LABORATORY MANUAL FOR GEOTECHNICAL ENGINEERING

Subject Code: CEP 1501

Course Coordinator

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CEP 1501 GEOTECHNICAL ENGINEERING LABORATORY (0 - 0 - 2)

1. Course Description

The Lab sessions would include experiments on different tests on soils to find out their properties.

2. Learning Outcome

On completion of the course, the students will be able to:

- Determine index properties of soils.
- Classify soils.
- Determine engineering properties of soils.

3. Broad Course Outline

- Sieve analysis
- Consistency limits
- Specific gravity
- Permeability tests
- Unconfined compression test
- SPT test
- Direct shear test
- Core cutter and sand replacement method
- Compaction test
- California bearing ratio test
- Vane shear test
- Triaxial test
- Consolidation test
- Plate load test

List of Experiments

Experiment No 1

Sieve Analysis

AIM: To determine the grain size distribution of the given soil by dry sieving.

THEORY:

Soil gradation is the distribution of different particle sizes expressed as a percent of the total dry weight. The grain size analysis results are shown graphically in the form of a grain size distribution curve, in which the cumulative percentages finer are plotted against the particle size in the semilogarithmic scale.

NEED AND SCOPE:

The results of grain size analysis are used for the soil classification. GSD curves are also used in the design of earth dam filter to determine its suitability.

APPARATUS REQUIRED:

1. A series of sieve sets ranging from 4.75mm to 75µm (4.75mm, 2.00mm, 1.00mm, 425µm, 212µm, 150µm, 75µm)

2. Balance sensitive to ± 0.01g

3. Mechanical sieve shaker

4. Wire brush

PROCEDURE:

Soil passing 4.75mm I.S. Sieve and retained on 75-micron I.S. Sieve contains no fines. Those soils can be directly dry sieved rather than wet sieved.

PRESENTATION OF DATA:

Weight of Sample taken for Sieve Analysis = ______ gms.

Weight of Sample taken for Dry Sieve Analysis = ______ gms

OBSERVATION TABLE

Sr. No.	I.S. Sieve No	Wt. Retained in Grams	Cumulative Wt. Retained in Grams	Percent (%) weight retained	Percent (%) weight passing
1	4.75mm				
2	2.00mm				
3	1.00mm				
4	425 microns				
5	212 microns				
6	150 microns				
7	75 microns				
8	Pan				

QUESTIONS:

1. Compare mechanical and wet sieving.
2. State the different sizes of sieves used in this experiment.
3. Mention the sieve set range for coarse type of soil.
4. State the minimum time of sieving the soil sample.
5. Write the weight of the soil sample taken in this test.
6. Is gradation affecting the soil properties? State properties.
7. State the use of pan/receiver in sieve analysis.
8. State the application of the particle size distribution curve.

Experiment No 2

Liquid Limit Test

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

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 12 mm on being given 25 blows in a standard manner. This is the limiting moisture content at which the cohesive soil passes from a plastic state to a liquid state.

NEED AND SCOPE:

Liquid limit is used for soil classification. It gives an idea of the consistency of the soil in the field, if the in-situ moisture content is known. If the in-situ moisture content of the soil is closer to the liquid limit, the soil can be considered as soft. If the moisture content is lesser than the liquid limit, the soil is brittle and stiffer. From the results of the liquid limit, the compression index may also be estimated. The compression index value helps in settlement analysis.

APPARATUS REQUIRED:

1. Balance (sensitive to 0.01g)
2. Casagrande's Liquid limit device
3. Grooving tool (Casagrande or ASTM tool)
4. Mixing dishes
5. Spatula
6. Electrical Oven
7. Squeeze Bottle

PROCEDURE:

1. Take 250 gm of oven-dried soil, passed through a 425 µm IS sieve, into an evaporating dish. Add distilled water into the soil and mix it thoroughly to form a uniform paste. (The paste should have a consistency that would require 30 to 35 drops of the cup to cause a closer of standard groove for sufficient length.)

2. The drop of the cup is adjusted to be exactly 1 cm using an adjustment plate. This procedure is called the calibration of the Liquid limit device.

3. Place a portion of the paste in the cup of the Liquid Limit device and spread it with a few strokes of a spatula.

4. Trim it to a depth of 1 cm at the point of maximum thickness and return the excess soil to the dish.

5. Using the grooving tool, cut a groove along the center line of the soil pat in the cup, so that a clean sharp groove of proper dimension (11 mm wide at top, 2 mm at bottom, and 8 mm deep for Casagrande's tool) is formed.

6. Lift and drop the cup by turning the crank at the rate of two revolutions per second until the two halves of the soil cake come in contact with each other for a length of about 12 mm by flow only, and record the number of blows, N.

7. Take a representative portion of soil from the cup for moisture content determination.

8. Repeat the test with different moisture contents at least five more times for blows between 15 and 35.

OBSERVATIONS:

Details of the sample:

Natural moisture content: Room temperature:

OBSERVATION TABLE

Determination Number	1	2	3	4	5	6
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 ($W_s=w_3-w_1$)						
Moisture content (%) =(W_w/W_s)						
No. of blows						

COMPUTATION / CALCULATION:

Plot the relationship between water content (on the y-axis) and the number of blows (on the x-axis) on a semi-log graph. The curve obtained is called the 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.

Liquid limit, W_L = (At 25 blows, from semi log-graph of water content Vs. No. of blows)

Flow index, $I_f = \frac{(W_2 - W_1)}{\log\left(\frac{N_1}{N_2}\right)}$

= slope of the flow curve

=

QUESTIONS:

1. What are Atterberg limits?

2. Define liquid limit. How are they useful in classifying soils?

3. Name the apparatus commonly used for determining liquid limit.

4. Name the sieve no. used in preparing soil samples.

5. If the plastic limit is greater than or equal to the limit, how will you report the Ip of the soil?

6. Is soil fully saturated at shrinkage limit?

7. What is the value of the shear strength of soil possessed at limit liquid?

8. What is the size of the groove cut?

9. What is the rate of revolution of the mechanical device?

Experiment No 3

Plastic Limit Test

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

THEORY:

The plastic limit (PL) is determined by rolling out a thread of the fine portion of a soil on a flat, non-porous surface. The plastic limit is defined as the moisture content where the thread breaks apart at a diameter of 3 mm. A soil is considered non-plastic if a thread cannot be rolled out down to 3 mm at any moisture content.

NEED AND SCOPE:

Plastic Limit (PL or WP) is the water content of the soil at the boundary between the plastic and semi-solid states. The plastic limit is used for the classification of soils. In addition, the plastic limit of soil is also used, either individually or with other soil properties, to correlate engineering properties such as compressibility, permeability, compatibility, shrink-swell, and shear strength.

APPARATUS REQUIRED:

1. Porcelain dish
2. Squeeze Bottle and Spatula
3. Balance of capacity 200 gm and sensitive to 0.01gm
4. Ground glass plate for rolling the specimen
5. Containers to determine the moisture content
6. Oven thermostatically controlled with the interior of non-corroding material to maintain the temperature around 105^0C and 110^0C
7. Metal rod of 3 mm diameter and about 10 cm long

PROCEDURE:

1. Take 20 gm of oven-dried soil and pass it through the 425-micron sieve (In accordance with I.S. 2720: part-1) into an evaporating dish. Add distilled water into the soil and mix it thoroughly to form a uniform paste (the soil paste should be plastic enough to be easily molded with fingers).

2. Prepare several ellipsoidal-shaped soil masses by squeezing the soil between your fingers. Take one of the soil masses and roll it on the glass plate using your figures. The pressure of rolling should be just enough to make a thread of uniform diameter throughout its length. The rate of rolling shall be between 60 to 90 strokes per minute.

3. Continue rolling until you get the thread diameter of 3 mm.

4. If the soil thread does not crumble at a diameter of 3 mm, knead the soil together to make a uniform soil mass and re-roll.

5. Continue the process until the thread crumbles when the diameter is 3 mm.

6. Collect the pieces of the crumbled thread for moisture content determination. (Prepare threads at least with 10gm of soil for water content measurement).

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

PRESENTATION OF DATA:

Description	Trial 1	Trial 2	Trial 3
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 (%) = $(W_2 - W_3) / (W_3 - W_1) \times 100$			
Average Plastic Limit, (%)			

Plasticity Index, (I_P) = (LL - PL)

=

=

Toughness Index = I_P/I_F

=

=

Interpretation:

1- Soil classification according to their plasticity index, I_P

Plasticity index, I_P (%)	Soil description
0	Non-plastic
< 7	Low plastic
7-17	Medium plastic
> 17	Highly plastic

QUESTIONS:

1. If the plastic limit is greater than or equal to the liquid limit, how will you report the I_P of the soil?
2. How will you report the plasticity index if the plastic limit isn't determined for sandy soil?
3. Whether oven drying of the sample before the test is permitted? If not, why?

Experiment No 4
Shrinkage Limit Test

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

THEORY:

The water content at which a reduction in water content will not cause a decrease in the volume of the soil mass, but an increase in water will increase the volume. It is the minimum water content at which soil is still in a saturated condition. It is the state which acts as the boundary between solid and semi-solid states.

NEED AND SCOPE:

A shrinkage limit test gives an indication of how much moisture content can change before any significant volume change. The shrinkage limit is useful in areas where soils undergo large volume changes when going through wet and dry cycles (e.g., Black cotton soil) due to seasonal variation.

APPARATUS REQUIRED:

1. Evaporating Dish of Porcelain
2. Spatula and Straight Edge
3. Balance-Sensitive to 0.01 g minimum
4. Shrinkage Dish - Circular, porcelain or non-corroding metal dish
5. Glass cup. 50-55 mm in diameter and 25 mm in height
6. Glass plates - Two, 75 × 75 mm one plate of plain glass and the other prongs
7. Thermostatically controlled Oven
8. Wash bottle containing distilled water
9. Graduate-Glass, with capacity of 25 ml
10. Mercury
11. Grease

PROCEDURE:

Preparation of soil paste

1. Take about 100 gm of a soil sample from a thoroughly mixed portion of the material passing through a 425 µm Sieve. Place about 30 gm of the above soil sample in the evaporating dish and thoroughly mixed with distilled water and make a creamy paste. (Use water content slightly higher than the liquid limit) Filling the shrinkage dish

2. Coat the inside of the shrinkage dish with a thin layer of grease to prevent the soil from sticking to the dish.

3. Fill the dish in three layers by placing approximately 1/3 rd of the amount of wet soil with the help of the 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 the 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.

4. Weigh immediately the dish with wet soil and record the weight.

5. Air-dry the wet soil cake for 24 hrs until the color of the pat turns from dark to light. Then oven-dry the cake at 1050C to 110^{0}C say about 24 hours.

6. Remove the dried disk of the soil from the oven. Cool it in a desiccator. Then obtain the weight of the dish with a dry sample.

7. Determine the weight of the empty dish and record it.

8. Determine the volume of the shrinkage dish, which is evidently equal to the 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 a 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 shrinkage dish volume directly. Record this volume as the volume of wet soil pat.

Volume of the dry soil pat

9. 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 overflow with mercury. Remove the excess mercury by covering the cup with a 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. Submerge the pat, which is floating with the pronged glass plate, which is again made flush with the top of the cup. The mercury spills over into the larger plate. Pour the mercury that is displaced by the soil pat into the measuring jar and find the volume of the soil pat directly.

TABULATION AND RESULTS:

Sr. No	Determination No.	1	2	3
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			
4	Wt. of oven-dry soil pat, W_0 in gm = (W_3-W_1)			
5	Wt. of water in gm = (W_2-W_3)			
6	Moisture content (%), W = $(W_2-W_3)/ (W_3-W_1)*100$			
7	Volume of wet soil pat (V), in cm			
8	Volume of dry soil pat (V_d) in cm^3 = $(W_m)/ (G_m)$ By mercury displacement method a. Weight of displaced mercury in gm (W_m) b. Specific gravity of the mercury (G_m)			
9	Shrinkage limit (W_S) = $[W – \{(V-V_d)*(\gamma_w /W_o)\}] \times 100$			
10	Shrinkage ratio (R) = $\{(V-V_d)/V_d\}*100/(W-W_s)$			

INTERPRETATION:

The correlation between the shrinkage limit and with degree of expansion is given in the table below:

Shrinkage Limit	Degree of expansion
> 15	Low
10-15	Medium
7-12	High
< 7	Very high

CAUTION: DO NOT TOUCH THE MERCURY WITH GOLD RINGS.

QUESTION:

1. State the diameter of the evaporating dish that you used in this test.
2. What is the density of mercury?
3. Mention ways to prevent the inclusion of air bubbles in the shrinkage dish.
4. State the necessity of dry pat used in the experiment.
5. State the alternate method to determine the shrinkage limit of soil.
6. State the practical applications of shrinkage limit of soil.
7. State the shrinkage value of four different types of soils.

Experiment No 5
Specific Gravity Test

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

THEORY:

The specific gravity of a soil is the ratio of the mass of a given volume of the soil solids at a stated temperature to the mass of an equal volume of de-aired water at the same temperature.

NEED AND SCOPE:

The specific gravity is used in the computations of laboratory tests such as the hydrometer test and oedometer test (1-D consolidation test). It can be used in relating the weight of soil to its volume and in calculating phase relationships, i.e., the relative volume of solids to water and air in a given volume of soil. The value of specific gravity can give a rough idea of the presence of organic matter or any metal present in the soil. Lower specific gravity values around 2 or below indicate the presence of high organic content in the soil. Higher specific gravity values in a range of 2.75-2.85 indicates the presence of iron or any other metal in the soil.

APPARATUS REQUIRED:

1. Specific gravity bottles of glass with 50 ml/100 ml capacity with a fitted glass stopper

2. Glass-stopper with a small hole through the center to permit the emission of air and water

3. Balance - 0.001 g sensitivity

4. Oven - capable of 105^0C $\pm 1^0$C

5. Thermometer

6. Funnel

7. Sand bath for heating

PROCEDURE:

1. Take the weight of the empty specific gravity bottle, ‘W_1’.

2. Transfer the oven-dried soil sample to the specific gravity bottle (*about 10 gm when 50 cc stoppered bottle is used and about 20 gm when 100 cc stoppered bottle is used*).

3. Take the weight of bottle filled with soil, ‘W_2’.

4. Add water to fill the bottle about three fourth of its volume.

5. Remove the entrapped air either by subjecting the contents to a partial vacuum or by boiling gently in a sandbath till the air bubbles cease to appear while occasionally rolling the bottle to assist in the removal of air

6. Then cool to room temperature and fill the bottle with water up to the mark and clean and dry the outside surface with a clean, dry cloth and note down the temperature.

7. Determine the weight of the bottle with water and soil, ‘W_3’.

8. Then remove the soil and water from the bottle and clean it.

9. Fill the bottle completely with water up to the mark and take the weight of the bottle filled with water, ‘W_4’.

10. From data obtained, determine the specific gravity of the soil.

TABULATION AND RESULTS:

Test No	**1**	**2**	**3**
Temperature °c			
Bottle no.			
Weight of specific gravity bottle (W_1) (g)			
Weight of specific gravity bottle + soil (W_2) (g)			
Weight of specific gravity bottle + soil + water (W_3) (g)			
Weight of specific gravity bottle + water (W_4) (g)			
Specific gravity of soil at temperature °c $G_s' = \frac{(W_2 - W_1)}{(W_4 - W_1) - (W_3 - W_2)}$			
Temperature correction, k_{27}			
Specific gravity of soil at temperature, 27 °c Gs = K_{27} x G's (see K_{27} from Table I)			
Average			

The specific gravity of the given sol is = (No unit)

Determine the type of soil according to your interpretations from the specific gravity of the soil

For any temperature T, the correction factor can be given as,

$$K_{27} = \frac{Specific\ gravity\ of\ water\ at\ T^0\ C\ temprature}{Specific\ gravity\ of\ water\ at\ 27^0 C\ temprature}$$

Correction factors for different temperatures are given in Table I.

Table-I: Correction Factor for Variation in Specific Gravity of Water due to Temperature

Temperature ^{0}C	K_{27}
15	1.0026
16	1.0024
17	1.0023
18	1.0021
19	1.0019
20	1.0017
21	1.0015
22	1.0013
23	1.0010
24	1.0008
25	1.0005
26	1.0003
27	1
28	0.9997
29	0.9994
30	0.9991
31	0.9988
32	0.9985
33	0.9982
34	0.9979
35	0.9975
36	0.9972
37	0.9968
38	0.9964
39	0.9961

QUESTIONS:

1. State the effect of variation in room temperature on the value of specific gravity of soil.
2. Give the reason for using oven-dried soil samples in this test.
3. Sate two physical properties where specific gravity is required for its determination.
4. State two field applications where soil having a specific gravity of less than 2.70 can be used.
5. State two field applications where soil having a specific gravity of more than 2.70 can be used.
6. State the unit of specific gravity of soil.

Experiment No 6
Constant Head Permeability Test

AIM: To determine the permeability of the soil sample using the constant head permeability test method.

THEORY:

The rate of flow under laminar flow conditions through a unit cross-sectional area of the porous medium under a unit hydraulic gradient is defined as the coefficient of permeability.

NEED AND SCOPE:

Permeability is useful in solving problems involving the yield of water-bearing strata, seepage through earthen dams, stability of earthen dams, and embankments of canal banks affected by seepage, settlement, etc. The falling head method of determining permeability is used for soil with low discharge, whereas the constant head permeability test is used for coarse-grained soils with a reasonable discharge in a given time. Usually, the permeability of soils is determined by two methods.

1. Constant Head Permeability method

2. Falling Head Permeability method

PREPARATION OF THE SPECIMEN:

The preparation of the specimen for this test is important. There are two types of specimens, the undisturbed soil sample and the disturbed or remolded soil sample.

A. Undisturbed soil specimen

1. Note down-sample no., borehole no., and depth at which the sample is taken.

2. Remove the protective cover (wax) from the Shelby tube.

3. Place the Shelby tube in the sample extractor and push the plunger to get a cylindrical-shaped specimen not larger than 95 mm in diameter and height equal to that of the permeameter mold.

4. This specimen is placed centrally over the porous stone of base plate.

7. A porous stone is also placed at the top of the sample

8. The specimen is now ready for test.

B. Remolded specimen

The remolded specimen can be prepared by static compaction or by dynamic compaction.

Preparation of Dynamically Compacted (Remolded) sample:

1. Take 2500 gms of representative soil and mix it with water to get O.M.C, if necessary.

2. Assemble the permeameter for dynamic compaction. Grease the inside of the mould and place it upside down on the dynamic compaction base. Weigh the assembly correct to a gm (w). Put the collar to the other end.

3. Now, compact the wet soil in 3 layers with 25 blows to each layer with a 2.6 kg dynamic tool. Remove the collar and then trim off the excess. Weigh the mould assembly with the soil.

4. Place the filter paper or fine wire mesh on the top of the soil specimen and fix the perforated base plate on it.

5. Turn the assembly upside down and remove the compaction plate. Insert the sealing gasket and place the top perforated plate on the top of soil specimen. And fix the top cap.

6. Now, the specimen is ready for test.

OBSERVATION AND RECORDING:

The flow is very low at the beginning, gradually increases and then stands constant. The constant head permeability test is suitable for Cohesionless (Coarse and medium Sands) soils.

PRESENTATION OF DATA:

The coefficient of permeability is reported in cm/sec at 27^{o} C. The dry density, the void ratio and the degree of saturation shall be reported. The test results should be tabulated as shown in the following manner:

Test Record

Project: ……… Tested By: ……..

Location: …….. Boring No. : …….. Depth: ………

Details of sample

Diameter of specimen ………………. cm

Area of specimen (A) ………….…….cm^2

Volume of specimen (V) …………….cm^3

Moisture content, w …..………..…… %

Void Ratio, $e = (G_s.\gamma_w / \gamma_d) - 1$ = ………..

Length of specimen (L) …..……… cm

Specific gravity of soil G_s ……………..

Weight of dry specimen (W_s) ……. gm

Dry density, $\gamma d = W_s / V$ = ……. gm /cc

Saturation, $S = G_s.w / e$ = ………… %

Experiment No		**1**	**2**	**3**
Discharge	Q (cm^3)			
Time t	sec			
Height of water	h(cm)			
Temperature	(ºC)			
Coefficient of Permeability at …… ºC $k = Q.L / (A.h.t)$	cm/sec			
Average Permeability, kt	cm/sec			
Permeability at 27 ºC: $k_{27} = k_t \times \eta_t / \eta_{27}$	cm/sec			

Variation of ηt / η27 with temperature

Temperature	15	16	17	18	19	20	21	22
ηt / η27	1.336	1.301	1.268	1.237	1.206	1.177	1.149	1.122
Temperature	23	24	25	26	27	28	29	30
ηt / η27	1.096	1.071	1.046	1.023	1.000	0.979	0.958	0.938

GENERAL REMARKS:

1. During the test, there should be no volume change in the soil, and there should be no compressible air present in the voids of the soil, i.e., the soil should be completely saturated. The flow should be laminar and in a steady state condition.

2. Coefficient of permeability is used to assess drainage characteristics of soil to predict the rate of settlement of structure founded on the soil bed.

3. Coefficient of permeability: High permeability: $k > 10^{-4}$ cm/sec

Medium permeability: 10^{-7}cm/sec < k < 10^{-4} cm/sec

Low permeability: $k < 10^{-7}$cm/sec

4. General values of permeability for different types of soils are given below:

a. Gravel: 10^{-3} to 1 cm/sec
b. Medium and Coarse Sand: 1 to 10^{-3} cm/sec
c. Fine Sand and Silt: 10^{-3} to 10^{-6} cm/sec
d. Clay: less than 10^{-7}cm/sec
e. Fly Ash: 1×10^{-4} to 5×10^{-4} cm/sec

QUESTIONS:

1. Explain the function of porous stones on both sides of the soil sample.
2. State the capacity and least count of measuring cylinder used to measure discharge.
3. State the overall cost of apparatus required for the constant head method.
4. State the practical applications of permeability of soil.
5. Give the values of the coefficient of permeability of any two types of soil.
6. State the units of measurement of the coefficient of permeability of the soil.
7. State the type of soil for which the constant heat test is suitable or recommended.
8. Enlist the factors affecting the permeability of soil.

Experiment No 7

Falling Head Permeability Test

AIM: To determine the permeability of the soil sample using the constant head permeability test method.

THEORY:

The rate of flow under laminar flow conditions through a unit cross-sectional area of the porous medium under a unit hydraulic gradient is defined as the coefficient of permeability.

NEED AND SCOPE:

Permeability is useful in solving problems involving the yield of water-bearing strata, seepage through earthen dams, stability of earthen dams and embankments of canal banks affected by seepage, settlement, etc. The falling head method of determining permeability is used for soil with low discharge, whereas the constant head permeability test is used for coarse-grained soils with a reasonable discharge in a given time. For very fine-grained soil, a capillarity permeability test is recommended. Usually, permeability of soils is determined by two methods:

1. Constant head Permeability method

2. Falling Head Permeability method

PREPARATION OF THE SPECIMEN:

The preparation of the specimen for this test is important. There are two types of specimens, the undisturbed soil sample and the disturbed or remolded soil sample.

A. Undisturbed soil specimen

1. Note down-sample no., borehole no., depth at which sample is taken.

2. Remove the protective cover (wax) from the Shelby tube.

3. Place the Shelby tube in the sample extractor and push the plunger to get a cylindrical-shaped specimen not larger than 95 mm diameter and height equal to that of the permeameter mould.

4. This specimen is placed centrally over the porous stone of the base plate.

7. A porous stone is also placed at the top of the sample.

8. The specimen is now ready for testing.

B. Remolded specimen

The disturbed specimen can be prepared by static compaction or by dynamic compaction.

Preparation of Dynamically Compacted (Remolded) sample:

1. Take 2500 gms of representative soil and mix it with water to get O.M.C, if necessary.

2. Assemble the permeameter for dynamic compaction. Grease the inside of the mould and place it upside down on the dynamic compaction base. Weigh the assembly correct to a gm (w). Put the collar to the other end.

3. Now, compact the wet soil in 3 layers with 25 blows to each layer with a 2.6 kg dynamic tool. Remove the collar and then trim off the excess. Weigh the mould assembly with the soil.

4. Place the filter paper or fine wire mesh on the top of the soil specimen and fix the perforated base plate on it.

5. Turn the assembly upside down and remove the compaction plate. Insert the sealing gasket and place the top perforated plate on the top of the soil specimen. And fix the top cap.

6. Now, the specimen is ready for test.

APPARATUS REQUIRED:

1. Permeameter with its accessories

2. Standard soil specimen

3. Deaired water

4. Balance to weigh up to 1 gm

5. I.S sieves 4.75 mm and 2 mm

6. Mixing pan

7. Stopwatch

8. Measuring jar

9. Meter scale

10. Thermometer

11. Container for water

12. Trimming knife

TEST PROCEDURE:

1. Prepare the soil specimen as specified.

2. Saturate the specimen, preferably by using Deaired water.

3. Assemble the Permeameter (It is made of non-corrodible material with a capacity of 1000 ml, with an internal diameter of

100±0.1 mm and an effective height of 127.3±0.1 mm).

4. The inlet nozzle of the mold is connected to the standpipe. Allow the water to flow until a steady flow is obtained.

5. Note down the time interval ‘t’ for a fall of the head in the standpipe ‘h.’

6. Repeat step 5 three times to determine ‘t’ for the same head.

For fine sands and silts, falling head method is suitable.

OBSERVATION & RECORDING:

Sample No. ………………… Molding water content: ………………..

Dry Density: ………………. Specific Gravity: ………………………..

Void ratio ………………….

OBSERVATION TABLE

Sr. No.	Description		1st Set	2nd Set	3rd Set
1	Area of standpipe (dia. 5 cm)	a (cm)			
2	Cross-sectional area of soil specimen	A (cm^2)			
3	Length of soil specimen	L (cm)			
4	Initial reading of standpipe	h_1 (cm)			
5	Final reading of stand pipe	h_2 (cm)			
6	Time	t (sec)			
7	Test temperature	T (°C)			
8	Coefficient of permeability at …….. °C $k = 2.303.a.L.\{\log_e (h_1/h_2)\}/ (A.t)$	k (cm/sec)			

9	Average Permeability, k_t	k_t (cm/sec)			
10	Coefficient of permeability at 27ºC: $k_{27} = k_t \times \eta_t / \eta_{27}$	k_{27} (cm/sec)			

Variation of η_t / η_{27} with temperature

Temperature	15	16	17	18	19	20	21	22
η_t / η_{27}	1.336	1.301	1.268	1.237	1.206	1.177	1.149	1.122
Temperature	23	24	25	26	27	28	29	30
η_t / η_{27}	1.096	1.071	1.046	1.023	1.000	0.979	0.958	0.938

GENERAL REMARKS:

1. During the test, there should be no volume change in the soil, and there should be no compressible air present in the voids of the soil, i.e., the soil should be completely saturated. The flow should be laminar and in a steady state condition.

2. Coefficient of permeability is used to assess drainage characteristics of soil to predict the rate of settlement of structure founded on the soil bed.

3. Coefficient of permeability: High permeability: $k > 10^{-4}$ cm/sec

Medium permeability: 10^{-7}cm/sec < k < 10^{-4} cm/sec

Low permeability: $k < 10^{-7}$cm/sec

4. General values of permeability for different types of soils are given below:

a. Gravel: 10^{-3} to 1 cm/sec
b. Medium and Coarse Sand: 1 to 10^{-3} cm/sec
c. Fine Sand and Silt: 10^{-3} to 10^{-6} cm/sec
d. Clay: less than 10^{-7}cm/sec
e. Fly Ash: 1×10^{-4} to 5×10^{-4} cm/sec

QUESTIONS:

1. State the soil type you used in this test.
2. Explain the function of the burette pipe of the soil sample.
3. Explain the method of filling the soil sample in the permeameter.
4. State the purpose of the air vent pipe in this method.
5. State the suitability to the soil of the falling head method.

6. Compare the falling head method with the constant head method. with respect to the type of soil and discharge.
7. State the types of soil for which the falling head method is suitable or preferable.

Experiment No 8

Unconfined Compression Test

AIM: To determine the unconfined compressive strength of clayey soil.

THEORY:

The unconfined compression (UC) test, also known as the uniaxial compression test, is a special case of a triaxial test, where the confining pressure is zero. It is a very quick and simple test as compared to a triaxial test and does not require a sophisticated triaxial setup. In this test, a cylindrical specimen of soil without lateral support is tested for failure in simple compression at a constant deformation rate. The compressive load per unit area required to fail the specimen without any confinement is called unconfined compressive strength of the soil. This test is mainly performed for the cohesive soil, whose specimens can stand without any support.

NEED AND SCOPE:

The unconfined compression test gives undrained shear strength (Su) of cohesive soils. Su is useful in the determination of the bearing capacity of the soil, stability of earthen dam embankments (cohesive soil is used in the core of earthen dam), etc. One of the critical conditions for stability of earthen embankments occurs, immediately after construction, which represents the undrained condition. In such conditions, undrained shear strength obtained from the UC test can be helpful for stability analysis.

APPARATUS REQUIRED:

Undisturbed Specimen Preparation

1) Hydraulic sample extractor

2) Sampling tubes/ Extraction tubes of required diameter

3) Metal cap for sampling tubes

4) Wire saw/ Soil Trimmer

5) Split sampler

6) Weighing balance of sensitivity 0.01 gm

7) Silicon spray

Remolded Specimen Preparation Using Moist Tamping Method

1) Split mold of same diameter as of specimen with bottom plate and collar arrangement

2)Mixing bowls

3) Cylindrical block with markings

4) Rammer to apply blows

5) Knife

6) Weighing balance of sensitivity 0.01 gm

7) Silicon spray

UC Test

1) Loading frame capable of generating a constant rate of deformation.

2) Proving ring (Capacity ranging from 1 kN to 50 kN)

3) Bottom platen of the required diameter made with perspex glass (the diameter of the platen is selected according to the diameter of the sample).

4) Top cap of required diameter made with perspex glass, having a circular impression to accommodate steel ball arrangement (diameter of the plate is selected according to the diameter of the sample).

5) Dial gauge (0.01 mm accuracy)

PREPARATION OF SPECIMEN:

In this test, a cylindrical specimen of soil with aspect ratio 2 without lateral support is tested for failure in simple compression at a constant deformation rate (1.25 mm/min, 2.25 mm/min, 2.5 mm/min). The compressive load per unit area required to fail the specimen is called the unconfined compressive strength of the soil.

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 shallby tubes.

3. Place the sampling tube extractor and push the plunger till a small length of sample moves out.

4. Trim the projected sample using a wire saw and push the plunger until a sample larger than the required length comes out.

5. Cut out this sample carefully and hold it on the split sampler so that it does not fall, and trim the specimens to the required height.

6. Take about 10 to 15 g of soil from the tube for water content determination.

7. Measure the diameter at the top, middle, and bottom of the sample. Find the average and record the same.

8. Measure the weight of the sample and record.

If the extracted sample has cracks, it cannot be used for testing. Remolded specimens at in-situ density and water content needs to be prepared to conduct UC test.

B. Remolded 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 the required dimensions (diameter and height)

2. Add the required quantity of water, W_w, to this soil.

$W_W = W_S$ x W/100 gm

3. Mix the soil thoroughly with water.

4. Divide the wet soil into equal parts, the same as the number of layers in which the soil is to be compacted.

5. Apply silicon spray coating on the inner side of the split mold and the bottom plate of the mold.

6. Place the soil required for one layer in the split mold arrangement with the bottom cap and collar.

7. Compact the soil using the cylindrical block and rammer until the required height of the layer is achieved.

8. Check the height of the layer using the markings on the cylindrical block.

9. Scratch the layer before placing the soil in the next layer to ensure the proper bonding between the two layers.

10. Repeat steps 7-9 for each layer until the required height of the specimen is achieved.

11. Extract the specimen from the split mold.

12. Record the height, weight, and diameter of the specimen.

PROCEDURE:

1. Place the bottom platen on the loading frame and then place the specimen on the bottom platen.

2. Place the top cap on the specimen and a steel ball on the circular impression of the top cap.

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 a suitable deformation rate. The deformation rate of 1.25 mm/min is commonly used to conduct the UC test on soil specimens of 38 mm diameter.

7. Start applying the load and record the readings of the proving ring and compression dial for every 25-dial gauge reading.

8. Continue loading till failure or 20% axial strain (whichever is reached earlier) (IS-2720-PART-10-1991), and then take a picture of the failure pattern of the specimen

9. Repeat the procedure for at least three specimens

OBSERVATION AND READING:

Data Sheet for Unconfined Compression Test

Project: Tested by:

Location: Boring No. :

Depth:

Sample details:

Type Undisturbed/Remoulded:

Dry density = _____________ g/cc

Water content (%) = ______

Degree of saturation = _______ %

Diameter (Do) of the sample ______ cm

Area of cross-section = _______ cm^2

Initial height (Lo) of the sample =______ cm

Proving ring constant = _______

Dial gauge constant = _______mm

Deformation rate= __________ mm/min

OBSERVATION TABLE

Elapsed time (minutes)	Compression dial reading (divisions)	Axial deformation, ΔL (mm)	Axial Strain (ΔL / Lo) *100 (ε %)	Corrected Area A= Ao / (1-(ε/100)) $(cm)^2$	Proving ring reading (Divisions)	Axial load (kN)	Compressive stress (kPa)

CALCULATIONS:

1. Axial stress = (Proving ring reading x Proving ring constant) / A_{corr}

2. $A_{corr} = A_0/ (1-\varepsilon)$; A_0 is the initial cross-sectional area of the soil specimen, ε is the axial strain at that point of loading.

3. Repeat the test 3 times.

4. Plot the axial stress- axial strain curve for all three specimens on a single plot.

5. Maximum axial stress is obtained, which is also considered to be the failure point of the specimen. Find the average value of maximum axial stress obtained in all three UC tests.

6. Unconfined compression strength of the soil, q_u = average value of maximum axial stress of three tests (If the plots are not overlapping, and the variation in the maximum values is quite high, then the tests should be repeated until three similar plots are obtained).

7. Shear strength of the soil (cohesion, c) = $q_u/2$.

8. Sensitivity = (q_u for undisturbed sample)/ (q_u for remoulded sample).

QUESTIONS:

1. What soil properties are determined from the unconfined compression test?
2. What type of soils is the unconfined compression test applicable to?
3. Does the pole of the Mohr circle move during the unconfined compression test?
4. What is the theoretical inclination of failure planes predicted for purely cohesive material during an unconfined compression test?
5. What is the range of unconfined shear strength for soils?
6. What is the relation between the unconfined shear strength and the undrained shear strength measured from UU and Cu triaxial compression tests?
7. What is the effect of the water content on the unconfined shear strength?

Experiment No 9
Direct Shear Test

AIM: To determine the shear strength parameters of a soil (i.e. Cohesion intercept and angle of internal friction) by direct shear test.

THEORY:

The concept of direct shear is simple and mostly recommended for granular soils, sometimes on soils containing some cohesive soil content. The cohesive soils have issues regarding controlling the strain rates to drained or undrained loading. In granular soils, loading can always be assumed to be drained. A schematic diagram of the shear box shows that the soil sample is placed in a square box, which is split into upper and lower halves. The lower section is fixed, and the upper section is pushed or pulled horizontally relative to the other section, thus forcing the soil sample to shear/fail along the horizontal plane separating the two halves. Under a specific Normal force, the Shear force is increased from zero until the sample is fully sheared (failed). The relationship between Normal stress and Shear stress at failure gives the failure envelope of the soil and provides the shear strength parameters (cohesion and internal friction angle).

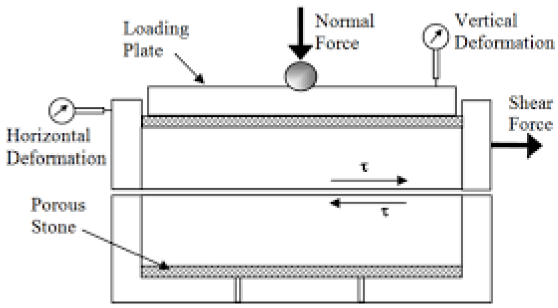

Fig. 9.1: Direct Shear Setup Box

NEED AND SCOPE:

The value of internal friction angle and cohesion of the soil is required for the design of many engineering structures such as foundations, retaining walls, bridges, and sheet piling. The direct shear test can provide these parameters quickly.

APPARATUS REQUIRED:

1) Direct shear box apparatus and Loading frame (motor attached).

2) Two Dial gauges, proving ring, Weighing Balance with an accuracy of 0.01g.

3) Sample Extractor (Undisturbed sample) / Sampler for preparation of a remolded sample of dimension (60mm*60mm*25mm).

4) Tamper, Straight edge, Spatula.

5) Filter paper

6) Two porous stones

7) Two corrugated metallic plates with perforation (drained) / metallic imperforated plates with corrugation (undrained)

8) Metallic Pressure pad

KNOWLEDGE OF EQUIPMENT:

Strain-controlled direct shear machine consists of a shear box, soil container, loading unit, proving ring, and dial gauge to measure shear deformation and vertical deformation. A proving ring is used to indicate the shear load taken by the soil along the shearing plane.

PROCEDURE:

1. Check the inner dimension of the soil sampler and put the parts of the direct shear apparatus together.

2. Calculate the volume of the sampler. Weigh the sampler.

3. Place the soil inside the sampler in three smooth and equal layers. If the dense sample is desired, tamp the soil with an appropriate equal number of blows in each layer for the required density.

4. After completing three layers, level the top layer and weigh the soil sampler with the soil. Find the weight of wet soil and calculate the density of soil to confirm whether the required density is achieved.

5. Place the base plate in the shear box and perforated grid plate (for submerged condition) over it in such a way that the serrations of the grid plate are perpendicular to the direction of the shear. Then, put the filter paper and place the soil specimen over it.

6. Lock the upper and lower half of the shear box with locking screws. After locking, place the upper filter paper, perforated grid plate, porous stone, and loading pad sequentially on the top of the soil.

7. Create a small gap of approximately 1 mm between two parts of the shear box using spacing screws.

8. Place the whole assembly in the box of the loading frame and put the loading yoke on top of the loading pad.

9. Adjust the dial gauges and proving ring to zero position after setting up the specimen set up. Apply the desired normal stress, say, 0.5 kg/cm^2, add water (if soaked condition) at the top of the direct shear box set up, and wait for at least 20 minutes to ensure saturation (until the reading in the vertical dial gauge becomes constant) and then remove the locking screws.

10. Measure the final vertical dial gauge reading, which measures the deformation in the vertical direction due to saturation.

11. Record the initial reading of the horizontal dial gauge and proving ring values before starting the shearing.

12. Check all adjustments to see that there is no connection between the two parts except the soil.

13. Set the strain-controlled frame to the required strain rate. Start the motor. Take the reading of the shear force in the proving ring with respect to the change in horizontal dial gauge reading and vertical deformation in the vertical dial gauge till failure.

14. The steps from 1 to 13 have to be repeated for another two normal stresses (1.0 kg/cm^2 and 1.5 kg/cm^2).

DATA CALCULATION SHEET FOR DIRECT SHEAR TEST:

Normal stress =0.5 kg/cm²

Size of the sample = 60 mm x 60 mm x 25 mm

Area of the sample (Cross Sectional) = 36 sq.cm

Volume of the sample = 90 cm^3

Weight of the sample (gm) = _______

Density of the sample (gm/cc) = _______

Water content (%) = _______

Least count of dial gauge (Horizontal) = _______

Least count of dial gauge (Vertical) = _______

Proving Ring No. = _______

Proving ring constant = _______

Normal stress (Kg/ sq.cm) = _______

OBSERVATION TABLE-1

Time (min)	1	2	3	4	5	6	10	15	20	25	30	35	40	45	50	55	60	90	120
Vertical Dial Reading																			

OBSERVATION TABLE-2

Horizontal Dial reading	20	40	60	80	100	120	140	160	180
Proving Ring Reading									
Shear Stress (Kg/sq.cm)									
Horizontal Dial reading	200	220	240	260	280	300	320	340	360
Proving Ring Reading									
Shear Stress (Kg/sq.cm)									
Horizontal Dial reading	380	400	420	440	460	480	500	520	540
Proving Ring Reading									
Shear Stress (Kg/sq.cm)									
Horizontal Dial reading	560	580	600	620	640	660	680	700	720
Proving Ring Reading									
Shear Stress (Kg/sq.cm)									
Horizontal Dial reading	740	760	780	800	820	840	860	880	900
Proving Ring Reading									
Shear Stress (Kg/sq.cm)									

*L.C – Least Count, P.R.C – Proving Ring Constant

Water content calculation:

Name of container =

Weight of container, w_1=

Weight of container and wet soil, w_2 =

Weight of container and dry soil, w_3 =

Water content, (%) = $(w_2-w_3)/(w_3-w_1) \times 100$

Normal stress =1.0 kg/cm²

Size of the sample = 60 mm x 60 mm x 25 mm

Area of the sample (Cross Sectional) = 36 sq.cm

Volume of the sample = 90 cm^3

Weight of the sample (gm) = _______

Density of the sample (gm/cc) = _______

Water content (%) = _______

Least count of dial gauge (Horizontal) = _______

Least count of dial gauge (Vertical) = _______

Proving Ring No. = _______

Proving ring constant = _______

Normal stress (Kg/ sq.cm) = _______

OBSERVATION TABLE-3

Time (min)	1	2	3	4	5	6	10	15	20	25	30	35	40	45	50	55	60	90	120
Vertical Dial Reading																			

OBSERVATION TABLE-4

Horizontal Dial reading	20	40	60	80	100	120	140	160	180
Proving Ring Reading									
Shear Stress (Kg/sq.cm)									
Horizontal Dial reading	200	220	240	260	280	300	320	340	360
Proving Ring Reading									
Shear Stress (Kg/sq.cm)									
Horizontal Dial reading	380	400	420	440	460	480	500	520	540
Proving Ring Reading									
Shear Stress (Kg/sq.cm)									
Horizontal Dial reading	560	580	600	620	640	660	680	700	720
Proving Ring Reading									
Shear Stress (Kg/sq.cm)									
Horizontal Dial reading	740	760	780	800	820	840	860	880	900
Proving Ring Reading									
Shear Stress (Kg/sq.cm)									

*L.C – Least Count, P.R.C – Proving Ring Constant

Water content calculation:

Name of container =

Weight of container, w_1=

Weight of container and wet soil, w_2 =

Weight of container and dry soil, w_3 =

Water content, (%) = $(w_2-w_3)/(w_3-w_1) \times 100$

Normal stress =1.5 kg/cm²

Size of the sample = 60 mm x 60 mm x 25 mm

Area of the sample (Cross Sectional) = 36 sq.cm

Volume of the sample = 90 cm^3

Weight of the sample (gm) = _______

Density of the sample (gm/cc) = _______

Water content (%) = _______

Least count of dial gauge (Horizontal) = _______

Least count of dial gauge (Vertical) = _______

Proving Ring No. = _______

Proving ring constant = _______

Normal stress (Kg/ sq.cm) = _______

OBSERVATION TABLE-5

Time (min)	1	2	3	4	5	6	10	15	20	25	30	35	40	45	50	55	60	90	120
Vertical Dial Reading																			

OBSERVATION TABLE-6

Horizontal Dial reading	20	40	60	80	100	120	140	160	180
Proving Ring Reading									
Shear Stress (Kg/sq.cm)									
Horizontal Dial reading	200	220	240	260	280	300	320	340	360
Proving Ring Reading									
Shear Stress (Kg/sq.cm)									
Horizontal Dial reading	380	400	420	440	460	480	500	520	540
Proving Ring Reading									
Shear Stress (Kg/sq.cm)									
Horizontal Dial reading	560	580	600	620	640	660	680	700	720
Proving Ring Reading									
Shear Stress (Kg/sq.cm)									
Horizontal Dial reading	740	760	780	800	820	840	860	880	900
Proving Ring Reading									
Shear Stress (Kg/sq.cm)									

*L.C – Least Count, P.R.C – Proving Ring Constant

Water content calculation:

Name of container =

Weight of container, w_1=

Weight of container and wet soil, w_2 =

Weight of container and dry soil, w_3 =

Water content, (%) = $(w_2-w_3)/(w_3-w_1) \times 100$

CALCULATIONS:

1. Shear stress (τ) on the horizontal failure plane is calculated as τ = S/A; Where S is shear force. A is the horizontal cross-sectional area of the sample, which decreases slightly with the horizontal deformations.

2. Corrected area (A_{corr}) needs to be calculated for calculating the shear stress at failure. $A_{corr} = A_0*(1-\delta/6)$, where δ is horizontal displacement due to the shear force applied to the specimen. A0 is the initial area of the soil specimen. A_0 and δ are in cm.

3. i. Shear Stress = (Proving ring reading x Proving ring constant)/A_{corr}

ii. Horizontal displacement = Horizontal dial gauge reading x Least count of horizontal dial gauge

iii. Vertical displacement = Vertical dial gauge reading x Least count of vertical dial gauge

4. Shear stress at failure needs to be calculated for all three tests performed at three different normal stresses to plot the failure envelope.

GENERAL 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., the 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 the lower half of the box and another material in the upper half of the box.

3. The angle of shearing resistance of sands depends on the state of compaction, coarseness of grains, particles, shape, roughness of grain surface, and grading. It varies between 28° (uniformly graded sands with round grains in a very loose state) to 46° (well-graded sand with angular grains in a 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 contract, and dense sands expand in volume on shearing. Expansion or contraction can be inferred from the movement of the 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 the shear parameter for both loose sand and dense sand approximately attain the same value so, if the angle of friction value is calculated at the ultimate stage, slight disturbance in density during sampling and preparation of test specimens will not have much effect.

QUESTIONS:

1. State the dimensions of the shear box assembly used in this test.
2. State whether the direct shear test apparatus is motorized or not.
3. Mention the constant of the proving ring you use.
4. State the rate of loading in the horizontal direction.
5. Give the meaning of cohesion and angle of internal friction in case of shear strength of soil.
6. State any three advantages of the direct shear test.
7. State any two limitations of the direct shear test.
8. State the conditions in which the direct shear test is conducted.
9. Name the soil for which this test is unsuitable.

Experiment No 10

Field Density by Core Cutter Method

AIM: To determine the dry density of the soil in-situ by core cutter method.

THEORY:

The core cutter test is used to determine the in-situ density of soil. The in-situ density is defined as the density of soil measured at its actual depth on the field. The in-situ moisture content of soil varies with time, resulting in variable in-situ bulk density. To avoid variation with time, the in-situ density should be reported in terms of the dry density with moisture content.

NEED & SCOPE:

The in-situ density of the soil is needed for the determination of the following:

- Bearing capacity of soils.
- Stability analysis of slopes and earth-retaining structures.
- Determination of pressures on underlying strata for the calculation of settlement and the design of underground structures.

Where soil compaction is required (projects like embankment and earth dam construction), a core cutter test can be used as a quality control test to evaluate the degree of compaction.

LIMITATIONS

This method cannot be used for gravelly soil, in which the sharp edges of the core cutter would deteriorate on ramming. Moreover, it cannot be used for purely cohesionless soil, where the soil is not able to stick to the inner surface of the core cutter. In such cases, the core cutter cannot retain the soil. Hence, the sand replacement method shall be used.

APPARATUS REQUIRED:

1. Core Cutter

2. Dolly

3. Vernier Callipers

4. Rammer

5. Straight edge

6. Balance of 20 kg capacity

7. Small containers

8. Balance with a sensitivity of 0.01 gm

9. Oven controlled at 105˚ C

PROCEDURE:

Determination of In-situ Bulk density

1. Take the empty weight of the core cutter and measure the internal diameter and height of the core cutter using a vernier calliper.

2. Level the soil surface, where we need to find the in-situ density and place the core cutter vertically on the surface, with a dolly over it.

3. Using the rammer, give blows to the core cutter assembly to drive it inside the ground. Stop ramming when the dolly is just around the surface.

4. Dig the cutter containing the soil out of the ground and trim off any solid extruding from its ends so that the cutter contains a volume of soil equal to its internal volume determined from the dimensions of the core cutter.

5. Determine the weight of the collected soil inside the core cutter and find the in-situ bulk density of the soil sample.

6. Take out the soil from the core cutter and take three soil samples for moisture content determination.

Determination of Moisture Content

1. Take the weight of empty containers used for moisture content determination.

2. Place the wet soil sample in the container and take the weight of the container filled with wet soil.

3. Place the containers with wet soil in an oven set at 105˚ C temperature for at least 24 hours for drying.

4. Take out the containers from the oven after 24 hours and weigh the container filled with dry soil.

5. Take the average of the moisture content of the three samples and report the average moisture content of the soil sample.

OBSERVATIONS & RECORDINGS:

Dimensions of Core Cutter

Internal diameter of core cutter = cm

Height of core cutter = cm

Volume of core cutter = cm^3

Bulk density:

Wt. of Core-Cutter (W_1) = gm.

Wt. of Core-Cutter + Wet Soil (W_2) = gm.

Wt. of Wet Soil ($W_s = W_2 - W_1$) = gm.

Volume of Core-cutter V_c = cm^3

Bulk Density of Soil ($\gamma_t = W_s/V_c$) = g/cm^3

Moisture Content:

Container No.	**1**	**2**	**3**
Wt. of container, W_c (gm)			
Wt. of container + Wet soil, W_w (gm)			
Wt. of container + Dry Soil , W_d (gm)			
Wt. of water, W_w-W_d (gm)			
Wt. of dry soil, W_d-W_c (gm)			
Moisture Content, w % = (W_w-W_d / W_d-W_c) * 100			
Average Moisture Content, w %			

Dry Density:

Dry Density of Soil =

QUESTIONS:

1. State the capacity of mold used in this practical in liters.
2. State the wall thickness of the core cutter.
3. State the diameter and height of the dolly used on the Core cutter.
4. Give a reason for the application of oil/grease on the inside wall surface of the core cutter.
5. State the name of the tool used to trim the soil after sampling.
6. Give the reason for providing a dolly over the core cutter while driving in the ground.
7. State the unit of density and unit weight of soil.

Experiment No 11

Field Density by Sand Replacement Method

AIM: To determine the dry density of the soil in-situ by sand replacement method.

THEORY:

The sand replacement method is used to determine the in-situ density of soil. The in-situ density is defined as the density of soil measured at its actual depth on the field. The in-situ moisture content of soil varies with time, resulting in variable in-situ bulk density. To avoid variation with time, the in-situ density should be reported in terms of the dry density with moisture content.

NEED & SCOPE:

The in-situ density of the soil is needed for the determination of the following:

- Bearing capacity of soils
- Stability analysis of slopes and earth retaining structures
- Determination of pressures on underlying strata for the calculation of settlement and the design of underground structures

Where soil compaction is required (projects like embankment and earth dam construction), sand replacement method can be used as a quality control test to evaluate the degree of compaction.

APPARATUS REQUIRED:

1. Sand pouring apparatus

2. Calibration cylinder

3. Glass plate

4. Vernier calliper

5. Standard sand-graded between 300 micron and 600 micron

6. Soil tray with a central hole

7. Digging tools like chisels

8. Balance of 20 kg capacity

9. Containers for moisture content determination

10. Sensitive balance accurate to 0.01gm

11. Oven controlled at 105˚ C

PROCEDURE:

Weight of Sand Occupying the Cone of the Sand Pouring Apparatus

1. Pour sand into the sand pouring apparatus with the valve closed and determine the weight of the apparatus filled with sand (W_1).

2. Place the apparatus on a smooth glass plate and open the valve to fill the conical portion. After the sand stops running from the apparatus, close the valve sharply and weigh the remaining sand with the apparatus (W_2).

3. The weight ($W_1 - W_2$) represents the weight of sand required to fill the cone of the apparatus.

Density of Sand

1. Fill the Sand Pouring Apparatus again with the valve closed and determine the weight of the apparatus filled with sand (W_3).

2. Place the sand pouring apparatus concentrically on top of the calibrating cylinder. Open the shutter and allow the sand to drain out. When no further movement of sand takes place in the apparatus, close the shutter and weigh the apparatus with the remaining sand (W_4).

3. The weight (W_3-W_4) represents the quantity of sand used in filling the calibrating cylinder as well as the cone of the apparatus.

4. The weight of sand required to fill the calibrating cylinder can be calculated as $[(W_3-W_4) - (W_1 - W_2)]$.

5. Volume (V_c) of the cylinder may be determined either by measuring its internal dimensions or by filling it with water and determining the volume of water required to fill the cylinder.

6. The density of sand can be computed using a mass of sand filled in the cylinder and the volume (V_c) of the cylinder.

Density of Soil

1. Prepare the surface of the location to be tested so that it is a level plane. Keep the soil tray firmly on the surface.

2. Excavate with hand tools a hole with a diameter equal to that of the hole of the plate and about 10 cm in depth with smooth walls and rounded bottom edges.

3. Place the extracted soil from a hole in a container, being careful to avoid losing any material, and determine the weight of the extracted soil.

4. Place the already weighed sand pouring apparatus filled with sand (W_5) on the hole of the tray. Open the valve, and after the sand has stopped flowing, close the valve.

5. Weigh the apparatus with remaining sand (W_6) and determine the weight of sand occupying the cavity [(W_6-W_5) - (W_1-W_2)].

6. Take three representative samples from the extracted soil for moisture content determination.

OBSERVATIONS & RECORDINGS:

From the known density of sand and the weight of sand occupying the hole, calculate the volume of the hole. From the weight of the soil scooped out of the hole whose volume is now known, and the value of moisture content, calculate the wet and dry density of the soil.

Dimensions of Calibration Cylinder

Internal diameter of calibration cylinder = cm

Height of calibration cylinder = cm

Volume of calibration cylinder from the dimensions = cc

Volume of calibration cylinder from the weight of filled water = cc

I) Density of Standard Sand

a) Sand Occupying Cone	
Weight of sand pouring cylinder + sand before opening shutter (Glass Plate) (W_1)	
Weight of sand pouring cylinder + sand after opening shutter (Glass Plate) (W_2)	
Weight of sand in cone (W_1-W_2)	
b) Sand Occupying Calibrating Cylinder	
Weight of sand pouring cylinder + sand before opening shutter (W_3)	
Weight of sand pouring cylinder + sand after opening shutter (W_4)	
Weight of sand in Calibrating Cylinder W_c= (W_3-W_4) – (W_1 – W_2)	

Density of the standard sand $\gamma_s = W_c/V_c$ =

II) In-situ Density using Sand Replacement Method:

No.	Particulars	
1	Bulk density of standard sand, γ_s (gm/cc)	
2	Weight of sand pouring apparatus +sand before experiment (W_5), gm	
3	Weight of sand pouring apparatus + sand after experiment (W_6), gm	
4	Weight of sand drained out (W_6-W_5), gm	
5	Weight of sand occupying cone (W_1-W_2), gm	
6	Weight of sand occupying cavity [W_s= (W_6-W_5) – (W_1-W_2)], gm	
7	Volume of cavity ($V= W_s/ \gamma_s$), cc	
8	Weight of soil scooped out from the cavity (W), gm	
9	Bulk density ($\gamma_t = W/V$), gm/cc	
10	Moisture content, w%	
11	Dry density, [$\gamma_d = \gamma_t /(1+w)$], (gm/cc)	

III) Moisture Content Percent:

CONTAINER No.	**1**	**2**	**3**
Wt. of container, W_c (gm)			
Wt. of container + Wet soil, W_w (gm)			
Wt. of container + Dry Soil , W_d (gm)			
Wt. of water, W_w-W_d (gm)			
Wt. of dry soil, W_d-W_c (gm)			
Moisture Content, w % = (W_w-W_d / W_d-W_c) * 100			
Average Moisture Content, w %			

- Average Moisture Content of the Soil Layer = %
- Average Dry Density of the Soil Layer = gm/cc

QUESTIONS

1. State the suitability of the core cutter and sand replacement methods.
2. State the capacity of the cylinder used in this experiment.
3. State the type of sand used for the experiment.
4. Give a reason for calibrating the cone before starting the experiment.
5. State the suitability of the sand replacement method.
6. State the dimension of the tray used in the experiment.
7. State the method used for the determination of water content for this experiment.

8. ‘Uniformly graded clean sand is recommended for in-field density measurement’, justify the statement.
9. The density of wet and dry soil will differ; give reasons.

Experiment No 12
Compaction Test

AIM: To determine the water content – dry density relationship for a given soil by Indian Standard light compaction test and hence, to obtain optimum moisture content and maximum dry density for the given soil.

THEORY:

In geotechnical engineering, soil compaction is the process in which stress applied to soil causes densification as air is removed from the pores between the soil grains. It is an instantaneous process and always takes place in partially saturated soil (three phase system). 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.

NEED & SCOPE:

To determine the relationship between moisture content and dry density of soil. This test provides optimum moisture content (OMC) and maximum dry density (MDD) of a given soil, which is important for man-made (compacted) earth structures. The results obtained from this test will be helpful in increasing the bearing capacity of foundations, decreasing the undesirable settlement of structures, controlling undesirable volume changes, reducing hydraulic conductivity, increasing the stability of slopes, and so on.

APPARATUS REQUIRED:

1. Proctor mould having a capacity of 1000 cc with an internal diameter of 100 mm and a height of 127.3 mm. The mould shall have a detachable collar assembly and a detachable base plate.

2. Rammer: A hand operated metal rammer having a 50.8 mm face diameter and a weight of 2.6 kg. The rammer shall be equipped with a suitable arrangement to control the height of drop to a free fall of 310 mm.

3. Sample extruder, mixing tools such as mixing pan, spoon, towel, and spatula.

4. A balance of 15 kg capacity, sensitive balance, straight edge, graduated cylinder, and moisture tins.

PROCEDURE:

1. Take a representative oven-dried sample, approximately 5 kg in the given pan. Thoroughly mix the sample with sufficient water to dampen it with approximate water content (for cohesionless soils, approx. 4-6% and for cohesive soils, approx.14- 18%).

2. Weigh the proctor mould without the base plate and collar. Fix the collar and base plate. Place the soil in the Proctor mould and compact it in 3 layers giving 25 blows per layer with the 2.6 kg rammer falling through. The blows shall be distributed uniformly over the surface of each layer.

3. Remove the collar; trim the compacted soil even with the top of mould using a straight edge and weigh.

4. Divide the weight of the compacted specimen by the volume of the mould and record the result as the bulk density (ρb).

5. Remove the sample from the mould and slice and obtain a small sample from the mid layer for water content.

6. Thoroughly break up the remainder of the material until it will pass 4.75 mm sieve as judged by the eye. Add water in sufficient amounts to increase the moisture content of the soil sample by one or two percentage and repeat the above procedure for each increment of water added. Continue this series of determinations until there is either a decrease or no change in the wet unit weight of the compacted soil.

OBSERVATIONS:

Mould Diameter ………... cm, Height ………… cm, Volume ………. cc, Weight ……… gm

OBSERVATION TABLE

Density						
Determination No	1	2	3	4	5	6
Weight of water added, W_w (gm)						
Weight of mould + compacted soil (gm)						
Weight of compacted soil, W (gm)						
Average moisture content, w %						
Bulk density (gm /cc) = W / (Mould volume)						
Dry density (gm/cc) = Bulk density/(1+w)						
Water content						

Container No.						
Wt. of container (gm) = W_c						
Wt. Of container + wet soil (gm) = W_1						
Wt. Of container + dry soil (gm) = W_2						
Water content, $w = (W_2–W_1)/(W_1–W_c) \times 100\%$						

Note: Plot dry density vs. moisture content and find out the max dry density and optimum moisture for the soil.

GENERAL REMARKS:

(i) <u>The peak point of the compaction curve:</u>

The peak point of the compaction curve is the point with the maximum dry density ρ_d max. Corresponding to the maximum dry density ρ_d max is a water content known as the optimum water content (also known as the optimum moisture content, OMC). Note that the maximum dry density is only a maximum for a, specific compactive effort and method of compaction. This does not necessarily reflect the maximum dry density that can be obtained in the field.

(ii) <u>Zero air voids curve:</u>

The curve represents the fully saturated condition (S = 100 %). (It is a hypothetical situation and cannot be reached by compaction).

QUESTIONS:

1. State the volume of mould used in this test.
2. State the weight of the hammer used in this test.
3. State the apparatus used, giving compaction effort.
4. State no. of layers and no. of blows given to compact soil in standard compactor test.
5. State the practical applications of standard proctor tests.
6. List any three factors affecting soil compaction.
7. Give the meaning of zero air void line.
8. Differentiate between the standard proctor test and the modified proctor test with respect to the weight of the rammer and the height of the fall.

Experiment No 13

California Bearing Ratio Test

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

THEORY:

California Bearing Ratio (CBR) is defined as the ratio expressed in the percentage of force per unit area required to penetrate a soil mass with a circular plunger of 50 mm diameter at the rate of 1.25 mm/min to that required for corresponding penetration in a standard material. Tests are performed on natural or compacted soils in water-soaked or un-soaked conditions, and the results so obtained are compared with the curves of standard tests.

APPARATUS REQUIRED:

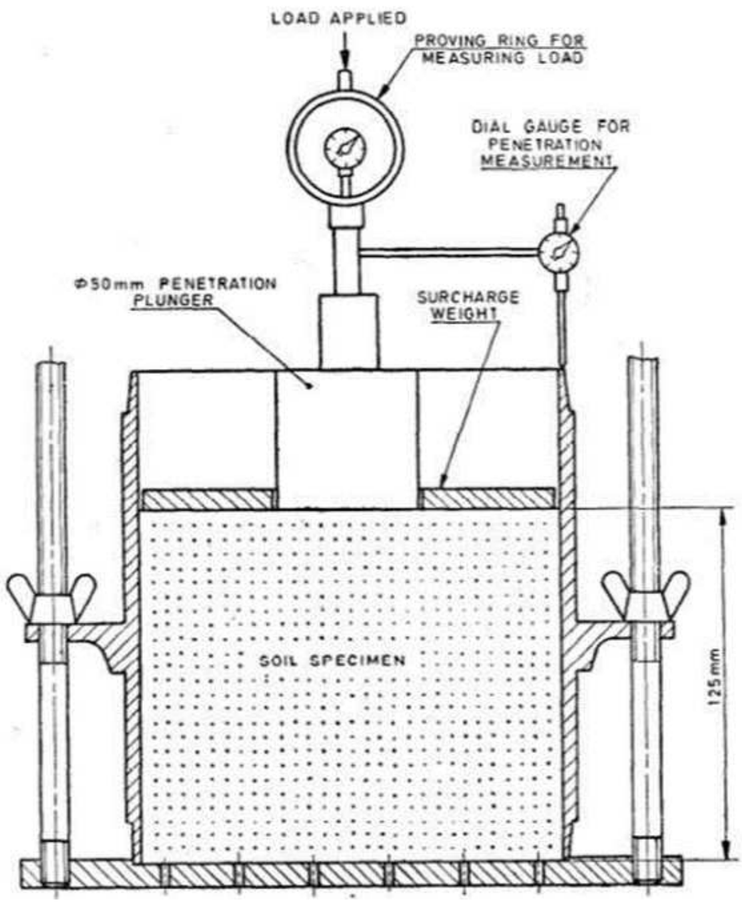

Fig 13.1: Setup for CBR Test

1. CBR mould with detachable perforated base plate
2. Spacer disc with a removable handle (to be placed inside the mould)
3. Collar of 50mm high
4. Penetration plunger of 50 mm diameter
5. One annular and a few slotted surcharge masses 2.5 kg each
6. Rammer (2.6 kg with 310mm drop for standard proctor results) and (4.89 kg with 450mm drop for modified proctor results)
7. Straight cutting edge
8. Loading machine of 50 kN capacity fitted with a calibrated proving ring to which plunger has to be attached
9. Penetration measuring dial gauge of 0.01mm accuracy
10. Soaking tank
11. Swelling gauge consisting of a perforated plate with adjustable extension stem.

Mould Specification:

Diameter of the mould = 150 mm

Height of the mould = 175 mm

Height of the CBR soil specimen = 125 mm

Soil specification:

Particle size = should pass through 19mm sieve

Soil particles of size greater than 19mm should be replaced by particles of size between 4.75mm and 19mm.

PROCEDURE:

1. Take the weight of the empty mould

2. Keep the spacer disc on the base plate and a filter paper on the disc and fix the mould to the base plate with the

disc inside the mould and attach the collar over the mould.

3. Add water to the specimen and compact it in accordance with the Standard proctor test or modified proctor test.

4. After compaction, remove the collar and level the surface using a cutting edge.

5. Detach the base plate and remove the spacer disc.

6. Take the weight of mould + compacted specimen and determine the bulk density of the specimen

7. Take a sample for moisture content determination and hence find the dry density

8. Place filter paper on the perforated base plate.

9. Fix the mould upside down to the base plate so that the surface of the specimen, which was downwards in contact with the spacer disc during compaction, is now turned upwards on which the penetration test is to be performed (for unsoaked condition).

10. For soaked condition, Fix the adjustable stem and perforated plate on the compacted soil specimen in the mould along with a 2.5kg surcharge load

11. Place the above setup in the soaking tank for four days (ignore this step in case of unsoaked CBR).

12. After four days, measure the swell reading and find % swell with the help of a dial gauge reading

13. Remove the mould from the tank and allow water to drain.

14. Then place the specimen under the penetration piston and place a total surcharge load of 4 kg (2.5 kg during soaking + 1.5 kg during testing).

15. The load and deformation gauges shall then be set to zero.

16. Load shall be applied to the plunger into the soil at the rate of 1.25 mm per minute.

17. Reading of the load shall be taken at penetrations of 0.5, 1.0, 1.5, 2.0, 2.5, 4.0, 5.0, 7.5, 10.0 and 12.5 mm.

18. Remove the plunger and determine the water content of the soil.

19. Plot load versus deformation curve.

CALCULATIONS:

Expansion ratio:

$$Expansion\ Ratio = \frac{d_f - d_s}{h} \times 100$$

Where,

d_f = final dial gauge reading in mm (after 96 hrs)

d_s = initial dial gauge reading in mm, and

h = initial height of the specimen in mm

California bearing Ratio (CBR):

$$California\ Bearing\ Ratio = \frac{P_T}{P_s} \times 100$$

Where,

P_T = corrected unit (or total) test load corresponding to the chosen penetration from the load penetration curve.

P_S = unit (or total) standard load for the same depth of penetration as for PT taken from the table given below.

OBSERVATION TABLE

Penetration Depth (mm)	Unit Standard Load (Kgf)	Total Standard Load (Kgf)
2.5	70	1370
5.0	105	2055

Generally, the CBR value at 2.5 mm penetration will be greater than that at 5 mm penetration and in such a case, the former shall be taken as the CBR value for design purposes. If the CBR value corresponding to a penetration of 5 mm exceeds that for 2.5 mm, the test shall be repeated. If identical results follow, the CBR corresponding to 5 mm penetration shall be taken for design.

Corrections in load vs. deformation curve:

The curve plotted may be convex upwards although the initial portion of the curve may be concave upwards due to surface irregularities. A correction shall then be applied by joining the tangent to the curve at the point of maximum slope. The corrected curve shall be taken to be this tangent, together with the convex portion of the original curve, with the origin of strains shifted to the point where the tangent cuts the horizontal axis for penetration.

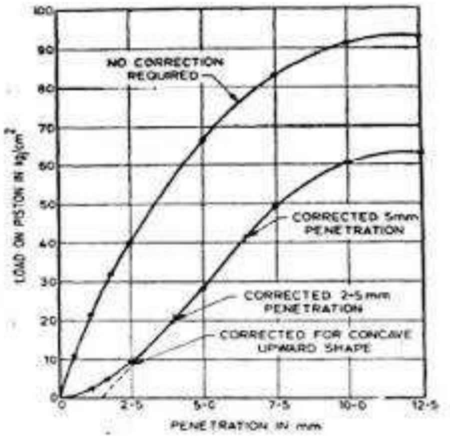

Fig 13.2: Load Penetration Curve

IRC-37 SPECIFICATIONS:

SUBGRADE:

The CBR values for subgrade should range from 2% to 10%. Preferably it should be greater than 2%. If the CBR value is less than 2%, a soil capping layer of 150mm thickness, having a CBR value greater than or equal to 10%, should be provided between subgrade and sub-base. The subgrade should be compacted to 97% of the maximum dry density achieved with heavy (modified proctor) compaction as well as the dry density obtained should not be less than 1.75gm/cc for Expressways, National Highways, State Highways, Major District Roads, and other heavily trafficked roads. In other cases, the subgrade should be compacted to at least 97% of the standard proctor density.

SUB-BASE:

The sub-base soil should have a liquid limit of less than 25% and a plasticity index of less than 6%. For cumulative traffic up to 2 msa (million standard axles), the CBR value should not be less than 20%. For cumulative traffic greater than 2 msa (million standard axles), the CBR value should not be less than 30%.

Note:

CBR test is performed for both soaked and unsoaked soil specimens. Usually, the unsoaked CBR value will be greater than the CBR value for the soaked condition. The CBR values for unsoaked specimens are suitable for (i) arid regions, (ii) where comparatively thick bituminous surfacing of an impermeable nature is provided on top, and where the water table is very deep. For other cases, soaked CBR results are preferred.

OBSERVATIONS:

Unsoaked condition:

OBSERVATION TABLE-1

Maximum dry density of the specimen to be prepared	g/cc	
Optimum moisture content to be taken	%	
Weight of the empty mould	g	
Weight of the soil specimen and mould before soaking	g	
Volume of the soil specimen	cm^3	
Bulk density of the specimen	g/cc	
Water content of the specimen	%	
Dry density of the specimen	g/cc	
Diameter of plunger	cm	
Area of plunger	sq.cm	
Deformation rate	mm/minute	
Proving ring constant	kN/division	
Standard pressure for 2.5mm penetration	kg/cm^2	
Standard pressure for 5mm penetration	kg/cm^2	

OBSERVATION TABLE-2

Dial gauge reading in divisions	Penetration in mm	Load in division	Load in kN	Pressure in kg/cm^2	CBR (after Correction)
0					
50					
100					
150					
200					
250					
400					
500					
750					
1000					
1250					

Soaked condition:

OBSERVATION TABLE-3

Maximum dry density of the specimen to be prepared	g/cc	
Optimum moisture content to be taken	%	
Weight of the empty mould	g	
Weight of the soil specimen and mould before soaking	g	

Volume of the soil specimen	cm^3	
Bulk density of the specimen	g/cc	
Water content of the specimen	%	
Dry density of the specimen	g/cc	
Diameter of plunger	cm	
Area of plunger	sq.cm	
Deformation rate	mm/minute	
Proving ring constant	kN/division	
Standard pressure for 2.5mm penetration	kg/cm^2	
Standard pressure for 5mm penetration	kg/cm^2	

OBSERVATION TABLE-4

Dial gauge reading in divisions	Penetration in mm	Load in division	Load in kN	Pressure in kg/cm^2	CBR (after Correction)
0					
50					
100					
150					
200					
250					
400					
500					
750					
1000					
1250					

QUESTIONS:

1. State the significance of the C.B.R. Test.
2. State the hours required to soak the specimen for the soaked condition of the C.B.R. Test.
3. State the maximum value of penetration up to which loading readings are to be noted down.
4. State two applications of the C.B.R. test in construction work.
5. State the physical features of the field soil that you have tested.
6. Give the details of the working area of the field CBR test that you performed.
7. State the capacity and least count of proving ring used in this test.

Experiment No 14

Vane Shear Test

AIM: To determine the undrained shear strength of a given cohesive soil using a laboratory vane shear apparatus.

THEORY:

The objective of this test is to find the shear strength of soil. This test is performed to find the shear strength of a given (generally very soft) soil specimen. The Vane shear test is a useful method of measuring the shear strength of soft clay. It is a cheaper and quicker method. The test can be conducted in the field as well as 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 unconfined tests cannot be performed.

NEED & SCOPE:

The test gives the undrained strength of the soil. The undisturbed and remolded strength obtained is also useful for evaluating the sensitivity of soil. The data acquired from the vane shear test can be used to determine:

- Undrained shear strength
- Evaluate rapid loading strength for total stress analysis
- Sensitivity of soil to disturbance
- Analysis of stability problems with embankment on soft ground.

APPARATUS REQUIRED:

1. Vane shear apparatus
2. Soft Soil Specimen
3. Specimen container
4. Vernier Caliper
5. Sensitive weighing balance with 0.01 g accuracy
6. Spring of different stiffness

PROCEDURE:

1. In the case of remolded soil specimen, the dry weight of soil and the required water content to be taken depends on the requirement. (Usually in-situ dry density and water content will be taken for sample preparation).

2. Prepare four specimens of the soil sample by rapidly mixing the soil with the water taken until a uniform soil sample is obtained.

3. The uniformly prepared sample is filled in the specimen container whose height is 76mm and diameter is 38mm (Having (H/D) aspect ratio of 2).

4. The application of torque can be done using springs of different stiffness referred as spring constants (2, 4, 6, 8 kg-cm). To start with, the spring of stiffness (spring constant, 2 kg-cm) is attached to the vane shear apparatus.

5. 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.

6. 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 initial readings of the (upper and lower) needles of the angle of twist before applying torque.

7. Both needles should essentially be at the same angle before starting the experiment.

8. Rotate the vanes at a uniform rate (say 0.1^{o} per second) by suitably operating the torque application handle until the lower needle of the angle handle reverts back, which signifies the failure of the soft soil specimen.

9. Note the final reading of the angle of twist by measuring the upper needle's indicated angle.

10. Find the value of blade height in cm and find the value of blade diameter (total width) in cm.

11. The same procedure needs to be done by changing the springs of other stiffness/spring constant, say 4, 6, 8 kgcm.

12. The repetition of tests for all springs of different stiffness is mandatory for reporting the results.

OBSERVATIONS & RECORDINGS:

$$S = \frac{T}{\pi\left(\frac{HD^2}{2} + \frac{D^3}{6}\right)}$$

Where, S = Undrained shear strength of soil in kg/cm^2;

T = Torque in cm-kg (corrected for the vane rod and torque rod resistance, if any);

D = Diameter of vane (in cm);

H = Height of vane (in cm)

Soil Description: ……………………………..

Sr. No	Initial Reading (Deg)	Final Reading (Deg)	Difference (Deg)	Spring-Constant (kg-cm)	T = Spring Constant × Difference / 180	$G = \frac{1}{\pi\left(\frac{HD^2}{2} + \frac{D^3}{6}\right)}$	S = T×G	Avg. S (Kg/cm^2)
1				2				
2				4				
3				6				
4				8				

Note: This test is useful when the soil is soft, and its in-situ water content is nearer to the liquid limit.

QUESTIONS:

1. Mention the number of blades in a vane used for this test.
2. State the vanes' rotation rate in the soil sample.
3. Explain the method of preparation of soil specimens for this practical.
4. State the types of soil recommended for the vane shear test.
5. Differentiate between direct and vane shear tests.
6. State the drainage condition followed to conduct the vane shear test.
7. List out the other tests to determine the shear strength of the soil.

Experiment No 15

Triaxial Shear Test

AIM: To determine the shear strength parameters of soil by unconsolidated, undrained triaxial compression test without the measurement of pore water pressure.

THEORY:

The Unconsolidated Undrained (UU) triaxial test provides the undrained stress-strain response of a cylindrical soil specimen under triaxial compression loading without consolidating the specimen. It also provides the undrained shear strength parameters by performing the tests on different confining pressures. Initially, a confining pressure (σ_3) is applied through the water around the specimen in the triaxial cell. The drainage valve is closed throughout the test, which does not allow the consolidation of the specimen. The specimen is then subjected to shearing by applying the constant rate of deformation under undrained compression loading conditions. Excess pore water pressure is not measured during shearing; hence the shear strength parameters are analyzed in total stress conditions only.

The initial state of stress is hydrostatic, with all three principal stresses the same as applied confining pressure (σ_3). The vertical stress acts as the major principal stress (σ_1) during shearing, while the confining pressure (σ_3) acts in the other two principal directions of the cylindrical specimen. The intermediate principal and minor principal stresses are equal to each other. Deviatoric stress (σ_d) is the difference between σ_1 ($\sigma_1 = \sigma_d + \sigma_3$) and σ_3, acting on the specimen while its shear deformation.

NEED AND SCOPE:

The unconsolidated undrained triaxial test is a quick test as compared to consolidated undrained (CU) and consolidated drained (CD) triaxial tests. UU test can be performed on any type of soil to determine its shear strength parameters under undrained conditions, i.e., cohesion (c_u) and angle of internal friction (φ_u). These undrained shear strength parameters are useful in the determination of the bearing capacity of the soil, stability analysis of highway embankments, earthen embankments, etc. One of the critical conditions for the stability of any slope occurs immediately after construction, which represents the undrained condition. In such conditions, undrained shear strength parameters should be used for stability analysis.

APPARATUS REQUIRED

1) Loading frame capable of generating a constant rate of movement.

2) Proving ring (Capacity ranging from 1 kN to 50 kN).

3) Bottom platen of the required diameter made with Perspex glass (the diameter of the plate is selected according to the diameter of the sample).

4) Top cap of the required diameter made with Perspex glass with a circular groove to accommodate the plunger of the triaxial cell.

5) Dial gauge (0.01 mm accuracy).

6) Hardened Steel ball.

7) Triaxial cell, in which using water hydrostatic pressure can be applied to the specimen and having a central plunger. that can be connected to a proving ring to measure the vertical load/pressure. The cell (made of Perspex) is usually designed with a non-ferrous metal top and base connected by tension rods.

8) Bottom base plate with a pedestal of a diameter similar to the diameter of specimen and valve arrangements to apply cell pressure.

9) Air-water interface system (Cylinder filled with water and a balloon inside it which applies air pressure to the water filled in the cylinder).

10) Air Compressor.

11) Constant pressure system with regulators, valves and pressure meter to control the cell pressure.

12) De-aeration tank.

13) Latex rubber membrane.

14) Rubber O-rings.

15) Membrane Stretcher (An open-ended cylindrical section former, required inside diameter fitted with a small rubber tube on its side).

SPECIMEN PREPARATION AND DEFORMATION RATE:

The UU triaxial test can be performed on undisturbed soil samples, wherever the undisturbed sample (UDS) collection is possible. When UDS sample collection is not possible or the UDS sample shows cracks while extraction, reconstituted specimens can be prepared. The samples can be reconstituted at in-situ density and moisture content. The UU triaxial test is commonly conducted on specimen sizes of 38 mm diameter and 76 mm height. The loading frame is used to provide a constant rate of deformation to the specimen commonly 0.4 mm/min for fine soils and 0.6 mm/min for coarse soil.

PROCEDURE:

1. Place the bottom platen on the pedestal of the base plate of the triaxial cell, then place the specimen on the bottom platen.

2. Place the top cap on the specimen.

3. Seal the specimen arrangement properly with the latex rubber membrane and rubber O-rings using the membrane stretcher.

4. Place the cell such that it must be properly set up and uniformly clamped down to prevent leakage of pressured water during the test.

5. Move down the plunger and set it up on the circular groove of the top cap. Place a steel ball on the top of the plunger.

6. Adjust the center line of the specimen such that the proving ring, the steel ball, the plunger and the specimen are in the same line.

7. Fill the cell with the water with the bleed valve open. Close the bleed valve tightly after filling the cell with water.

8. The air-water interface is then regulated using valves and a regulator of a constant pressure system, and the pressure is applied to water with the balloon in the interface system. This pressure is applied through water to the cell.

9. Open the valve that connects pressure to the cell to apply the required cell pressure. (For example, 50 kPa, 100 kPa and 150 kPa or 100kPa, 200 kPa and 300 kPa as per the depth where the sample is brought and the application requirements.)

10. The pressure gauge must be watched during the test and any necessary adjustments must be made to keep the pressure constant.

11. A small deformation is applied to the system until the underside of the hemispherical seating of the proving ring, through which the loading is applied, just touches the steel ball on the cell piston. This procedure is called the docking of the triaxial system.

12. After docking, fix a dial gauge to measure the vertical compression of the specimen.

13. Adjust the gear position on the load frame to give a suitable rate of deformation.

14. Start applying the load and record the readings of the proving ring and compression dial for every 25 divisions in the compression dial gauge.

15. Continue loading till failure or 20% axial strain (whichever is reached earlier) (IS-2720-PART-10-1991), and then take a picture of the failure pattern of the specimen.

OBSERVATION & RECORDING:

At particular intervals of strain, dial gauge readings and the corresponding proving ring readings are taken, and the corresponding load is determined using the proving ring constant. The experiment is stopped either at failure or at the 20% axial strain.

Data Sheet for Triaxial Test (UU)

Sample No :

Length of specimen :	cm
Diameter of specimen :	cm
Initial area of specimen (A_0) :	cm^2
Initial Volume :	cc
Dry density :	g/cc
Moisture Content :	%
Deformation rate :	mm/minute
Proving ring constant:	N
Strain dial least count :	mm

OBSERVATION TABLE-1

Cell Pressure kPa (σ3)	Dial Gauge Reading (Divisions)	Deformation (mm) = Divisions × Least count	Strain %, ε = (Deformation/Ht of specimen)×100	Proving ring Reading (Divisions)	Load (kN)= Divisions × Proving ring constant	Corrected Area (m^2)=A_0/{1-(ε/100)}	Deviator stress, σd (kPa) = Load taken/ Corrected area
	25						
	50						
	75						
	100						
	125						
	150						
	175						
	200						
	225						
	250						
	275						
	300						
	325						
	350						
	375						
	400						
	425						
	450						
	475						
	500						
	525						
	550						
	575						
	600						
	625						
	650						
	675						
	700						

OBSERVATION TABLE-2

Cell Pressure kPa (σ3)	Dial Gauge Reading (Divisions)	Deformation (mm) = Divisions × Least count	Strain %, ε = (Deformation/Ht of specimen)×100	Proving ring Reading (Divisions)	Load (kN)= Divisions × Proving ring constant	Corrected Area (m^2)=A_0/{1-(ε/100)}	Deviator stress, σd (kPa) = Load taken/ Corrected area
	25						
	50						
	75						
	100						
	125						
	150						
	175						
	200						
	225						
	250						
	275						
	300						
	325						
	350						
	375						
	400						
	425						
	450						
	475						
	500						
	525						
	550						
	575						
	600						
	625						
	650						
	675						
	700						

OBSERVATION TABLE-3

Cell Pressure kPa (σ3)	Dial Gauge Reading (Divisions)	Deformation (mm) = Divisions × Least count	Strain %, ε = (Deformation/Ht of specimen)×100	Proving ring Reading (Divisions)	Load (kN)= Divisions × Proving ring constant	Corrected Area (m^2)=A_0/{1-(ε/100)}	Deviator stress, σd (kPa) = Load taken/ Corrected area
	25						
	50						
	75						
	100						
	125						
	150						
	175						
	200						
	225						
	250						
	275						
	300						
	325						
	350						
	375						
	400						
	425						
	450						
	475						
	500						
	525						
	550						
	575						
	600						
	625						
	650						
	675						
	700						

OBSERVATION TABLE-4

Sample No	Cell Pressure, σ_3 (kPa)	Compressive stress at failure, σ_d (kPa)	Strain at failure (%)	$\sigma_1 = \sigma_3 + \sigma_d$	$p = (\sigma_1+\sigma_3)/2$	$q=(\sigma_1-\sigma_3)/2$

* Plot σ_d vs ε, (Deviatoric stress vs. axial strain plot) for all confining pressure in a single plot.

*Plot p versus q for the peak values from three tests (Modified failure envelope).

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.

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

c) The stress results of the series of triaxial tests at increasing cell pressure are plotted as a Modified failure envelope using $p = (\sigma_1+\sigma_3)/2$ as abscissa and $q = (\sigma_1-\sigma_3)/2$ as ordinate. In this diagram, a best-fit line is plotted in which the slope represents the value of ψ while the intercept represents the value of a.

d) From the relation, $\sin\varphi = \tan\psi$ $\quad\quad$ $a = c \times \cos\varphi$

The value of cohesion, c and the angle of shearing resistance, φ will be determined as the soil shear strength parameters.

QUESTIONS:

1. What are the advantages of the triaxial test over the direct shear test?
2. What is the practical significance of cell pressure in this test?
3. Explain the changes to be incorporated for a drained test in the procedure for an undrained test.
4. Explain the stress conditions at the time of failure by drawing Mohr's circle.

Experiment No 16
Consolidation Test

AIM: To determine the consolidation properties of a given soil.

THEORY:

When a compressive load is applied to soil mass, a decrease in its volume takes place. The decrease 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 voids filled with incompressible water, a 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 consolidation. When the load is applied to the saturated soil mass, the entire load is carried by pore water in the beginning. As the water begins escaping from the voids, the hydrostatic pressure in the water gets gradually dissipated, and the load is shifted to the soil particles, which increases effective stress on them. As a result, the soil mass decreases in volume. The rate of escape of water depends on the permeability of the soil.

NEED AND SCOPE:

This test simulates one-dimensional primary consolidation with double drainage. The following parameters are determined by conducting a Consolidation test on fine-grained soils:

a. Pressure-void ratio relationship

b. Compression and Recompression index

c. Coefficient of consolidation at various pressures

d. Preconsolidation pressure

e. Degree of consolidation at any time

f. Rate of consolidation under vertical loads

The above information can be used 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.

APPARATUS REQUIRED:

1. Consolidometer consisting essentially

a) A ring of 60 mm diameter and 20 mm height
b) Two porous stones
c) Guide ring
d) Outer ring
e) Water jacket with base
f) Pressure pad

2. Loading device consisting of a frame, lever system, loading yoke, steel ball, dial gauge fixing device, and weights.

3. Dial gauge (accuracy of 0.01 mm), thermostatically controlled oven, stopwatch, sample extractor, balance, soil.

trimming tools, spatula, filter papers, sample containers, and wash bottles.

SAMPLE PREPARATION:

1. Undisturbed sample:

From the sample tube (Shelby tube), eject the sample into the consolidation ring. The sample should project about one cm from the outer ring. Trim the sample smoothly and flush with the top and bottom of the ring by using a wire saw. Clean the ring from the outside and keep it ready for weighing.

2. Remolded sample:

a. Choose the density and water content at which the sample has to be compacted from the moisture-density curve, and calculate the quantity of soil and water required to mix and compact.

b. Compact the specimen in compaction mould in three layers using the standard rammers (moist tamping technique).

c. Eject the specimen from the mould using the sample extractor.

PROCEDURE:

1. Saturate two porous stones either by boiling them in distilled water for about 15 minutes or by keeping them submerged in the distilled water for 4 to 8 hrs. Fittings of the Consolidometer, which is to be enclosed, shall be moistened.

2. Assemble the Consolidometer with the soil specimen and porous stones at the top and bottom of the specimen, and provide a filter paper between the soil specimen and porous stone.

3. Position the pressure pad centrally on the top porous stone. Mount the mould assembly on the loading frame, and center it such that the load applied is axial. Make sure that the porous stone and pressure pad are not touching the walls of mould on their sides.

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 at the beginning of its release run, and also allowing sufficient margin for the swelling of the soil, if any.

5. Fill the mould with water and 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 0.05 kg/cm^2 for ordinary soils & 0.025 kg/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.

6. Note the final dial reading under the initial load. Apply the first load of intensity 0.1 kg/cm^2 (Approx.) and start the stopwatch 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.

7. 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 for successive load increments. The usual loading intensity is as follows (approx.): 0.1, 0.2, 0.5, 1, 2, 4 and 8 kg/cm^2. Dial gauge reading with time should be recorded for each loading increment.

8. On completion of the final loading stage, the specimen shall be unloaded by pressure decrements, which decrease the loadto one-fourth of the last load. Dial gauge readings may be taken as necessary during each stage of unloading. If desired, the time intervals used

during the consolidation increments may be adopted; usually, it is possible to proceed much more rapidly (IS 2720- Part 15).

9. In the unloading phase, the load needs to be reduced in the reverse order and allowed to stand for at least 2 hrs or until the dial gauge reading becomes constant. Take the final reading of the dial gauge.

10. Quickly dismantle the specimen assembly and remove the excess water on the soil specimen in the oven; note its dry weight.

CALCULATIONS:

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

$H_S = W_S / (G_S . \gamma_w . A)$

2. **Void ratio**. The void ratio at the end of various pressures is calculated from the equation

$e = (H - H_S)/H_S$

3. Coefficient of consolidation. The Coefficient of consolidation at each pressure 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 readings and logarithmic of time, and the time corresponding to 50% consolidation is determined. In the square root fitting method, a plot is made between dial readings and the square root of time, and the time corresponding to 90% consolidation is determined. The values of C_v are recorded in Table II.

4. Compression Index. To determine the compression index, a plot of voids ratio (e) Vs log (t) is made. The virgin compression curve would be a straight line and the slope of this line would give the compression index Cc.

5. **Coefficient of compressibility.** It is calculated as follows

$$a_v = \frac{\Delta e}{\Delta \sigma'}$$

Δe = Change in void ratio

$\Delta \sigma'$ = Change in vertical stress

6. **Coefficient of permeability.** It is calculated as follows

$$k = \frac{C_v a_v \gamma_w}{1 + e_0}$$

GRAPHS:

1. Dial reading Vs log of time or

2. Dial reading Vs square root of time

3. Voids ratio (e) Vs effective vertical stress ($log_e \sigma_v'$)

General Remarks:

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

2. During trimming, care should be taken in handling the soil specimen with the least pressure.

3. Smaller increments of sequential loading have to be adopted for soft soils.

OBSERVATION AND READING (LOADING):

Table I: Data Sheet for Consolidation Test: Time Displacement Relationship

Ring Dimensions: Diameter (cm): ________ Area (cm^2): ______ Height (cm): _________

Initial Data: Specimen Ht (cm).____________ Specific Gravity of Soil: ____________

Weight of wet soil + Ring (g): _______ Weight of Ring (g): ______ Bulk Density (g/cc): ___

OBSERVATION TABLE-1

Pressure intensity (kg/cm^2)	0.1	0.2	0.5	1	2	4	8
Time (min)							
0							
0.25							
1							
2							
4							
8							
15							
30							
1 hr							
2 hrs							
4 hrs							

8 hrs							
24 hrs							

OBSERVATION AND READING (UNLOADING):

Removed Pressure (kg/cm^2)	Retained Pressure (kg/cm^2)	Dial gauge reading
0	8	
4	4	
2	2	
1	1	
0.5	0.5	
0.3	0.2	
0.1	0.1	
0.1	0.05 (Seating pressure)	

Water Content Determination:

Weight of Saturated Sample + Ring (g): ____________

Weight of oven-dried soil +Ring (g): ____________

Water Content (%): _________

Table II: Data Sheet for Consolidation Test: Pressure-Voids Ratio

OBSERVATION TABLE-2

Applied Pressure	Final dial reading	Change in Specimen Height	Final Specimen Height	Height of solids	Height of voids	Void ratio	Average Height during Consolidation	Fitting Time, t_{90}	Coefficient of Consolidation, c_v
0									
0.1									
0.2									
0.5									
1.0									
2.0									
4.0									
8.0									
2.0									
0.5									
0.1									

QUESTIONS:

1. What is the use of a C_V? When is it used?
2. Can permeability be determined from the consolidation test indirectly?
3. Which type of permeability test can be done directly? Explain.
4. What result do you expect if a consolidation test is conducted on sand?

Experiment No 17

Plate Load Test

Aim: To determine the bearing capacity of soil and settlement of footing.

THEORY:

Plate load test, though useful in obtaining the necessary information about the soil with particular reference to the design of the foundation, has some limitations. The test results reflect only the character of the soil located within a depth of less than twice the width of the bearing plate. Since the foundations are generally larger than the test plates, the settlement and shear resistance will depend on the properties of a much thicker stratum. Moreover, this method does not give the ultimate settlements, particularly in the case of cohesive soils. Thus, the results of the test are likely to be misleading if the character of the soil changes at shallow depths, which is not uncommon. A satisfactory load test should, therefore, include adequate soil exploration (see IS: 1892-1979), with due attention being paid to any weaker stratum below the level of the footing.

APPARATUS:

1. Loading platform truss of sufficient size and properly designed members so as to estimate load reaction for conducting the test shall be used.
2. Hydraulic jack, pressure gauge, electronic load cell, and proving ring.
3. Circular or square bearing plates of mild steel not less than 25 mm in thickness and varying in size from 300 to 750 mm.
4. Dial gauges with 25 mm travel, capable of measuring settlement to an accuracy of 0.01 mm.
5. Beam or rod of sufficient strength capable of maintaining straightness when fitted on two independent supports fitted with arms or magnetic bases for holding dial gauges.
6. A ball and socket arrangement, loading columns, steel shims, wooden blocks, collar, and reaction girder with cradles for independent fitting to the reaction platform.

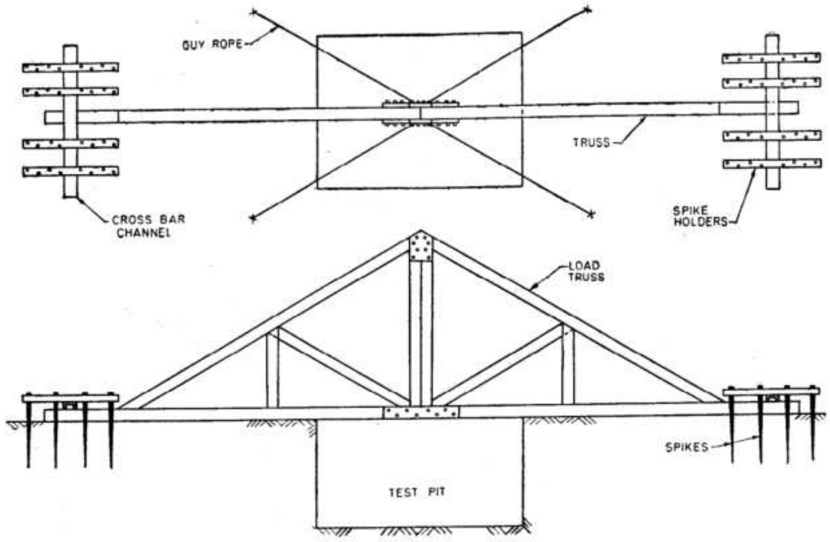

Fig 18.1: Typical setup for Loading Truss

PROCEDURE:

1. The test is carried out at the proposed level of the foundation, having, in general, normally of width equal to five times the test plate or block, shall have a carefully leveled and cleaned bottom at the foundation level, protected against disturbance or changes in a natural formation.
2. The test plate is kept over the sand layer of 5 mm and is properly concentric with the loading arrangement.
3. Loading: Gravity loading, Reaction frame loading.
4. A seating pressure of 7 kPa is applied initially and removed before the test.
5. Loading increments can be done at intervals of 0.5 kN, and settlement readings are taken at time intervals of 1, 2, 4, 6, 9, 16, 25 min, and then 1 hour.
6. For clayey soils, the load is increased when the settlement exceeds 70-80% of probable ultimate settlement at that stage or at the end of 24 hours.
7. For other soils, the rate of settlement drops below 0.02 mm/min.
8. A load settlement curve shall be plotted out on an arithmetic scale. From this load settlement curve, the zero correction, which is given by the intersection of the early straight lines or the nearly straight-line part of the curves with zero deadlines, shall be determined and subtracted from the settlement readings to allow for the perfect seating of the bearing plate and other causes.
9. Four typical curves are shown in Fig 18.2. Curve A is typical for loose to medium cohesionless soil; it is a straight line in the earlier stages but flattens out after some

time, but there is no clear point of failure. Curve B is for cohesive soil; it may not be quite straight in the early part and leans towards the settlement axis as the settlement increases. For partially cohesive soils, curve C, possessing the characteristics of both curves il and B, is obtained, while curve D is purely for dense cohesionless soils.

10. From the corrected load settlement curves, no difficulty should be experienced in arriving at the ultimate bearing capacity in the case of dense cohesionless soils or cohesive soils (see Fig. 18.2, curves D and B) as the failure is well defined. But in the case of Curves A and C, where the yield point is not well-defined, settlements shall be plotted as abscissa against corresponding load intensities as ordinate, both to logarithmic scales (see Fig. 18.3), which give two straight lines, the intersection of which shall be considered as yield value of soil.

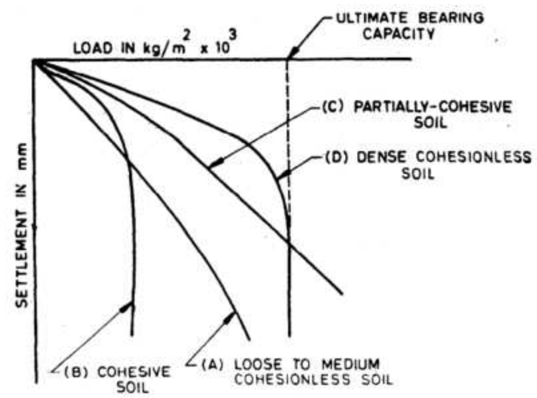

Figure 18.2: Load Settlement Curves

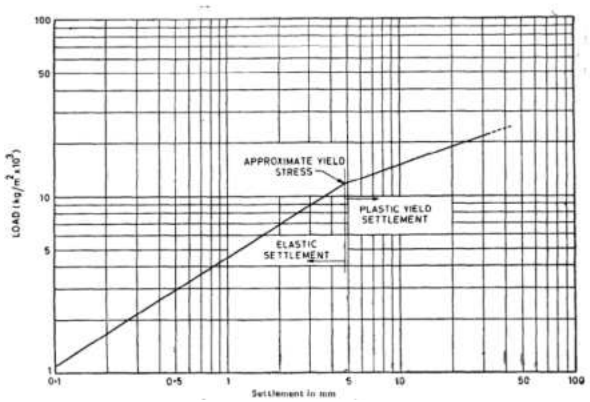

Figure 18.3: Log-Log Scale of Load Settlement Curve

OBSERVATION TABLE AND CALCULATION:

20 kN Load		40 kN Load		60 kN Load		80 kN Load	
Time (min)	Average Settlement	Time (min)	Average Settlement	Time (min)	Average Settlement	Time (min)	Average Settlement
0		0		0		0	
1		1		1		1	
2		2		2		2	
4		4		4		4	
6		6		6		6	
9		9		9		9	
16		16		16		16	
25		25		25		25	
60		60		60		60	
120		120		120		120	

The safe bearing pressure for medium and dense sands could be read, corresponding to a settlement (S_p), which shall be calculated as under S_f taken as permissible settlement of footing.

$$S_f = S_p \left[\frac{B\left(B_p + 0.3\right)}{B_p(B + 0.3)} \right]^2$$

Where,

B = The size of footing in m,

B_p = Size of test plate in m,

S = Settlement of test plate in m, and

S_f = Settlement of footing in m

The safe bearing capacity of soil is ____________________kg/m^2

The permissible settlement of footing is ________________mm

QUESTIONS:

1. How much seating pressure is applied on the plate before starting the load test?
2. What are the ranges of size of bearing plate used in the plate load test?
3. What is the value of factor of safety is used for finding the safe bearing capacity of soil?