DEPARTMENT OF CIVIL ENGINEERING

CIVIL ENGINEERING LABORATORY - II

(Geotechnical Engg. lab)

5TH SEMESTER

LIST OF EXPERIMENT

EXPERIMENT NO-1

WATER CONTENT OF SOIL

OVEN DRYING METHOD

AIM

T o determine the water content in soil by oven drying method as per IS: 2720 (Part II) – 1973

PRINCIPLE

The water content (w) of a soil sample is equal to the mass of water divided by the mass of solids.

APPARATUS

i) Thermostatically controlled oven maintained at a temperature of 110 ± 5°C

ii) Weighing balance , with an accuracy of 0.04% of the weight of the soil taken

iii) Air-tight container made of non-corrodible material with lid

iv) Tongs

SAMPLE

The soil specimen should be representative of the soil mass. The quantity of the specimen taken would depend upon the gradation and the maximum size of particles as under:

Size of particles mor than 90 percent passing through IS Sieve	Minimum quantity of the soil specimen to be taken for test (g)
425 µm	25
2.0 mm	50
4.75mm	200
9.50mm	300
19mm	500
37.5 mm	1000

PROCEDURE

i) Clean the container, dry it and weigh it with the lid (Weight 'W_{1}).

ii) Take the required quantity of the wet soil specimen in the container and weigh it with the lid Weight 'W_{2}).

iii) Place the container , with its lid removed , in the oven till its weight becomes constant (Normally for 24 hrs.)

iv) When the soil has dried , remove the container from the oven , using tongs.

v) Find the weight 'W_{3}' of the container with the lid and the dry soil sample.

REPORTING OF RESULTS

The water content $w = W_2 - W_3 / W_3 - W_1 \times 100\%$

An average of three determinations should be taken.

A sample proforma for the record of the test results is given in Annexure-IV.

EXPERIMENT NO-2

SPECIFIC GRAVITY

AIM

To determine the specific gravity of fine-grained soil by Pycnometer method as per IS: (part III/Sec)-1980.

PRINCIPLE

Specific gravity is the ratio of the weight in air of a given volume of a material at a standard temperature to the weight in air of an equal volume of distilled water at the same stated temperature.

APPARATUS

i) Two density bottles of approximately 50ml capacity along with stoppers.

ii) Constant temperature water bath (27.0 $\pm$ 0.2°C)

iii) Vacuum desiccator

iv) Oven, capable of maintaining a temperature of 105 to 110°C.

v) Weighing balance, with an accuracy of 0.001g.

vi) Spatula

PRAPARATION OF SAMPLE

The soil sample (50g) should if necessary be ground to pass through a 2mm IS Sieve. A 5 to 10g sub-sample should be obtained by riffling and oven-dried at a temperature of 105 to 110°C.

PROCEDURE

i) The density bottle along with the stopper, should be dried at a temperature of 105 to 110°C, cooled in the desiccators and weighed to the nearest 0.001g (W_1).

ii) The sub-sample , which had been oven-dried should be transferred to the density bottle directly from the desiccators in which it was cooled. The bottles and contents together with the stopper should be weighed to the nearest 0.001g (W_2).

iii) Cover the soil with air-free distilled water from the glass wash bottle and leave for a period of 2 to 3hrs. For soaking, add water to fill the bottle to about half.

iv) Entrapped air can be removed by heating the density bottle on a water bath or a sand bath.

v) Keep the bottle without the stopper in a vacuum desiccators for about 1 to 2hrs. Until there is no further loss of air.

vi) Gently stir the soil in the density bottle with a clean glass rod, carefully wash off the adhering particles from the rod with some drops of distilled water and see that no more soil particles are lost.

vii) Repeat the process till no more air bubbles are observed in the soil-water mixture.

viii) Observe the constant temperature in the bottle and record.

ix) Insert the stopper in the density bottle, wipe and weigh (W_3)

x) Now empty the bottle, clean thoroughly and fill the density bottle with distilled water at the same temperature . Insert the stopper in the bottle, wipe dry from the outside and weigh (W_4).

xi) Take at least two such observations for the same soil.

REPORTING OF RESULTS

The specific gravity G of the soil = $\frac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_2)}$

The specific gravity should be calculated at a temperature of 27°C and reported to the nearest 0.01. If the room temperature is different from 27°C, the following correction should be done :-

$G' = kG$

Where,

G' = Corrected specific gravity at 27°C

$$K = \frac{\text{Relative density of water at room temperature}}{\text{Relative density of water at 27°C.}}$$

A sample proforma for the record of the test results is given in Annexure –VI. Relative density of water at various temperatures, given in Annexure-VII , can be used in the above calculation.

EXPERIMENT NO-3

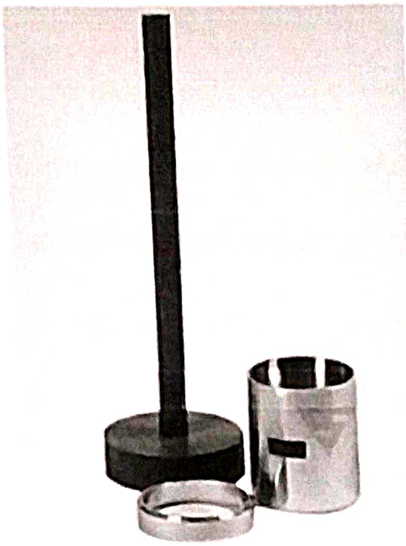
IN-SITU DRY DENSITY

CORE CUTTER METHOD

AIM

To determine the in-situ dry density of soil by core cutter method as per IS: 2720 (Part XXIX) - -1975.

APPARUS



i) Cylindrical core cutter

ii) Steel dolley

iii) Steel rammer

iv) Balance, with an accuracy of 1g

v) Straightedge

vi) Square metal tray = 300mm X 300mm X 40mm

vii) Trowel

PROCEDURE

i) The internal volume (V) of the core cutter in cc should be calculated from its dimensions which could be measured to the nearest 0.25mm.

ii) The core cutter should be weighed to the nearest gram (W_1).

iii) A small area, approximately 30cm square of the soil layer to be tested should be exposed and levelled. The steel dolly should be placed on top of the cutter and the latter should be rammed down vertically into the soil layer until only about 15mm of the dolly protrudes above the surface., care being taken not to rock the cutter. The cutter should than be dug out of the surrounding soil., care being taken to allow some soil to project from the lower end of the cutter. The ends of the soil core should then be trimmed flat in level with the ends of the cutter by means of the straightedge.

iv) The cutter containing the soil core should be weighed to the nearest gram (W_2).

v) The soil core should be removed from the cutter and a representative sample should be placed in an air-tight container and its water content (w) determined .

REPORTING OF RESULTS

Bulk density of the soil $\Upsilon = W_2 - W_1/V$ g/cc

Dry density of the soil $\Upsilon_d = 100\ \Upsilon/100 + W$ g/cc

Average of at least three determinations should be reported to the second place of decimal in g/cc.

A sample proforma for the record of the test results is given .

EXPERIMENT NO-4

TESTS ON AGGREGATES

SIEVE ANALYSIS

AIM

To determine the particle size distribution of fine and coarse aggregates by sieving as per IS: 2386 (Part I)- 1963.

PRINCIPLE

By passing the sample downward through a series of standard sieves, each of decreasing size openings, the aggregates are separated into several groups, each of which contains aggregates in a particular size range.

APPARATUS

i) A set of IS sieves of sizes- 80mm, 63mm, 50mm, 40mm, 31.5mm, 25mm, 20mm, 16mm, 12.5mm, 10mm, 6.3mm,4.75mm, 3,35mm, 2.36mm, 1.18mm, 600µm, 300 µm, 150 µm and 75 µm.

ii) Balance or scale with an accuracy to measure 0.1 percent of the weight of the test sample.

SAMPLE

The weight of sample available should not be less than the weight given below:-

Maximum size present in substantial proportions(mm)	Minimum weight of sample despatched for testing (kg)
63	100
50	100
40	50
25	50
20	25
16	25
12.5	12
10.0	6
6.3	3

The sample for sieving should be prepared from the larger sample either by quartering or by means of a sample divider.

PROCEDURE

i) The test sample is dried to a constant weight at a temperature of 110 $\pm$ 5°C and weighed.

ii) The sample is sieved by using a set of IS Sieves.

iii) On completion of sieving, the material on each sieve is weighed.

iv) Cumulative weight passing through each sieve is calculated as a percentage of the total weight.

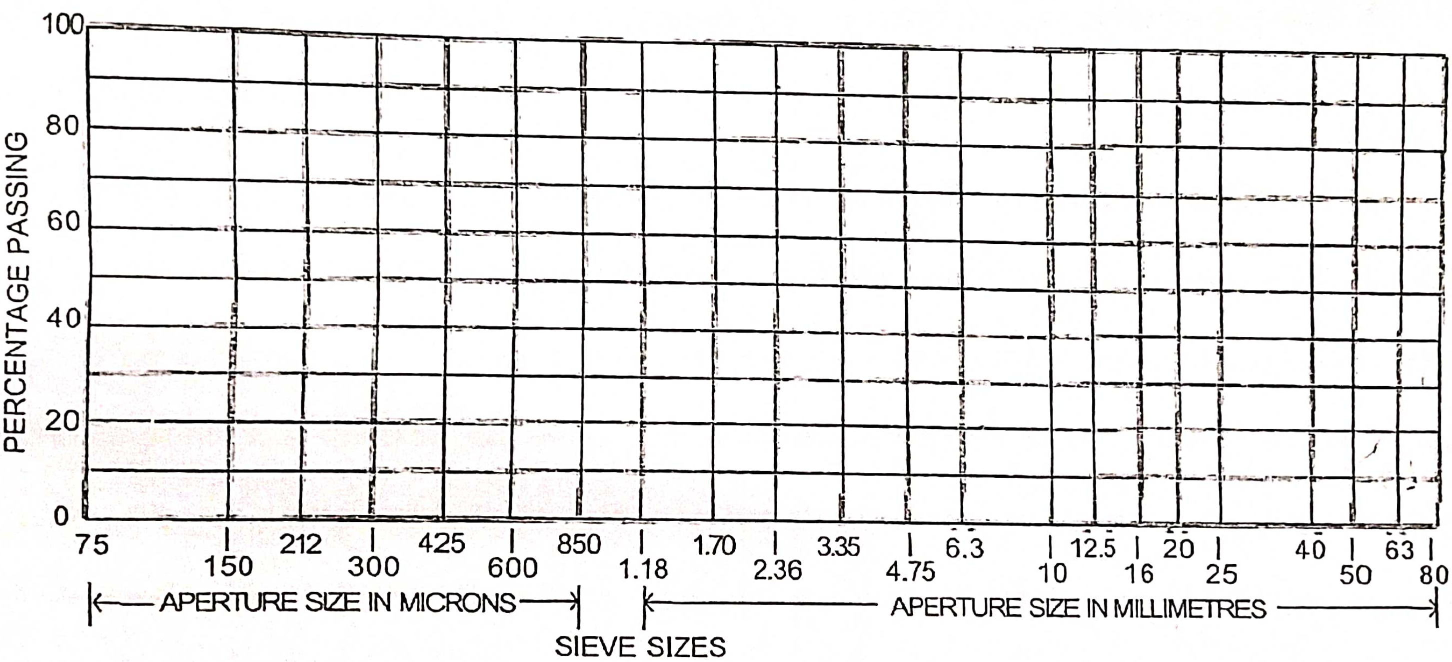
v) Fineness modules is obtained by adding cumulative percentage of aggregates on each and dividing the sum by 100.

REPORTING OF RESULTS

The result should be calculated and reported as:

i) The cumulative percentage by weight of the total sample passing through one sieve and retained on the next smaller sieve, to the nearest 0.1 percent.

The result of the sieve analysis may be recorded graphically on a semi-log graph with particle size as abscissa (log scale) and the percentage smaller than the specified diameter as ordinate. A sample chart is provided.



Note - The vertical scale of this chart is an arithmetic scale and the horizontal scale is logarithmic.

CHART FOR RECORDING SIEVE ANALYSIS RESULTS

EXPERIMENT NO-5

WET MECHANICAL ANALYSIS FOR CLAY AND SILT

I Objectives

Determine soil texture by mechanical analysis using the pipette method. Estimate soil texture by the feel method.

II Introduction

A general

Soil texture is the relative proportion of sand, silt and clay in a soil. Within each of these soil separates there is a continuum of particle sizes. Thus, there is a particle size distribution in soil ranging from the largest sand particles to the smallest clay particles. Texture is considered to be a permanent characteristic of a soil since weathering only very slowly changes particle size. Furthermore, cultivation and other management practices do not alter the sizes of individual soil particles. In some cases, however, erosion or deposition may rapidly alter the particle size distribution.

Texture is an important property of soils because particle size determines the surface area of solids per unit volume or mass of soil. Texture also influences the pore size distribution in soil. A sandy soil is dominated by large individual soil particles and therefore has a relatively small total surface area and large pore spaces between soil particles. At the other extreme, a clay soil consists of tiny individual particles and has a large total surface area but small pore spaces. However, small soil particles tend to be associated with one another to form aggregates of soil particles. Thus, the pore space in a clay soil consists of small into aggregates pores and much larger inter aggregates pores. In fact , the total volume of pore space per unit volume of soil (porosity) of a soil is actually smaller than the porosity of a clay soil.

Many chemical and physical processes in soil occur at the surface of soil particles. For example, the surface of soil particles is the site of a physicochemical reaction known as ion exchange. The negative (and , in some cases, positive) charge carried by certain soil particles is balanced by surface adsorbed cations (or anions) In ion exchange, an ion in solution exchanges for a surface adsorbed ion of like charge. Ions adsorbed in this way serve as a reservoir of nutrients for plant growth.

Adsorbed ions also complicate the matter of determining soil texture by mechanical analysis. Adsorbed ions, though in very close proximity to the surface of soil particles, are often not really bound to the soil particles. Rather , these exist as a diffuse layer-highest concentration nearest the surface and decreasing moving away from the surface. The nature of this diffuse layer is affected by the type of ion and the total concentration of ions in the soil solution. In turn, the interaction of adjacent soil particles is affected by the diffuse layer. For example, small soil particles in a concentrated solution of Ca^{2+} tend to be closely associated with one another (flocculated), whereas in a dilute Na^+ solution , small soil particles tend to be independent of one another (dispersed). It is crucial in a mechanical analysis to have soil particles thoroughly dispersed and independent.

B Definition of soil Separates

Separate	Diameter (mm)
Very coarse sand	2.00-1.00
Coarse sand	1.00-0.50
Medium sand	0.50-0.25
Fine sand	0.25-0.10
Very fine sand	0.10-0.05
Silt	0.05-0.002

Clay	Less than 0.002

Particles larger than 2.0 mm in diameter are not considered in determining soil texture.

C Principle Underlying a Mechanical Analysis

Soil particles suspended in solution settle out at a rate that depends on the size of the particles- the larger the particles, the faster it settles. Settling rate is given by stokes' law

$V = (2/9)\ (D_S - D_L)\ g\ r^2 / \eta$

Where

V is settling velocity	(cm/s)
Ds is particle density	(g/cm^3)
DL is water density	(g/cm^3)
G is acceleration due to gravity	(cm/s^2)
R is radius of particle	(cm)
η is water viscosity	(g/cm-s)

Given that v is distance /time, the time required for all sand-seized and all silt-seized particles to settle a distance of 10 cm in water at room temperature can be calculated. Substituting appropriate values inn stokes' Law gives

Very fine sand	(0.050 mm)	48s
Silt	(0.002 mm)	8 h

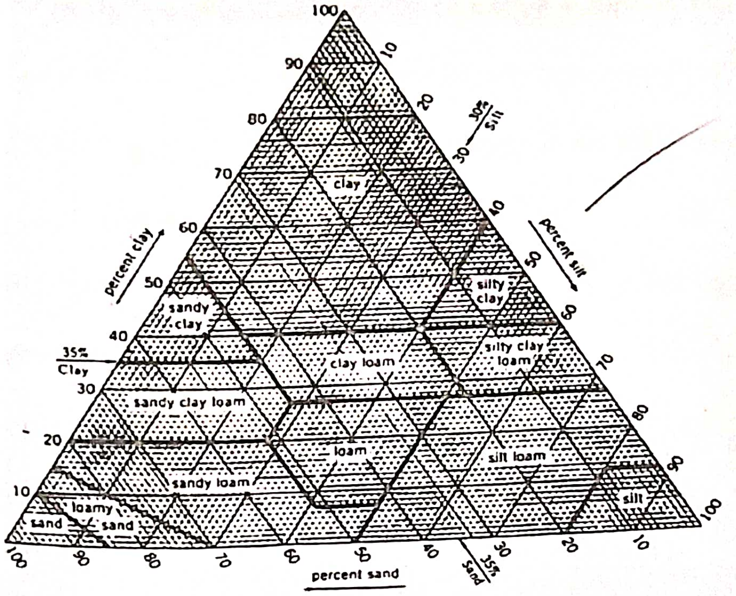
Thus, if you completely disperse a sample of soil in water and agitate the suspension so that at time zero sand, silt and clay particles were uniformly distributed in the water , an aliquot of the suspension taken at

48 s and above the 10 cm depth will contain only silt and clay particles. From these two aliquots, percentage clay, silt and sand (since percentage clay, silt and sand sum to 100) can be determined.

D Use of Textual Triangle to Determine Textural Class

Soils are grouped into textural classes on the basis of the percentage of sand , silt and clay. Soils within each textural class have similar soil properties and the class name reflects the relative influence of each soil separate on the properties of that soil. For a soil to be called a sand, it must contain over 855 sand, but soil must contain only 40% clay in order to be classified as a clay. Loams have properties resulting from about equal influences of sand , silt and clay , but the loams contain more sand and silt than clay.

The textural triangle contains twelve textural classes, each of which can be comprised of various combinations of sand, silt and clay. Each leg of the triangle represents either sand ,silt or clay and is divided in to percentages from 0 to 100% since a soil may contain any percentage of a soil separate as long as the total percentage of the three separates equals 100. Each leg of the triangle then represents the base or 0% value for one of the three soil separates. To determine the textural class of a soil based on a mechanical analysis, draw a line at the appropriate percentage for each separate across the triangle , parallel to the base for that separate (one line parallel to each base). If done correctly , the three lines will intersect at one point within a section of the triangle containing the correct textural class name.



III Procedures

A Mechanical Analysis by the pipette Method

To determine the relative masses of sand, silt and clay in the soil sample (thus, the texture) the combined mass of silt plus clay in the first aliquot and the mass of clay in the second must be determined. Also, the initial total volume of suspension and aliquot volume must be known. Pipetting a known fraction of suspension to an evaporating dish and boiling off the water is all that is done beyond dispersing the soil sample in water.

For an accurate mechanical analysis of soil , the soil sample must be completely dispersed so that each particle settles individually rather than as part of a aggregated clump. Addition of Na^+ to the soil-water suspension forces exchange of Na^+ for adsorbed flocculating captions such as Ca^{2+} soil particles with a diffuse layer saturated with Na^+ tend to act as individual particles in suspension and settle at rates dependent on their radii.

1. Weigh out 20g (to nearest 0.01g) of soil and transfer to a shaker cup.
2. Fill with water to a depth of 10 cm and add 5 mL Na hexametaphosphate . Stir for 5 minutes.
3. Pour contents into a 500 mL graduated cylinder. Use a stream of water from a wash bottle to transfer soil remaining in cup. Bring volume to 500 mL.
4. Cover top of cylinder with parafilm. Put palm of hand over top, grasp bottom of cylinder and invert several times to suspend soil.
5. Set on bench top, begin timing, gently remove parafilm and take a 25 mL aliquote from the upper 10 cm of suspension at 48 s. A mark on the pipette at 10 cm from the tips serves as a good guide for depth.
6. Transfer aliquot to a weighed (record mass in Table 1) evaporating dish and put in oven at 105 C. Higher temperature than boiling is needed due to presence of solutes. Label evaporating dish " silt + clay" . Also, write your lab group number on the evaporating dish.

Since it takes 8 h for all silt size particles to settle 10 cm, a mechanical analysis by the pipette method cannot be completed within the time allowed for this lab. However, the steps in this procedure can be followed and approximate results obtained in shorter time.

7. Take the second 25 mL aliquot after only 40 min but from upper 5 cm of the suspension. Mark pipette 5 cm above tip.
8. Transfer aliquot to weighed , labelled evaporating dish and put in oven at 105 C.

   After 40 min, all silt greater than 0.005 mm diameter will have settled to below 5 cm. Thus, the second aliquot contains some silt (0.005 to 0.002 mm diameter) as well as clay.

9. To demonstrate flocculation , add 5 mL of $CaCl_2$ solution to the suspension after taking second aliquot. Cover the top of cylinder with parafilm., invert several times, then set on bench top. Observe what happens.

10. Dispose of suspension and soil into waste bucket , not down sink drain.

11. T the beginning of the next lab, remove evaporating dishes from oven, cool and weigh. Record the net weight of the first evaporating dish as combined silt and clay in 1/20 of the soil-water suspension. The net weight of the second is assumed to be 1/20 of the clay.

12. Calculate percentage of each of the separates as

% clay = (20 X mass of clay in aliquot / total mass of soil) X 100%

% Silt = (20 X [mass of silt + clay – mass of clay]/ total mass of soil) X 100%

% sand = 100% - (%silt + % clay)

The 20g sample of soil used, even though air-dry , contained adsorbed water from the atmosphere. Depending on fineness of texture and organic matter content., adsorbed water accounts for up to several percent of total air-dry weight of soil. You should use the oven dry mass of soil in the above calculations. Convert air-dry mass to oven –dry by

Oven –dry mass= air-dry mass/ (1.00 +[moisture % / 100%])

Your instructor will provide air-dry moisture %. Air –dry moisture % is determined by weighting an air-dry soil sample before and after drying at 105 C for 24 h.

13. Use the textural triangle to assign a textural class name.

B Examination of soil Separates

Sample of sand , silt and clay are on display. Examine each under a hand lens. The first 5 separates can be readily seen. The individual silt and clay particles cannot be seen by means of hand lens. Most of the clay particles are too fine to be visible under a light microscope.

Feel th dry samples. Note the sand has a gritty feel, the silt a floury feel, while clay feels rather harsh. These distinctions are important is estimating texture by feel. Quartz is the dominant mineral in sand but as the sand becomes finer, minerals other than quartz increases. Silt particles are similar to sand in irregular shape and mineralogy (mostly quartz and feldspars) but are much smaller. Silt may exhibit some plasticity due to adhering films of clay. When wet, clay is very plastic. The high surface area and plate-like structure of clay particles give clay its plasticity.

C Soil Texture by Feel

It is often necessary of soil scientists to determine soil texture in the field. Since a mechanical analysis is impractical, they must estimate texture by only feeling soil. Properly calibrated fingers are accurate to within a percent or two of a mechanical analysis.

Put about 10g of soil in palm

Add water drop wise to form a workable putty

Put ball of soil between thumb and forefinger and form ribbon of soil

No ribbon forms	<1 inch ribbon	1-2 inch ribbon	> 2 inch ribbon
Sand	sandy Loam	Sandy clay Loam	Sandy Clay
Loamy sand	silt Loam	Silty clay Loam	Silty Clay
	Loam	Clay Loam	Clay

-	-	-	-
Add more water	Add more water	Add more water	Add more water
-	-	-	-
Hand only wet	Gritty feel	Gritty feel	Gritty feel
Sand	Sandy Loam	Sandy clay Loam	sandy Clay
Or	or	or	or
Hand Soiled	Smooth feel	Smooth feel	Smooth feel
Loamy Sand	Silt Loam	Silty clay Loam	Silty clay
	Or	or	or
	Neither	Neither	Neither
	Loam	Clay Loam	Clay

Practice the above key with the different soils providd. The various soils grade into each other which often makes the decision as to texture difficult.

IV Worksheet and Questions

A Mechanical Analysis

Table 1

	Aliquot 1	Aliquot 2
Weight Dish + Dry Sample		
Weight Dish		
Weight Silt + Clay		
Weight Clay		

Calculations

Table 2

% Clay	% Silt	% Sand	Textural Class Name

B **Questions**

1. Using the textural triangle , determine the textural class of solids with mechanical analysis given by your instructor

	Soil A	**Soil B**	**Soil C**
% sand	---------	----------	----------
% Silt	----------	----------	-----------
% Clay	------------	------------	------------
Textural Class	-----------	----------	-----------

2. What is the relationship between particle size and surface area of a given weight of soil?

3. How does particle size influence soil fertility in general?

4. Can the texture of a soil be changed readily? Why or why not?

5. If you had not used the Na hexametaphosphate dispersing agent, how would your results have differed?

6. Considering that you took the second aliquot early, does this soil contain more or less clay than you determined? More or less Silt? Sand?

EXPERIMENT NO-6

LIQUID LIMIT

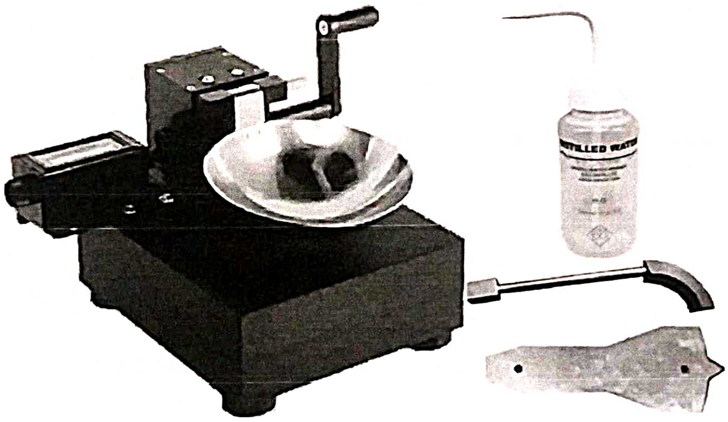
AIM

To determine the liquid limit of soil as per IS: 2720 (part 5)- 1985.

PRINCIPLE

The liquid limit of fine –grained soil is the water content at which soil behaves practically like a liquid, but has small shear strength. It's flow closes the groove in just 25 blows in Casagrande's liquid limit device.

APPARATUS



i) Casagrande's liquid limit device

ii) Groove tools of both standard and ASTM types

iii) Oven

iv) Evaporating dish

v) Spatula

vi) IS Sieve of size 425 µm

vii) Weighing balance , with 0.01g accuracy

viii) Wash bottle

ix) Air-tight and non- corodible container for determination of moisture content.

PREPARATION OF SAMPLE

i) Air-dry the soil sample and break the clods. Remove the oraganic matter tree roots, pieces of bark , etc.

ii) About 100g of the specimen passing through 425µm IS Sieve is mixed thoroughly with distilled water in the evaporating dish and left for 24 hrs for soaking.

PROCEDURE

I) Place a portion of the paste in the cup of the liquid limit device.

II) Level the mix so as to have a maximum depth of 1 cm

III) Draw the grooving tool through the sample along the symmetrical axis of the cup, holding the tool perpendicular to the cup.

IV) For normal fine grained soil: The casagrandes' tool is used to cut a groove 2mm wide at the bottom, 11mm wide at the top and 8mm deep.

V) For sandy soil: The ASTM tool is used to cut a groove 2mm wide at the bottom , 13.6 mm wide at the top and 10mm deep.

vi) After the soil pat has been cut by a proper grooving tool, the handle is rotated at the rate of about 2 revolutions per second and the no. Of blows counted, till the two parts of the soil sample come into contact for about 10mm length.

vii) Take about 10g of soil near the closed groove and determine its water content

viii) The soil of the cup is transferred to the dish containing the soil paste and mixed thoroughly after adding a little more water. Repeat the test.

ix) By altering the water content of the soil and repeating the foregoing operations, obtain at least 5 readings in the range of 15 to 35 blows. Don't mix dry soil to change its consistency.

x) Liquid limit is determined by plotting a flow curve on a semi-log graph, with no. Of blows as abscissa (log scale) and the water content as ordinate and drawing the best straight line through the plotted points.

xi) Water content corresponding to 25 blows , is the value of the liquid limit.

REPORTING OF RESULTS

Report the water content corresponding to 25 blows, read from the 'flow' as the liquid limit.

EXPERIMENT NO-7

PLASTIC LIMIT

AIM

To determine the plastic limit of soil as per IS: 2720 (part 5)-1985

PRINCIPLE

The plastic limit of fine –grained is the water content of the soil below which it ceases to be plastic. It begins to crumble when rolled into threads of 3mm dia.

APPARATUS

i) Porcelain evaporating dish about 120 mm dia.

ii) Spatula

iii) Container to determine moisture content

iv) Balance, with an accuracy of 0.01g

v) Oven

vi) Ground glass plate- 20cm X 15 cm

vii) Rod- 3mm dia, and about 10cm long

PREPARATION OF SAMPLE

Take out 30g of air-dried soil from a thoroughly mixed sample of the soil passing through 425µm IS Sieve. Mix the soil with distilled water in an evaporating dish and leave the soil mass for nurturing. This period may be up to 24 hrs.

PROCEDURE

i) Take about 8g of the soil and roll it with fingers on a glass plate. The rate of rolling should be between 80 to 90 strokes per minute to form a 3mm dia.

ii) If the dia. Of the threads can be reduced to less than 3mm, without any cracks appearing, it means that the water content is more than its plastic limit. Knead the soil to reduce the water content and roll it into a thread again.

iii) Repeat the process of alternate rolling and kneading until the thread crumbles.

iv) Collect and keep the pieces of crumbled soil thread in the container used to determine the moisture content.

v) Repeat the process at least twice mor with fresh samples of plastic soil each time.

REPORTING OF RESULTS

The plastic limit should be determined for at least three portions of the soil passing through 425µm IS sieve. The average water content to the nearest whole number should be reported.

EXPERIMENT NO-8

SHRINKAGE LIMIT LIST

OBJECTIVE

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

THEORY

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

NEED AND SCOPE

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

A shrinkage limit test should be performed on a soil.

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

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

AAPARATUS

1. Evaporating Dish. Porcelain , about 12cm diameter with flat bottom.
2. Spatula

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

PROCEDURE

Preparation of Soil paste

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

Use water content some where around the liquid limit.

Filling the shrinkage dish

3. Coat the inside of the shrinkage dish with a thin layer of Vaseline to prevent the soil sticking to the dish.

4. Fill the dish in three layers by placing approximately 1.3rd of the amount of wet soil with the help of Spatula. Tap the dish gently on a firm base until the soil flows over the edges and no apparent air bubbles exist. Repeat this process for 2nd and 3rd

   layers also till the dish is completely filled with the wet soil. Strike off the excess soil and make the top of the dish smooth. Wipe off al the soil adhering to the outside of the dish.

5. Weigh immediately , the dish with wet soil and record the weight.

6. Air-dry the wet soil cake for 6 to 8 hours, until the colour of the pat turns from dark to light. Then oven-dry the to constant weight at 105°C to 110°C say about 12 to 16 hrs.

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

8. Determine the weight of the empty dish and record.

9. Determine the volume of shrinkage dish which is evidently equal to volume of the wet soil as follows. Place the shrinkage dish in an evaporating dish and fill the dish with mercury till it overflows slightly. Press it with plain glass plate firmly on its top to remove excess mercury. Pour the mercury from the shrinkage dish into a measuring jar and find the volume of the shrinkage dish directly. Record this volume as the volume of the wet soil pat.

Volume of the Dry Soil pat

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

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

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

CALCULATiON

EXPERIMENT NO-9

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

Aim:

To determine the permeability of soil by content –head method.

The rate of flow under laminar flow conditions through a unit cross sectional are of porous medium under unit hydraulic gradient is defined as coefficient of permeability . Water flowing through soil experts considerable seepage force which has direct effect on the safety of hydraulic structures. The rate of settlement of compressible clay layer under load depends on its permeability . The quantity of water escaping through and beneath the earthen dam depends on the permeability of the embankments and its foundations respectively. The rate of discharge through wells and excavated foundation pits depends on the coefficient of permeability of the soils. Shear strength of soils also depends indirectly on permeability of soil, as dissipation of pore pressure is controlled by its permeability.

Specifications:

IS 2720-17 (1986): Methods of test for soils , part 17. This test is used to determine the permeability of granular soils like sands and gravels containing little or no silt.

Equipments Required:

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

6. Constant head tank: A suitable water reservoir capable of supplying water to the permeameter under constant head.
7. Graduated glass cylinder to receive the discharge.
8. Stop watch to note the time.
9. A meter scale to measure the head differences and length of specimen.

Theory

The knowledge of this property is much useful in solving problems involving yield of water bearing strata, seepage through earthen dams, stability of earth dams, and embankments of canal bank affected seepage, settlement etc. Permeability of soil can be determined from Darcy's Law. The equation to determine the pemeability of soil using constant head permeability test is given by:

K= (QxL)/(Axhxt) Where, k = coefficient of permeability

Q= Volume of water collected in time t

H= Head causing flow

A= Cross sectional area of sample

L=Length of sample

- A constant head permeameter shown schematically in the figure.
- For a typical setup the following dimensions are used

i. Internal diameter of the mould = 100mm

ii. Effective height of the mould= 127.3 mm

iii. Detachable collar : 100 mm diameter and 60 mm height.

iv. Drainage base, having a porousdisc.

v. Weighing balance , and other accessories.

Procedure:

a) A constant –head test assembly is as given in below figure.

b) Select a representative soil mass of about 2.5 kg properly mixed.

c) Fill the soil into the mould and compact it to the required dry density by making use of a suitable compacting device.

d) Set the assembly as shown in figure after saturating the porous stones.

e) The water supply is properly adjusted to maintain constant head.

f) Open the valve and saturate the sample by allowing water to flow through for a sufficiently long time to remove all air-bubbles.

g) When the whole setup is ready for the test, open the valve, allow the water to flow through the sample collect water in a graduated jar starting simultaneously a stopwatch. Note the time to collect a certain quantity of water Q.

h) Repeat the test three times and determine the average of Q for the same time interval.

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

j) Calculate k by making use of equation.

Observation:

Length of soil sample L= __________ cm

Diameter of soil sample D=__________cm

Area of soil sample A=______________cm

Constant head h= ________________cm

Sl. no	Quantity of water Q=______ml	Time t= _____sec	K=(QL)/(Ath) (cm/sec)
1			
2			
3			
4			

Result:

Coefficient of permeability of soil k=____________________cm/sec

Conclusion

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

EXPERIMENT NO-10

FALLING HEAD PERMEABILITY TEST FOR FINE GRAINED SOILS

AIM

To determine the coefficient of permeability of a given soil sample by variable head permeability test. The passage of water through porous material is called seepage. A material with continuous voids is called a permeable material. Hence permeability is a property of a porous material which permits passage of fluids through inter connecting conditions. Hence permeability is defined as the rate of flow of water under the laminar conditions through a unit cross-sectional area perpendicular to the direction of flow through a porous medium under unit hydraulic gradient and under standard temperature conditions.

Specifications:

IS 2720-17 (1986): Methods of test for soils, part 17. This test is used for fine grained soils with intermediate and low permeability such as silts and clays. This testing method can be applied to an undisturbed sample.

Equipments Required:

All the accessories are the same as the constant head test and the following:

1. Graduated glass stand pipe and the clamp
2. Supporting frame for the stand pipe and the clamp

Theory

The falling head permeability test involves flow of water through a relatively short soil sample connected to a standpipe which provides the water head and also allows measuring the volume of water passing through the sample. The diameter of the standpipe depends on the permeability of th tested soil. The test is carried out in falling head permeability cell.

Before starting the flow measurements, the soil sample is saturated and the standpipes are filled with de-aired water to a given level. The test then starts by allowing water to flow through the sample until the water in the stand pipe reaches a given lower limit. The time required for the water in the stand pipe to drop from the upper to the lower level is recorded. Often , the standpipe is refilled and the test is repeated for couple of times. The recorded time should be the same for each test within an allowable variation of about 10% (Head 1982) otherwise the test is failed.

The below equation can be used:

$$K = ((2.3 x a x L)/(A x (t2-t1))) x \log 10(h1/h2)$$

Where , L = length of soil sample column

A=sample cross-section

A= the cross-section of the standpipe

(t2-t1)= the recorded time for the water column to flow through the sample

H1 and h2 = the upper and lower water level in the standpipe measured using the same water head reference.

Procedure:

a) Open the valves in the standpipe and the bottom outlet. Ensure that the soil sample is fully saturated without any entrapping of air bubble before starting the test.

b) Fill the standpipe with water keeping the valves V1 and V2 open and allow the water to flow out through the outlet pipe for some time and then close the valves.

c) Select in advance the heights h1 and h2 for the water to fall and determine the height h1h2 and mark this height on the stand pipe.

d) Open the valves and fill the standpipe with water up to height h1 and start h1h2 to h2. These two time intervals will be equal if a steady flow condition has been established.

e) Repeat the step (e) at least after changing the heights h1 and h2.

f) Stop the test and disconnect all the parts.

g) Take a small quantity of the sample for water content determination.

Tables

Observations

Length of Soil sample L	= cm
Diameter of soil sample D	= cm
Area of soil sample A	= cm
Area of stand pipe a	= cm

Computation of coefficient of permeability

Sl. No	Initial Head (h1) cm	Final Head (h2) cm	Time t in seconds	K=((20.xaxL)/(Axt))xlog 10 (h1/h2)
1				
2				
3				
4				

Results

Coefficient of permeability of soil k=________________cm/sec

Conclusion

As per the value of coefficient of permeability (________________), type of soil from the above table is

______________.

EXPERIMENT NO-11

MAXIMUM DRY DENSITY AND OPTIMUM MOISTURE CONTENT

AIM

To determine the maximum dry density and the optimum moisture content of soil using heavy compaction as per IS: 2720 (part 8)-1983

APPARATUS

i. Cylindrical metal mould- it should be either of 100mm dia. And 1000cc volume or 150mm dia. And 2250cc volume and should confirm to : 10074-1982

ii. Balances-one of 10kg capacity , sensitive to 1g and the other of 200g capacity, sensitive to 0.01g

iii. Oven-thermostatically controlled with an interior of non-corroding material to maintain temperature between 105 and 110°C.

iv. Steel straightedge -30cm long

v. IS sieves of sizes- 4.75mm, 19 mm, 37.5 mm

PREPARATION OF SAMPLE

A representative portion of air-dried soil material, large enough to provide about 6kg of material passing through a 19mm IS sieve (for soils not susceptible to crushing during compaction) or about 15kg of material passing through a 19mm IS sieve (for soils susceptible to crushing during compaction). Should be taken . The portion should be sieved through a 19mm IS sieve and the coarse fraction rejected after its proportion of the total sample has been recorded.

Aggregations of particles should be broken down so that if the sample was sieved through a 4.75mm IS sieve, ony separated individual particles would be retained.

PROCEDURE

A) Soil not susceptible to crushing during compaction-

i. A 5 kg sample of air –dried soil passing through the 19mm IS sieve should be taken. The sample should be mixed thoroughly with a suitable amount of water depending on the soil type(for sandy and gravelly soil- 3 to 5% and for cohesive soil- 12 to 16% below the plastic limit). The soil sample should be stored in a sealed container for a minimum period of 16hrs.

ii. The mould of 1000cc capacity with base plate attached, should be weighed to the nearest 1g (W1). The mould should be placed on a solid base, such as a concrete floor or plinth and the moist soil should be compacted into the mould, with the extension attached, in five layers of approximately equal mass, each layer being given 25 blows from the 4.9kg rammer dropped from a height of 450 mm above the soil. The blows should be distributed uniformly over the surface of each layer. The amount of soil used should be sufficient to fill the mould, leaving not more than about 6mm to be struck off when the extension is removed. The extension should be removed and the compacted soil should be levelled off carefully to the top of the mould by means of the straight edge. The mould and soil should then be weighed to the nearest gram (W2).

iii. The compacted soil specimen should be removed from the mould and placed onto the mixing tray. The water content (w) of a representative sample of the specimen should be determined .

iv. The remaining soil specimen should be broken up, rubbed through 19mm IS sieve and then mixed with the remaining original sample. Suitable increments of water should be added successively and mixed into the sample, and the above operations i.e. should be repeated for each increment of water added. The total number of determinations made should be such that the optimum moisture content at which the maximum dry density occurs, lies within that range.

B) Soil susceptible to crushing during compaction-

Five or more 2.5 kg samples of air-dried passing through the 19mm IS sieve, should be taken. The samples should each be mixed thoroughly with different amounts of water and stored in a sealed container as mentioned above. Follow the operations above.

c) Compaction in large size mould

For compacting soil containing coarse material up to 37.5mm size, the 2250cc mould should be used. A sample weighing about 30kg and passing through the 37.5mm IS sieve is used for the test. Soil is compacted in five layers, each layer being given 55 blows of the 4.9kg rammer. The rest of the procedure is the same as in para A) or B) above.

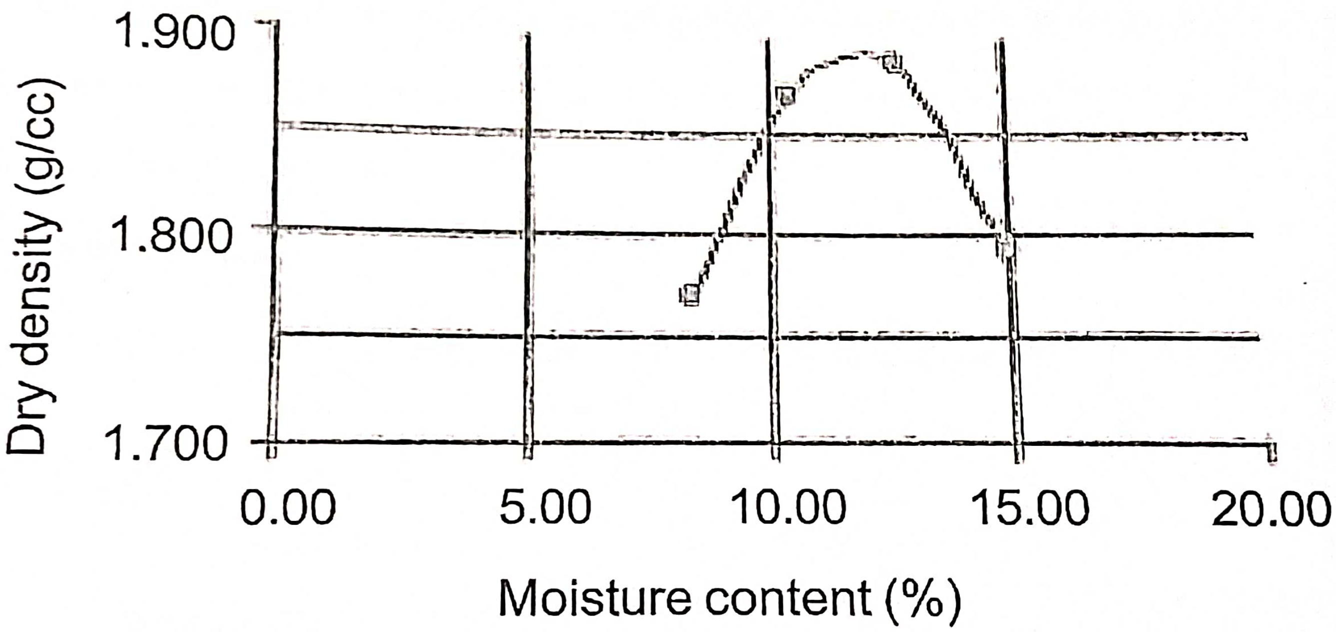
REPORTING OF RESULTS

Bulk density ϒ in g/cc of each compacted specimen should be calculated from the equation, ϒ= W2-W1/V

Where , V = Volume in cc of the mould.

The dry density $ϒ_d$ in g/cc= $\frac{100\ ϒ}{100 + w}$

The dry densities , $ϒ_d$ obtained in a series of determinations should be plotted against the corresponding moisture contents, w. A smooth curve should be drawn through the resulting points and the position of the maximum on the curve should be determined. A sample graph is shown below.



The dry density in g/cc corresponding to the maximum point on the moisture content/dry density curve should be reported as the maximum dry density to the nearest 0.01.

The percentage moisture content corresponding to the maximum dry on the moisture content/dry density curve should be reported as the optimum moisture content and quoted to the nearest 0.2 for values below 50percent, to the nearest 0.5 for values from 5 to 10 percent and to the nearest whole number for values exceeding exceeding 10 percent.

EXPERIMENT NO-12

TRIAXIAL SHEAR TEST

1. Objective

The tri-axial shear test is most versatile of all the shear test testing methods for getting shear strength of soil i.e. Cohesion (c) and Angle of internal Friction (ϕ) , though it is bit complicated. This test can measure the total as well as effective stress parameters both. These two parameters are required for design of slopes , calculation of bearing capacity of any strata, Calculation of consolidation parameters and in many other analysis. This test can be conducted on any type of soil, drainage conditions can be controlled, pore water pressure measurements can be made accurately and volume changes can be measured. In this test , the failure plane is not forced , the stress distribution of failure plane is fairly uniform and specimen can fall on any weak plane or can simply bulge.

2. Apparatus Required

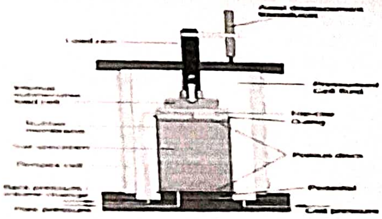


Fig. 1: Triaxial Shear Test Apparatus

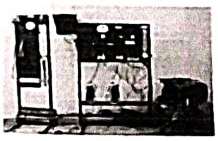


Fig. 2: Triaxial Shear Test Setup

Fig. 3: 3.8 cm (1.5 inch) internal diameter 12.5 cm (5 inches) long sample tubes.

Fig. 4: Rubber Ring

Fig. 5: Open ended cylindrical section

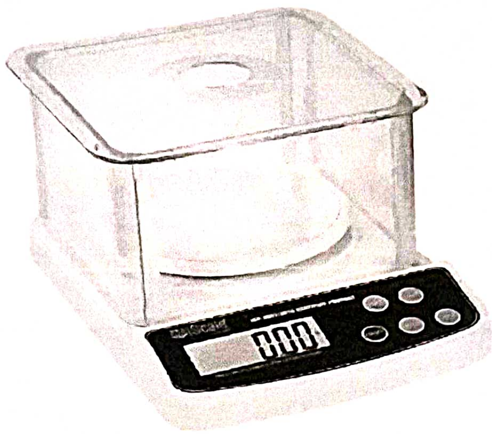


Fig.6: Weighing balance

3. **Reference**
   1. IS 2720 (part 11): 1993 Determine of the shear strength parameters of a specimen tested in unconsolidated ingrained triaxial compression without the measurement of pore water pressure (first revision). Reaffirmed –Dec 2016.
   2. IS 2720(part 12): 1981 Determination of shear strength parameters of soil from consolidated untrained triaxial compression test with measurement of pore water pressure (first revision). Reaffirmed –Dec2016

4) Procedure

Triaxial Test on Cohesive Soil:

Consolidated undrained test:

vi. A de-aired, coarse porous disc or stone is placed on the top of the pedestal in the triaxial test apparatus. A filter paper disc is kept over the porous stone. The specimen of the cohesive soil is then placed over the filter paper disc. The usual size of the specimen is about 37.5mm diameter and 75.0mm height. A porous stone is also placed on the top of the specimen. De-aired vertical filter strips are placed at regular spacing around the entire periphery such that these touch both the porous stones. The sample in then enclosed in a rubber membrane, which is slided over the specimen with the help of a membrane stretcher. The membrane is sealed to the specimen with o-rings.

vii. The triaxial cell is placed over the base and fixed to it by tightening the nuts. The cell is then filled with water by connecting it to the pressure supply. Some space in the top portion of the cell is filled by injecting oil through the oil valve. When excess oil begins to spill out through the air vent valve, both the valves (oil valve and air-vent valve) are closed. Pressure is applied to the water filled in the cell by connecting it to the mercury –pot system. As soon as the pressure acts on the specimen, it starts consolidating . The specimen is connected to the burette through pressure connections for measurement of volume changes. The consolidation is complete when there is no more volume change.

viii. When the consolidation is complete, the specimen is ready for being sheared. The drainage valve is closed. The pore water pressure measurement device is attached to the specimen through the provided in the loading frame, the ram is pushed into the cell but not allowed to touch the loading cap. The loading machine is then run at the selected speed. The proving ring records the force due to friction and the upward thrust acting on the ram. The machine is stopped, and with the manual control, the ram is pushed further into the cell bringing it in contact with the loading cap. The dial gauge for the measuring axial deformation of the specimen is set to zero.

ix. The sample is sheared by applying the deviator stress by the loading machine. The proving ring readings are generally taken corresponding to axial strains of 1/3%, 2/3%, 1%, 2%, 3%, 4%, 5%, until failure or 20% axial strain.

x. Upon completion of the test, the loading is shut off. Using the manual control, all additional axial stress is removed. The cell pressure is then reduced to zero and the cell is emptied. The triaxial cell is unscrewed and removed from the base. O-rings are taken out, and the membrane is removed.

The specimen is then recovered after removing the loading cap and the top porous stone. The filter paper strips are peeled off. The post –shear mass and length are determined. The water content of the specimen is also found.

Unconsolidated Undrained test:

- The procedure is similar to that for a consolidated –undrained test, with one basic difference that the specimen is not allowed to consolidate in the first stage. The drainage valve during the test is kept closed. However, the specimen can be connected to the pore-water pressure measurement device if required.
- Shearing of the specimen is started just after the application of the cell pressure. The second stage is exactly the same as in the consolidated –undrained test described above.

Consolidated Drained test:

- The procedure is similar to that for a consolidated –undrained test, with one basic difference that the specimen is sheared slowly in the second stage. After the consolidation of the specimen in the first stage, the drainage valve is not closed. It remains connected throughout the test. The volume changes during the shearing stage are measured with the help of the burette. As the permeability of cohesive soils is very low, it takes 4-5 days for the consolidated drained test.

Triaxial tests on cohessionless soils:

- Triaxial tests on specimens of cohesionless soils can be conducted using the procedure as described for cohesive soils. As the samples of cohesionless soils cannot stand of their own, a special procedure is used for preparation of the sample as described below.
- A metal former , which is a split mould of about 38.5mm internal diameter, is used for the preparation of the sample. A coarse porous stone is placed on the top of the pedestal of the triaxial base and the pressure connection is attached to a burette. One end of a membrane is sealed to the pedestal by o-

rings. The metal former is clamped to the base. The upper metal ring of the former is kept inside the top end rubber membrane and is held with the help of clamp before placing the funnel and the rubber bung in position.

- The membrane and the funnel are filled with de-aired water. The cohesionless soil which is to be tested is saturated by mixing it with enough water in a beaker. The mixture is boiled to remove the entrapped air. The saturated soil is deposited in the funnel, with a stopper imposition, in the required quantity. The glass rod is then removed and the sample boils up by a continuous rapid flow of saturated soil in the former. The funnel is then removed. The sample may be compacted if required. The surface of the sample is levelled and a porous stone is placed on its top. The loading cap is placed gently on the top porous stone. O-rings are fixed over the top of the rubber membrane.
- A small negative pressure is applied to the sample by lowering the burette. The negative pressure gives rigidity to the sample and it can stand without any lateral support. For sample of 37.5mm diameter, a negative pressure of 20cm of water (or 2 kN/m2) is sufficient. As soon as the negative the upper porous stone should be slightly smaller than that of the specimen so that it can go inside when the sample shortness; otherwise, a neck is formed.
- The split mould is then removed and the diameter and the height of the sample are measured. The thickness of the membrane is deducted from the total diameter to get the net diameter of the sample. The cell is then placed over the base and clamped to the base . It is then filled with water.
- The rest of the procedure is the same as for cohesive soils.

Computation of Various Parameters

Post-consolidation Dimensions:

In consolidated-drained and consolidated-undrained tests, the consolidation of the specimen takes place during the first stage. As the volume of the specimen decreases, its post-consolidation dimensions are different from the initial dimensions. The post consolidation dimensions can be determined approximately assuming that the sample remains cylindrical and it behaves isotropically. Let Li, Di and Vi be the length, diameter and the volume of the specimen before consolidation . Let L0, D0 and V0 be the corresponding quantities after consolidation.

Volumetric change, $\Delta vi = Vi - V0$

Volumetric change is measured with the help of burette.

Volumetric strain, $£v = \Delta vi/Vi$

For isotropic consolidation , the volumetric strain is three times the linear strain (£1), thus:

$£1 = £v/3$

$Lo = Li - \Delta li = Li - Li x £1$

$Lo = Li(1- £1) = Li (1- £v/3)$

Similarly, $Do = Di (1- £v/3)$

The post consolidation diameter Do can be computed after Lo has been determined from the relation:

Stresses:

Deviator stress The deviator stress ( ) acting on the specimen when the axial load applied by the machine is P can be obtained as:

The deviator stress ( ) is equal to ( )

It may be noted that the load indicated by the proving ring is slightly more than Because of friction on the ram and the upward thrust on the ram due to pressure of the wall in the cell. The correction can be determined separately.

A more convenient procedure is to lift the ram above the specimen when the cell pressure has been applied. The machine is started keeping the strain rate the same as to be used in the actual test. The proving ring records the load . To account for correction, the dial gauge on the proving ring is set to zero to indicator zero load. This automatically compensates the ram friction and the upward thrust be equal to the load P applied to the specimen.

The minor principal stress() is equal to the cell pressure (). The major principal stress() is equal to the sum of the cell pressure and the deviator actress.

The deviator stress at failure () is known as the compressive strength of the soil.

Presentation of Results of Tri-Axial Tests

Stress-strain curves

Drained Test: Shows the stress –strain curve for a drained test. The Y-axis shows the deviator stress () and the X-axis strain (). For dense sand (and over –consolidated clay), the deviator stress reaches a peak value and then it decreases and becomes almost constant, equal to the ultimate stress, at large strains. For loose sand (and normally consolidated clay), the deviator stress increases gradually till the ultimate stress is reached.

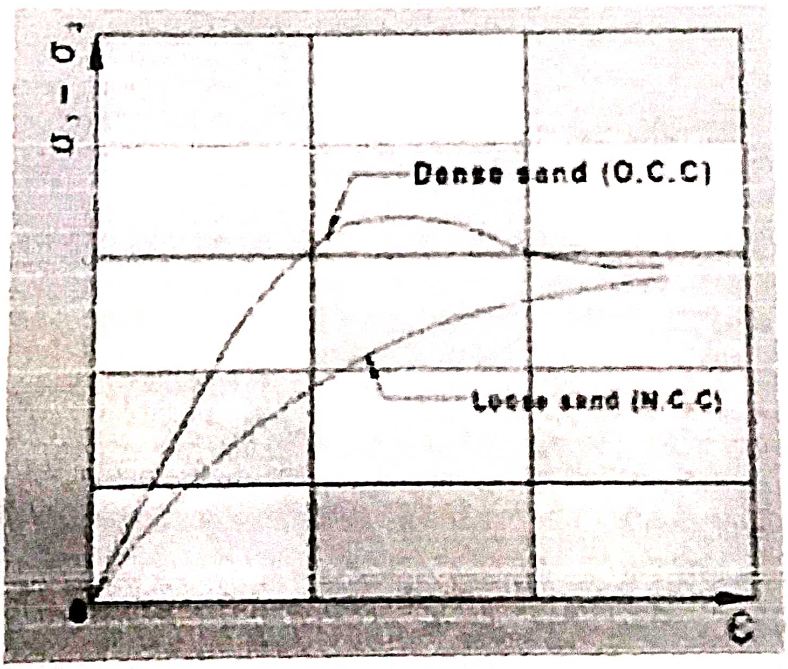


Fig.7: Stress – Strain Curve

The volumetric strain is shown in fig . In dense sand(and over-consolidated clay), there is a decrease in the volume at low strains, there is an increase in the volume . In loose sand (and normally consolidated clay), the volume decrease at all strains. (For some loose sands, there is a slight tendency to increase in the volume at large strains).

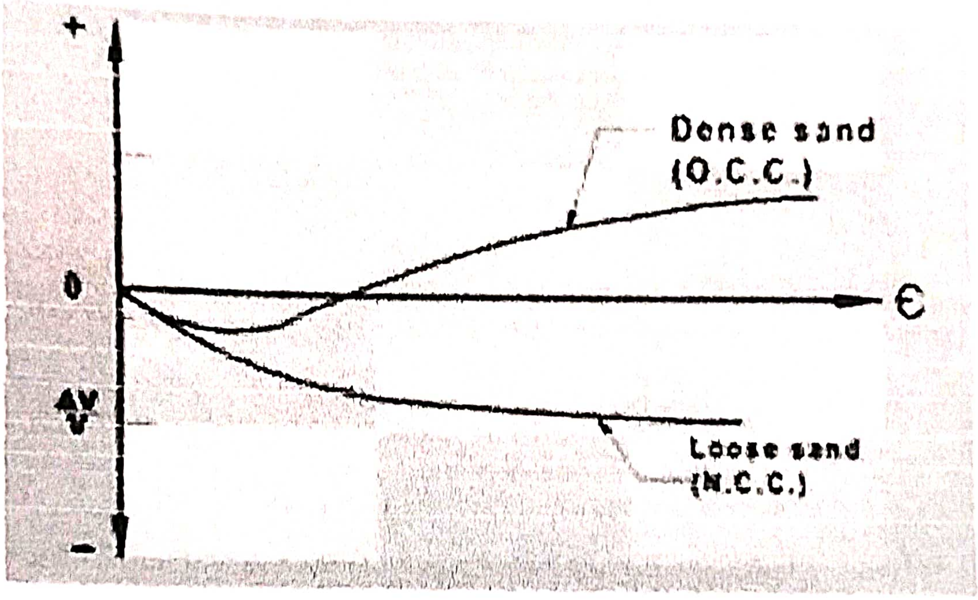


Fig.8: Volumetric Strain

Consolidated –undrained test: fig shows the stress –strain curve for a consolidated –undrained test. The shape of the curves is similar to that obtained in a consolidated-drained test. In a consolidated-undrained test, there is an increase in the pore water pressure throughout for loose sand (and normally consolidated clay), as shown in fig. However, in the case of dense sands (and over consolidated clay), the pore water pressure increases at low strains but at large strains it becomes negative (below atmospheric pressure).

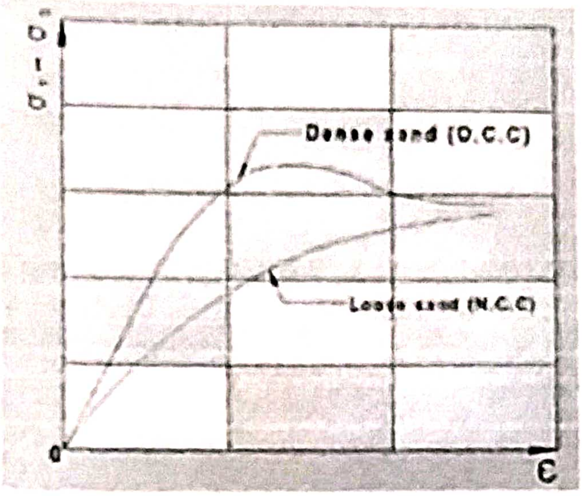
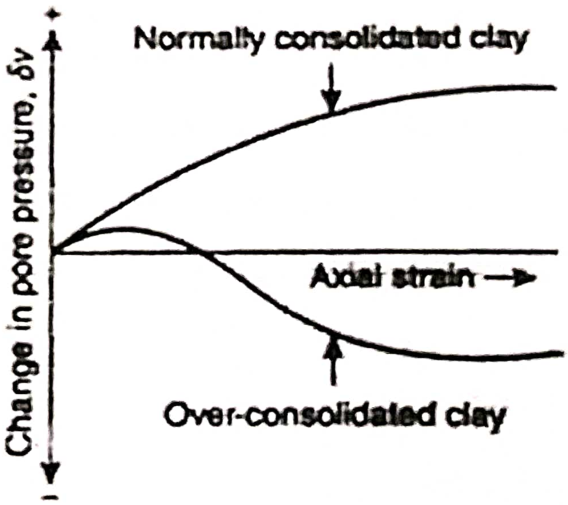


Fig.9: Stress – Strain Curve



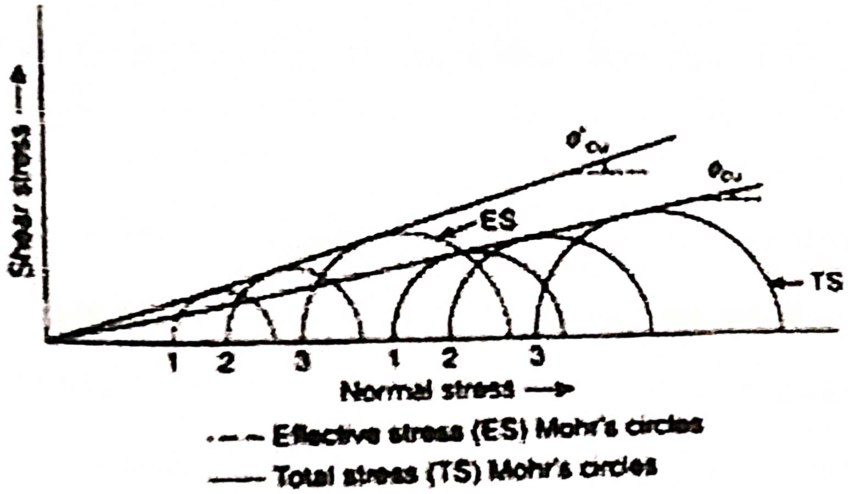
Mohr Envelopes: For drawing the failure envelopes, it is necessary to test at least three samples at three different cell pressures in the stress range of interest. For dense sands and over-consolidated clays, the failure envelope can be drawn either for the peak stress or for the ultimate stress, which is usually taken at 20%

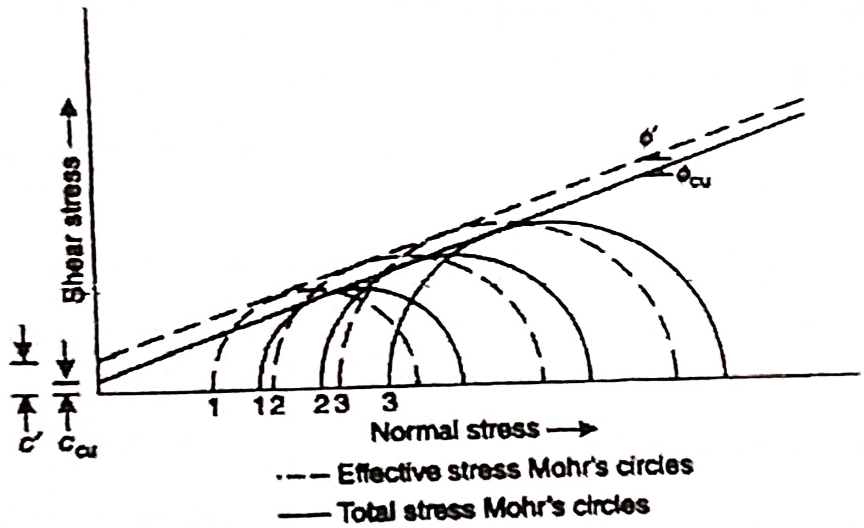
strain. Further, the failure envelope can be drawn either in terms of effective stresses or in terms of total stress. Of course, the two envelopes will give different values of strength parameter (c and ø)

(i) Effective Stresses:

Fig shows the failure envelope for a normally consolidated clay in terms of effective stresses obtained from a consolidated drained test. The failure envelope has an angle of **shearing** resistance of ø and passes through origin. First the mohr circles for the three tests are drawn in terms of effective stresses corresponding to failure conditions. Then the best common tangent is drawn to three circles. The common tangent is the failure envelope. As each circle represents a failure, there must be at least one point on it which gives the stresses satisfying the failure criterion. Obviously, the common tangent joins all such points of the three circles. Thus for normally consolidated clays, shear strength is:

Fig shows the failure envelope for over-consolidated clay in terms of effective stresses. The failure envelope is slightly curved in the initial portion., but, for convenience, it is approximated as a straight line. The failure envelope has an intercept c' on the Y-axis, the angle of shearing resistance ø'. In the case of over-consolidated clays, shear strength is:





The failure envelops in terms of effective stresses can also be drawn from the result of a consolidated –undrained test (CU test) when the poue water pressure measurements are also taken. The shear strength parameter c' and ø' obtained from the consolidated –undrained tests and that from consolidated-drained test ar approximately equal. Drained tests on dense sands and over-consolidated clays give slightly higher values of ø' due to extra work required during dilation (increase in volume), but the difference is small, and therefore, usually neglected.

(ii) **Total Stresses:**

The failure envelope in terms of total stresses can be drawn from the test results of a consolidated –undrained test.

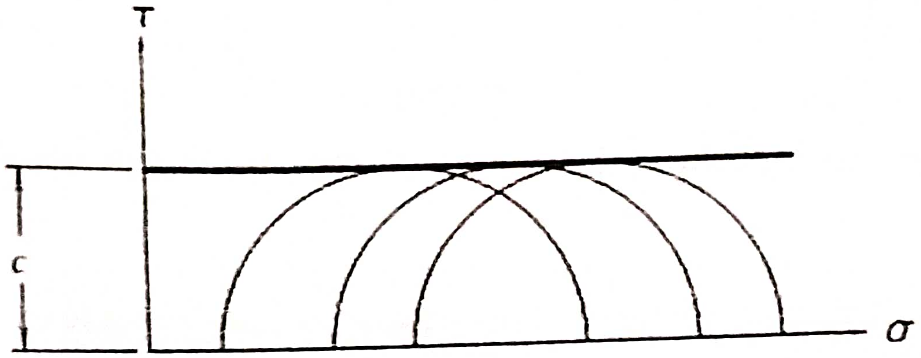
The failure envelopes are similar in shape to that in terms of effective stresses but the values of the strength parameters are quite different. Fig. Shows the failure envelopes for the effective stresses and also for total stresses for normally consolidated clay. The angle of shearing resistance in terms of total stresses (øcu) is much smaller than the angle (ø'). In the case of normally consolidated clays, shear strength is:

Shows the failure envelope for an over consolidated clay in terms of total stresses. The angle of shearing resistance (øcu) is much smaller than the angle (ø') obtained in terms of effective stresses. In the case of over consoliodated clays, shear strength is:

The angle of shearing resistance øcu obtained from the total stress envelops is also known as apparent angle of shearing resistance.

Fig shows the failure envelope in terms of total stress obtained from an unconsolidated-undrained test on normally consolidated clay. The failure envelope is horizontal (ø=0) and has a cohesion intercept of cu. In this case, Shear strength is S=cu. The failure envelope for over-consolidated clay is also horizontal, but the value of cu will be more , depending upon the degree of over-consolidation.

For an unconsolidated –undrained test, the failure envelope cannot be drawn in terms of effective stresses. In all the tests conducted at different confining pressures, the effective stress remains the same. This is due to the fact that an increase in confining pressure results in an equal increase in pore water for a saturated soil under undrained conditions. Thus only one Mohr circle in terms of effective stresses is obtained from all the three tests. It may be noted that the deviator stress at failure is the same for all specimens.



EXPERIMENT NO-13

CALIFORNIA BEARING RATIO TEST

1. **Objective**

CBR is the ratio expressed in percentage of force per unit area required to penetrate a soil mass with a standard circular plunger of 50mm diameter at the rate of 1.25 mm/min to that required for corresponding penetration in a standard material. The ratio is usually determined for penetration of 2.5 and 5,mm. When the ratio at 5mm is consistently higher than that at 2.5mm , the ratio at 5 mm is used.

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

Penetration of plunger(mm)	Standard Load (kg)
2.5	1370
5.0	2055

Standard Load values at penetration

For Railway Formation purpose , the test is performed on remoulded specimens which are compacted dynamically.

The methodology covers the laboratory method for the determination of C.B.R. of remoulded/ Compacted soil specimens in soaked state.

2. Apparatus Required

CBR Test Apparatus

Consisting of Loading machine with capacity of at least 5000 kg and equipped with a movable head or base which enables plunger of 50mm dia. To penetrate into the specimen at a rate of 1.25 mm/minute.

Inside dia. 150mm and height 175mm with a detachable perforated base plate of 235mm dia. And 10mm thickness. Net capacity-2250 ml; conforming to IS-9669:1980 (Reaffirmed-2016).

Collar

A detachable extension collar of 60 mm height.

Spacer Disc

148 mm in diameter and 47.7 mm in height along with handle.

Weights

One annular metal weight and several slotted weights weighing 2.5 kg each, 147 mm in diameter, with a central hole 53 mm in diameter.

Compaction Rammer

Weight -4.89 kg with a drop 450mm.

3. **Reference**

IS 2720(part 16): 1987 Methods of test for soils: Laboratory determination of CBR (second revision).Reaffirmed-Dec2016

RDSO report No. RDSO/2009/GE: G-0014- Guidelines and specification for design of Formation for Heavy Axle Load.

4. **Procedure**

Preparation of Test Specimen:

1. Remoulded specimen: The test material should pass 19mm IS sieve and retained on 4.75 mm IS sieve. The dry density for a remoulding shall be either the field density or the value of the maximum dry

density estimated by the compaction test (Heavy compaction Test as per IS 2720(part-8)- 1983, for Railway formation). The water content used for compaction shall be the optimum water content or the field moisture as the case may be.

2. Dynamic compaction: A representative sample of the soil weighing approximately 4.5 kg or more for fine grained soil and 5.5 kg or more for granular soil shall be taken and mixed thoroughly with water. If the soil is to be compacted to the maximum dry density at the optimum moisture content, the exact mass of the soil required shall be taken and the necessary quantity of water added so that the water content of the soil sample is equal to the determined optimum moisture content.
3. Fix the extension collar and the base plate to the mould. Insert the spacer disc over the base. Place the filter paper on the top of the spacer disc.
4. Apply Lubricating oil to the inner side of the mould. Compact the mix soil in the mould using heavy compaction. i.e. compact the soil in 5 layers with 55 blows to each layer by the 4.89 kg rammer.
5. Remove the extension collar and trim the compacted soil carefully at the level of top of mould, by means of a straight edge. Any holes developed on the surface of the compacted soil by removal of the coarse material, shall be patched with the smaller size material. Remove the perforated base plate, Spacer disc and filter paper on the perforated base plate, invert the mould and compacted soil and clamp the perforated base plate to the mould with the compacted soil in contact with the filter paper.
6. Place a filter paper over the specimen and place perforated plate on the compacted soil specimen in the mould. Put annular weights to produce a surcharge equal to weight of base material and pavement, to the nearest 2.5kg.
7. Immerse the mould assembly and weights in a tank of water and soak it for 96 hours. Mount the tripod for expansion measuring device on the edge of the mould and record initial dial gauge reading. Note

down the readings every day against time of reading. A constant water level shall be maintained in the tank throughout the period.

8. At the end of soaking period, note down the final reading of the dial gauge and take the mould out of water tank.

9. Remove the free water collected in the mould and allow the specimen to drain for 15 minutes. Remove the perforated plate and the top filter paper. Weigh the soaked soil and record the weight.

Procedure For Penetration Test

1. Place the mould assembly with test specimen on the lower plate of penetration testing machine. To prevent upheaval of soil into the hole of the surcharge weights, 2.5 kg annular weight shall be placed on the soil surface prior to seating the penetration plunger after which the remainder of the surcharge weights shall be placed.
2. Seat the penetration piston at the centre of the specimen with the smallest possible load, but in no case in excess of 4 kg so that full contact of the piston on the sample is established.
3. Set the load and deformation gauges to read zero. Apply the load on the piston so that the penetration rate is about 1.25 mm/min.
4. Record the load readings at penetrations of 0.5,1.0,1.5,2.0,2.5,4.0,5.0,7.5,10, and 12.5mm.
5. Raise the plunger and detach the mould from the loading equipment. Take about 20 to 50g of soil from the top 30 mm layer and determine the moisture content.

5) Observation and Recording

Penetration (mm)	Applied Load(kg)
0.50	
1.00	
1.50	
2.00	
2.50	
4.00	
5.00	
7.50	
10.00	
12.50	

Recordings during CBR Test

5) Calculation

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

$$C.B.R. = (P_T/P_S) \times 100$$

Where PT = Corrected tst load corresponding to the chosen penetration from the load penetration curve.

PS = Standard load for the same penetration taken from the table above.

2) C.B.R. of specimen at 2.5 mm penetration =

3) C.B.R. of specimen at 5.0 mm penetration =

4) The C.B.R. values are usually calculated for penetration of 2.5 mm and 5 mm. Generally the C.B.R. value at 2.5 mm will be greater than at 5 mm and in such a case / the former shall be taken as C.B.R. for design purpose . If C.B.R. for 5 mm exceeds that for 2.5 mm, the test should be repeated. If identical results follow, the C.B.R. corresponding to 5 mm penetration should be taken for design.

7) Graph

Draw graph between Load versus Penetration.