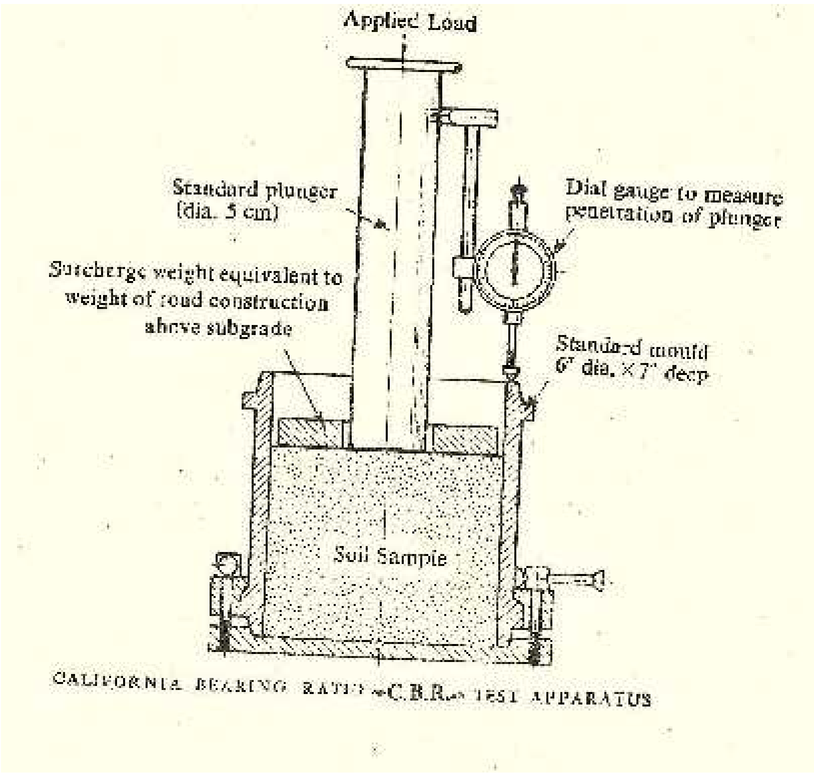
Penetration of plunger (mm)	Standard load (kg)
2.5	1370
5.0	2055
7.5	2630
10.0	3180
12.5	3600

The test may be performed on undisturbed specimens and on remoulded specimens which may be compacted either statically or dynamically.

PREPARATION OF TEST SPECIMEN:
Undisturbed specimen
Attach the cutting edge to the mould and push it gently into the ground. Remove the soil from the outside of the mould which is pushed in. When the mould is full of soil, remove it from weighing the soil with the mould or by any field method near the spot.

Determine the density
Remoulded specimen
Prepare the remoulded specimen at Proctor's maximum dry density or any other density at which C.B.R. is required. Maintain the specimen at optimum moisture content or the field moisture as required. The material used should pass 20 mm I.S. sieve but it should be retained on 4.75 mm I.S. sieve. Prepare the specimen either by dynamic compaction or by static compaction.

Dynamic Compaction
Take about 4.5 to 5.5 kg of soil and mix thoroughly with the required water.
Fix the extension collar and the base plate to the mould. Insert the spacer disc over the base (See Fig.38). Place the filter paper on the top of the spacer disc.
Compact the mix soil in the mould using either light compaction or heavy compaction. For light compaction, compact the soil in 3 equal layers, each layer being given 55 blows by the 2.6 kg rammer. For heavy compaction compact the soil in 5 layers, 56 blows to each layer by the 4.89 kg rammer.



Remove the collar and trim off soil.
Turn the mould upside down and remove the base plate and the displacer disc.
Weigh the mould with compacted soil and determine the bulk density and dry density.

Put filter paper on the top of the compacted soil (collar side) and clamp the perforated base plate on to it.

Static Compaction
Calculate the weight of the wet soil at the required water content to give the desired density when occupying the standard specimen volume in the mould from the expression.

W =desired dry density * (1+w) V

Where W = Weight of the wet soil
w = desired water content
V = volume of the specimen in the mould = 2250 cm^3 (as per the mould available in laboratory)

Take the weight W (calculated as above) of the mix soil and place it in the mould.
Place a filter paper and the displacer disc on the top of soil.
Keep the mould assembly in static loading frame and compact by pressing the displacer disc till the level of disc reaches the top of the mould.
Keep the load for some time and then release the load. Remove the displacer disc.
The test may be conducted for both soaked as well as unsoaked conditions.
If the sample is to be soaked, in both cases of compaction, put a filter paper on the top of the soil and place the adjustable stem and perforated plate on the top of filter paper.
Put annular weights to produce a surcharge equal to weight of base material and pavement expected in actual construction. Each 2.5 kg weight is equivalent to 7 cm construction. A minimum of two weights should be put.
Immerse the mould assembly and weights in a tank of water and soak it for 96 hours. Remove the mould from tank.
Note the consolidation of the specimen.
Procedure for Penetration Test
Place the mould assembly with the surcharge weights on the penetration test machine. (Fig.39).
Seat the penetration piston at the center of the specimen with the smallest possible load, but in no case in excess of 4 kg so that full contact of the piston on the sample is established.
Set the stress and strain dial gauge to read zero. Apply the load on the piston so that the penetration rate is about 1.25 mm/min.
Record the load readings at penetrations of 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 7.5, 10 and 12.5 mm. Note the maximum load and corresponding penetration if it occurs for a penetration less than 12.5 mm.
Detach the mould from the loading equipment. Take about 20 to 50 g of soil from the top 3 cm layer and determine the moisture content.

OBSERVATION AND RECORDING:

For Dynamic Compaction

Optimum water content (%)	:	
Weight of mould + compacted specimen g	:	
Weight of empty mould g	:	
Weight of compacted specimen g	:	
Volume of specimen cm^3	:	
Bulk density g/cc	:	
Dry density g/cc	:	

For static compaction

Dry density g/cc	:	
Moulding water content %	:	
Wet weight of the compacted soil, (W)g	:	
Period of soaking 96 hrs. (4days).	:	
For penetration Test	:	
Calibration factor of the proving ring	:	1 Div. = 1.176 kg
Surcharge weight used (kg)	:	2.0 kg per 6 cm construction
Water content after penetration test %	:	
Least count of penetration dial	:	1 Div. = 0.01 mm

If the initial portion of the curve is concave upwards, apply correction by drawing a tangent to the curve at the point of greatest slope and shift the origin (Fig. 40). Find and record the correct load reading corresponding to each penetration.

$$C.B.R. = P_T/P_S\ 100$$

where P_T = Corrected test load corresponding to the chosen penetration from the load penetration curve.
P_S = Standard load for the same penetration taken from the table.

Penetration Dial		Load Dial		Corrected Load
Readings	Penetration (mm)	proving ring reading	Load (kg)	

RESULT:
C.B.R. of specimen at 2.5 mm penetration
C.B.R. of specimen at 5.0 mm penetration

NOTE:
The C.B.R. values are usually calculated for penetration of 2.5 mm and 5 mm. Generally the C.B.R. value at 2.5 mm will be greater that at 5 mm and in such a case/the former shall be taken

C.B.R. for design purpose. If C.B.R. for 5 mm exceeds that for 2.5 mm, the test should be repeated. If identical results follow, the C.B.R. corresponding to 5 mm penetration should be taken for design

EXPERIMENT 7

CONSOLIDATION TEST

AIM: To determine the settlements due to primary consolidation of soil by conducting one dimensional test.

APPARATUS:

1. Consolidometer consisting essentially
   a) A ring of diameter = 60mm and height = 20mm
   b) Two porous plates or stones of silicon carbide, aluminum oxide or porous metal.
   c) Guide ring.
   d) Outer ring.
   e) Water jacket with base.
   f) Pressure pad.
   g) Rubber basket.
2. Loading device consisting of frame, lever system, loading yoke dial gauge fixing device and weights.
3. Dial gauge to read to an accuracy of 0.002mm.
4. Thermostatically controlled oven.
5. Stopwatch to read seconds.
6. Sample extractor.

Miscellaneous items like balance, soil trimming tools, spatula, filter papers, sample containers

THEORY:

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.

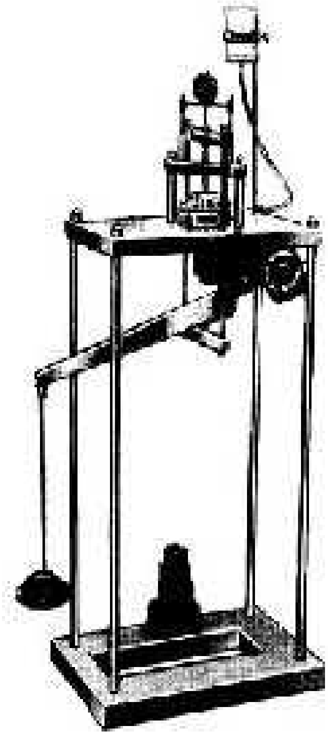
From the above information it will be possible for us to predict the time rate and extent of settlement of structures founded on fine-grained soils. It is also helpful in analyzing the stress history of soil. Since the settlement analysis of the foundation depends mainly on the values determined by the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

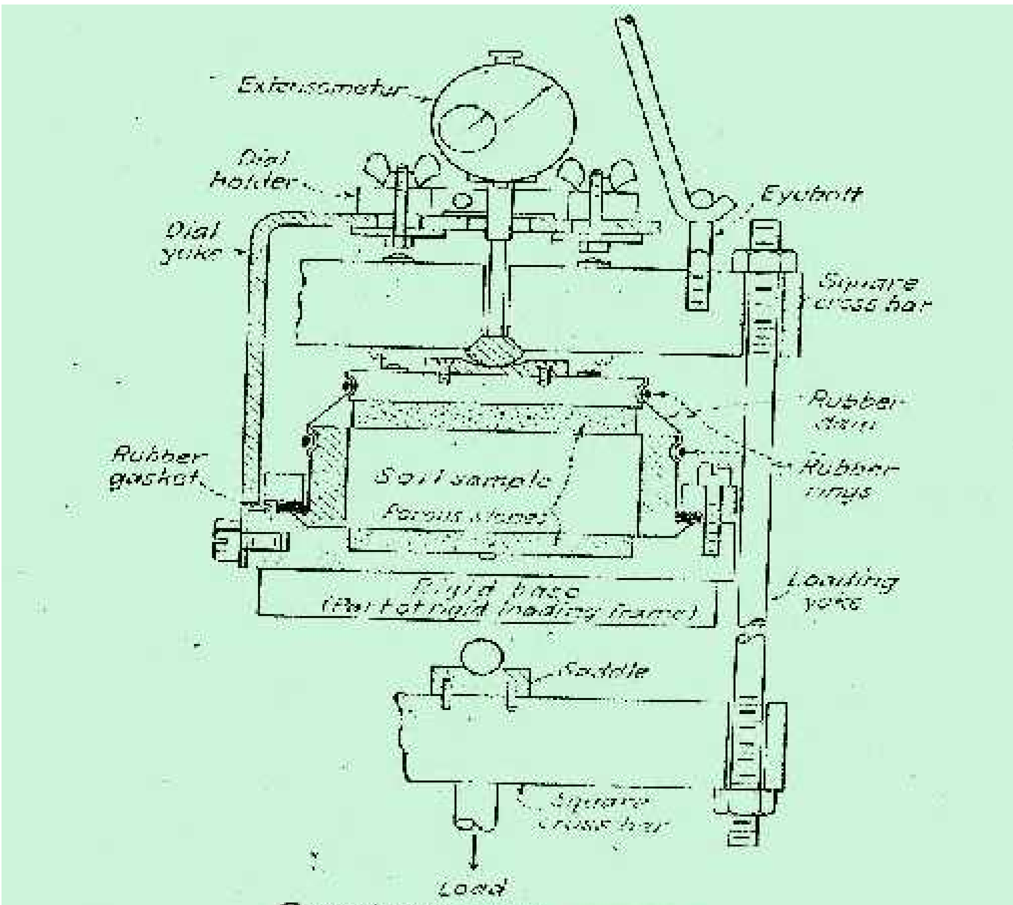
PRINCIPAL INVOLVED:

When a compressive load is applied to soil mass, a decrease in its volume takes place, the decease in volume of soil mass under stress is known as compression and the property of soil mass pertaining to its tendency to decrease in volume under pressure is known as compressibility. In a saturated soil mass having its void filled with incompressible water, decrease in volume or compression can take place when water is expelled out of the voids. Such a compression resulting from a long time static load and the consequent escape of pore water is termed as consolidation.

Then the load is applied on the saturated soil mass, the entire load is carried by pore water in the beginning. As the water starts escaping from the voids, the hydrostatic pressure in water gets gradually dissipated and the load is shifted to the soil solids which increases effective on them, as a result the soil mass decrease in volume. The rate of escape of water depends on the permeability of the soil.

1) From the sample tube, eject the sample into the consolidation ring. The sample should project about one cm from outer ring. Trim the sample smooth and flush with top and bottom of the ring by using a knife. Clean the ring from outside and keep it ready from weighing.
2) Remoulded sample :
   a) Choose the density and water content at which samples has to be compacted from the moisture density relationship.
   b) Calculate the quantity of soil and water required to mix and compact.
   c) Compact the specimen in compaction mould in three layers using the standard rammers.
   d) Eject the specimen from the mould using the sample extractor.





Consolidation-test apparatus

PROCEDURE:

1. Saturate two porous stones either by boiling in distilled water about 15 minute or by keeping them submerged in the distilled water for 4 to 8 hrs. Wipe away excess water. Fittings of the consolidometer which is to be enclosed shall be moistened.
2. Assemble the consolidometer, with the soil specimen and porous stones at top and bottom of specimen, providing a filter paper between the soil specimen and porous stone. Position the pressure pad centrally on the top porous stone.
3. Mount the mould assembly on the loading frame, and center it such that the load applied is axial.
4. Position the dial gauge to measure the vertical compression of the specimen. The dial gauge holder should be set so that the dial gauge is in the begging of its releases run, allowing sufficient margin for the swelling of the soil, if any.
5. Connect the mould assembly to the water reservoir and the sample is allowed to saturate. The level of the water in the reservoir should be at about the same level as the soil specimen.
6. Apply an initial load to the assembly. The magnitude of this load should be chosen by trial, such that there is no swelling. It should be not less than 50 g/cm^3 for ordinary soils & 25 g/cm^2 for very soft soils. The load should be allowed to stand until there is no change in dial gauge readings for two consecutive hours or for a maximum of 24 hours.
7. Note the final dial reading under the initial load. Apply first load of intensity 0.1 kg/cm^2 start the stop watch simultaneously. Record the dial gauge readings at various time intervals. The dial gauge readings are taken until 90% consolidation is reached. Primary consolidation is gradually reached within 24 hrs.
8. At the end of the period, specified above take the dial reading and time reading. Double the load intensity and take the dial readings at various time intervals. Repeat this procedure fir successive load increments. The usual loading intensity are as follows :

a. 0.1, 0.2, 0.5, 1, 2, 4 and 8 kg/cm^2.

9. After the last loading is completed, reduce the load to of the value of the last load and allow it to stand for 24 hrs. Reduce the load further in steps of the previous intensity till an intensity of 0.1 kg/cm^2 is reached. Take the final reading of the dial gauge.
10. Reduce the load to the initial load, keep it for 24 hours and note the final readings of the dial gauge.
11. Quickly dismantle the specimen assembly and remove the excess water on the soil specimen in oven, note the dry weight of it.

OBSERVATION AND READING:

Table

Data and observation sheet for consolidation test pressure, compression and time.

Project: Name of the project — Borehole no. : 1

Depth of the sample: 2m — Description of soil:

Empty weight of ring: 635 gm — Area of ring: 4560 mm^2 (45.60 cm^2)

Diameter of ring: 76.2 mm (7.62 cm) — Volume of ring: 115.82 cm^3

Height of ring: 25.4 (2.54 cm) — Specific gravity of soil sample No:

Dial Gauge = 0.0127 mm (least count)

Elapsed Time (Min)	Proving Sing Reading

CALCULATIONS:

1. **Height of solids** (H_S) is calculated from the equation

$$H_S = W_S/G\ A$$

2. **Void ratio.** Voids ratio at the end of various pressures are calculated from equation

$$e = (H - H_S)/H_S$$

3. **Coefficient of consolidation**. The Coefficient of consolidation at each pressures increment is

Calculated by using the following equations:

i. $C_v = 0.197\ d^2/t_{50}$ (Log fitting method)

ii. $C_v = 0.848\ d^2/t_{90}$ (Square fitting method)

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

In the square root fitting method, a plot is made between dial readings and square root of time and the time corresponding to 90% consolidation is determined. The values of C_v are recorded in table .

4. Compression Index. To determine the compression index, a plot of voids ratio (e) V_s $\log_t$ is made. The initial compression curve would be a straight line and the slope of this line would give the compression index C_c.

5. Coefficient of compressibility. It is calculated as follows

a_v = 0.435 C_c/Avg. pressure for the increment

where C_c = Coefficient of compressibility

6. Coefficient of permeability. It is calculated as follows

$K = C_v.a_v$ *(unit weight of water)/(1+e).

GRAPHS:

1. Dial reading V_S log of time or
   Dial reading V_S square root of time.
2. Voids ratio V_S $\log_t$ (average pressure for the increment).

NOTE:

1. While preparing the specimen, attempts has to be made to have the soil strata orientated in the same direction in the consolidation apparatus.

RESULT:

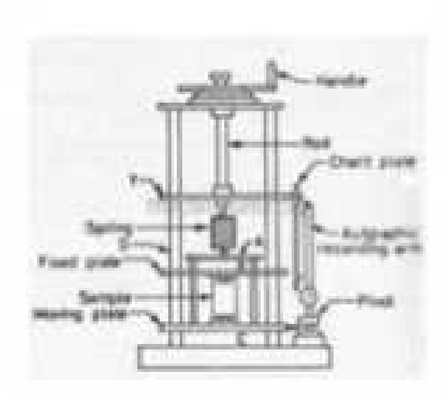
EXPERIMENT 8

UNCONFINED COMPRESSION TEST

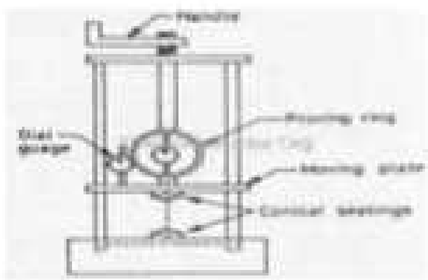
AIM: Determine shear parameters of cohesive soil

APPARATUS:
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 (Aluminum container).
6. Soil sample of 75 mm length.
7. Dial gauge (0.01 mm accuracy).
8. Balance of capacity 200 g and sensitivity to weigh 0.01 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 calipers

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



Unconfined Compression Testing Machine (Spring Type)



Unconfined Compression Testing Machine (Proving Ring Type)

PROCEDURE:

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.
   Preparation of specimen for testing

A. Undisturbed specimen

1. Note down the sample number, bore hole number and the depth at which the sample was taken.
2. Remove the protective cover (paraffin wax) from the sampling tube.
3. Place the sampling tube extractor and push the plunger till a small length of sample moves out.
4. Trim the projected sample using a wire saw.
5. Again push the plunger of the extractor till a 75 mm long sample comes out.
6. Cutout this sample carefully and hold it on the split sampler so that it does not fall.
7. Take about 10 to 15 g of soil from the tube for water content determination.
8. Note the container number and take the net weight of the sample and the container.
9. Measure the diameter at the top, middle, and the bottom of the sample and find the average and record the same.
10. Measure the length of the sample and record.
11. Find the weight of the sample and record.

B. Moulded sample

1. For the desired water content and the dry density, calculate the weight of the dry soil Ws required for preparing a specimen of 3.8 cm diameter and 7.5 cm long.
2. Add required quantity of water W_w to this soil.
   $W_w = W_S\ W/100$ gm
3. Mix the soil thoroughly with water.
4. Place the wet soil in a tight thick polythene bag in a humidity chamber and place the soil in a constant volume mould, having an internal height of 7.5 cm and internal diameter of 3.8 cm.
5. After 24 hours take the soil from the humidity chamber and place the soil in a constant volume mould, having an internal height of 7.5 cm and internal diameter of 3.8 cm.
6. Place the lubricated moulded with plungers in position in the load frame.
7. Apply the compressive load till the specimen is compacted to a height of 7.5 cm.
8. Eject the specimen from the constant volume mould.
9. Record the correct height, weight and diameter of the specimen.

TEST PROCEDURE:

1. Take two frictionless bearing plates of 75 mm diameter.
2. Place the specimen on the base plate of the load frame (sandwiched between the end plates).
3. Place a hardened steel ball on the bearing plate.
4. Adjust the center line of the specimen such that the proving ring and the steel ball are in the same line.
5. Fix a dial gauge to measure the vertical compression of the specimen.
6. Adjust the gear position on the load frame to give suitable vertical displacement.
7. Start applying the load and record the readings of the proving ring dial and compression dial for every 5 mm compression.
8. Continue loading till failure is complete.
9. Draw the sketch of the failure pattern in the specimen.

Project : Tested by :
Location : Boring No. :
Depth :

Sample details
Type UD/R : soil description
Specific gravity (G_S) 2.71 Bulk density
Water content Degree of saturation .%
Diameter (D_o) of the sample cm Area of cross-section = cm^2

Initial length (L_o) of the sample = 76 mm

Elapsed time (minutes) 1	**Compression dial reading (L) (mm) 2**	**Strain L 100/L_o (%) (e) 3**	**Area A $A_o/(1-e)$ $(cm)^2$ 4**	**Proving ring reading (Divns.) 5**	**Axial load (kg) 6**	**Compressive stress (kg/cm^2) 7**

CALCULATIONS:
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. Upto 6% strain the readings may be taken at every min (30 sec).

RESULT:
Unconfined compression strength of the soil = …………………
Shear strength of the soil = ………………………………………………

EXPERIMENT 9

TRI-AXIAL COMPRESSION TEST

AIM: To find the shear of the soil by Triaxial Compression Test.

APPARATUS:
a) 3.8 cm (1.5 inch) internal diameter 12.5 cm (5 inches) long sample tubes.
b) Rubber ring.
c) An open ended cylindrical section former, 3.8 cm inside dia, fitted with a small rubber tube in its side.
d) Stop clock.
e) Moisture content test apparatus.
f) A balance of 250 gm capacity and accurate to 0.01 gm.

THEORY:
The standard consolidated undrained 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 perform with or without measurement of pore pressure although for most applications the measurement of pore pressure is desirable.

PROCEDURE:
1. The sample is placed in the compression machine and a pressure plate is placed on the top. Care must be taken to prevent any part of the machine or cell from jogging the sample while it is being setup, for example, by knocking against this bottom of the loading piston. The probable strength of the sample is estimated and a suitable proving ring selected and fitted to the machine.
2. The cell must be properly set up and uniformly clamped down to prevent leakage of pressure during the test, making sure first that the sample is properly sealed with its end caps and rings (rubber) in position and that the sealing rings for the cell are also correctly placed.
3. When the sample is setup water is admitted and the cell is fitted under water escapes from the beed valve, at the top, which is closed. If the sample is to be tested at zero lateral pressure water is not required.
4. The air pressure in the reservoir is then increased to raise the hydrostatic pressure in the required amount. The pressure gauge must be watched during the test and any necessary adjustments must be made to keep the pressure constant.
5. The handle wheel of the screw jack is rotated until the under side of the hemispherical seating of the proving ring, through which the loading is applied, just touches the cell piston.
6. The piston is then removed down by handle until it is just in touch with the pressure plate on the top of the sample, and the proving ring seating is again brought into contact for the begging of the test.

OBSERVATION:

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.

Operator : Sample No:
Date : Job :
Location : Size of specimen :
Length : Proving ring constant :
Diameter : 3.81 cm Initial area L:
Initial Volume : Strain dial least count (const) :

Cell pressure kg/cm^2 1	Strain dial 2	Proving ring reading 3	Load on sample kg 4	Corrected area cm^2 5	Deviator stress 6
0.5	0 50 100 150 200 250 300 350 400 450				
0.5	0 50 100 150 200 250 300 350 400 450				
0.5	0 50 100 150 200 250 300 350 400 450				

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

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 = C + tan . 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 ( ) is angle between the tangent and a lineparallel to the shear stress.

RESULT:

EXPERIMENT 10

DIRECT SHEAR TEST

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

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 upto 200 mg.
8. Aluminum container.
9. Spatula.

THEORY:
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 cohesionless soils.

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.

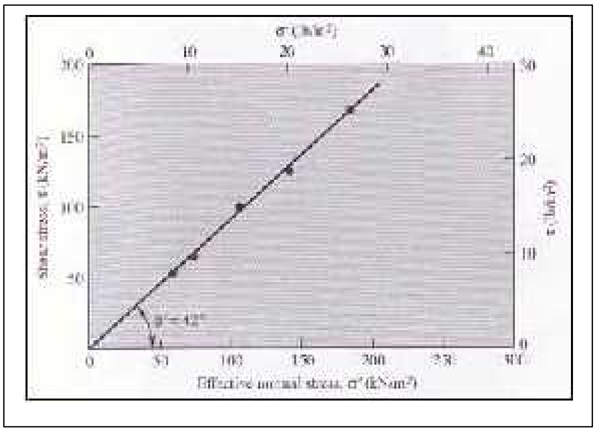
PROCEDURE:
1. Check the inner dimension of the soil container.
2. Put the parts of the soil container together.
3. Calculate the volume of the container. Weigh the container.
4. Place the soil in smooth layers (approximately 10 mm thick). If a dense sample is desired tamp the soil.
5. Weigh the soil container, the difference of these two is the weight of the soil. Calculate the density of the soil.
6. Make the surface of the soil plane.
7. Put the upper grating on stone and loading block on top of soil.
8. Measure the thickness of soil specimen.
9. Apply the desired normal load.
10. Remove the shear pin.
11. Attach the dial gauge which measures the change of volume.
12. Record the initial reading of the dial gauge and calibration values.
13. Before proceeding to test check all adjustments to see that there is no connection between two parts except sand/soil.
14. Start the motor. Take the reading of the shear force and record the reading.
15. Take volume change readings till failure.
16. Add 5 kg normal stress 0.5 kg/cm^2 and continue the experiment till failure
17. Record carefully all the readings. Set the dial gauges zero, before starting the experiment

OBSERVATION/CALCULATIONS:
Normal Stress 0.5 kg/cm^2 L.C. = ……………………………
P.R.C = ………………………

Normal Stress 1.0 kg/cm^2 L.C = …………………………
P.R.C = ………………………

Normal Stress 1.5 kg/cm^2 L.C = …………………………
P.R.C = ………………………

S.No	Normal load (kg)	Normal stress(kg/cm^2) load x leverage/Area	Normal stress(kg/cm^2) load x leverage/Area	Shear stress proving Ring reading x calibration / Area of container
1 2 3				



REMARKS:

1. In the shear box test, the specimen is not failing along its weakest plane but along a predetermined or induced failure plane i.e. horizontal plane separating the two halves of the shear box. This is the main drawback of this test. Moreover, during loading, the state of stress cannot be evaluated. It can be evaluated only at failure condition i.e., Mohr's circle can be drawn at the failure condition only. Also failure is progressive.
2. Direct shear test is simple and faster to operate. As thinner specimens are used in shear box, they facilitate drainage of pore water from a saturated sample in less time. This test is also useful to study friction between two materials one material in lower half of box and another material in the upper half of box.
3. The angle of shearing resistance of sands depends on state of compaction, coarseness of grains, particle shape and roughness of grain surface and grading. It varies between 28°(uniformly graded sands with round grains in very loose state) to 46°(well graded sand with angular grains in dense state).
4. The volume change in sandy soil is a complex phenomenon depending on gradation, particle shape, state and type of packing, orientation of principal planes, principal stress ratio, stress history, magnitude of minor principal stress, type of apparatus, test procedure, method of preparing specimen etc. In general loose sands expand and dense sands contract in volume on shearing. There is a void ratio at which either expansion contraction in volume takes place. This void ratio is called critical void ratio. Expansion or contraction can be inferred from the movement of vertical dial gauge during shearing.
5. The friction between sand particles is due to sliding and rolling friction and interlocking action. The ultimate values of shear parameter for both loose sand and dense sand approximately attain the same value so, if angle of friction value is calculated at ultimate stage, slight disturbance in density during sampling and preparation of test specimens will not have much effect.

RESULT:

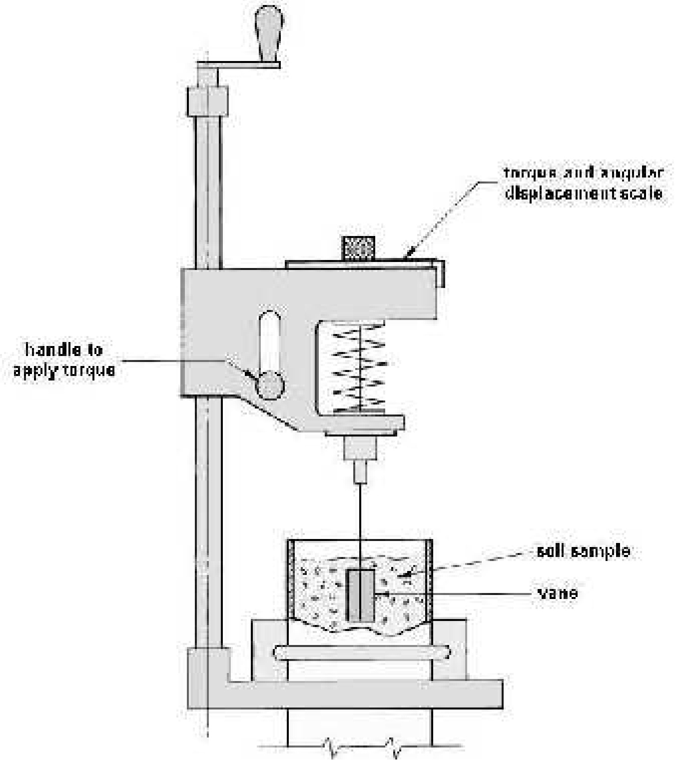
From graph shear strength of soil is ……………

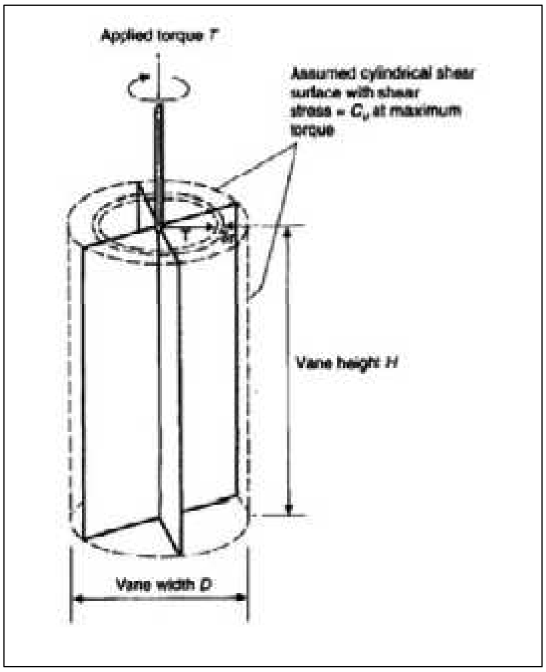
EXPERIMENT 11

VANE SHEAR TEST

AIM: To find shear strength of a given soil specimen.

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





THEORY:
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.

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 atleast 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.
6. 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.

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

OBSERVATIONS:

Shear Strength $S = \frac{T}{\pi\,[D^2H/2 + D^3]}$

Where S = Shear Strength of soil in kg/cm^2

T = Torque in Kg Cm

D = Overall Diameter of Vane in Cm

T = Spring Constant / 130 X Difference in degree

CALCULATIONS:

Diameter = ……………

Height = ………………

Area = ……………………

Volume = ……………………

Weight = ………………………

Water quantity required = weight x omc

GENERAL REMARKS:

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

RESULT:

Shear Strength or the given soil sample is ……………………………