GOVERNMENT OF GUJARAT

SHANTILAL SHAH ENGINEERING COLLEGE

APPLIED MECHANICS DEPARTMENT

Geotechnical Engineering (3130606)

3rd Semester (BE Civil)

Laboratory Manual

Name : ______________________________

Enrollment No : ______________________________

Semester : ______________________________

Branch : ______________________________

VISION

To be a leading program by providing excellent civil engineers capable of fulfilling the needs of industry and society.

MISSION

1. To offer an excellent academic environment to educate aspiring civil engineers.
2. To impart ethics and core values in civil engineering.
3. To Provide good infrastructure and industry linkage.

GOVERNMENT OF GUJARAT

SHANTILAL SHAH ENGINEERING COLLEGE, BHAVNAGAR

Certificate

This is to certify that

Shri/Kum.………………………......................................

Enrollment No. ……………….. of B.E. Semester……of

Branch……………………………………………………. has

satisfactorily completed the laboratory work in

***Geotechnical Engineering (3130606)**.*

Date of Submission: ……………………….

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Lab-in-charge Head of Department

GOVERNMENT OF GUJARAT

SHANTILAL SHAH ENGINEERING COLLEGE, BHAVNAGAR

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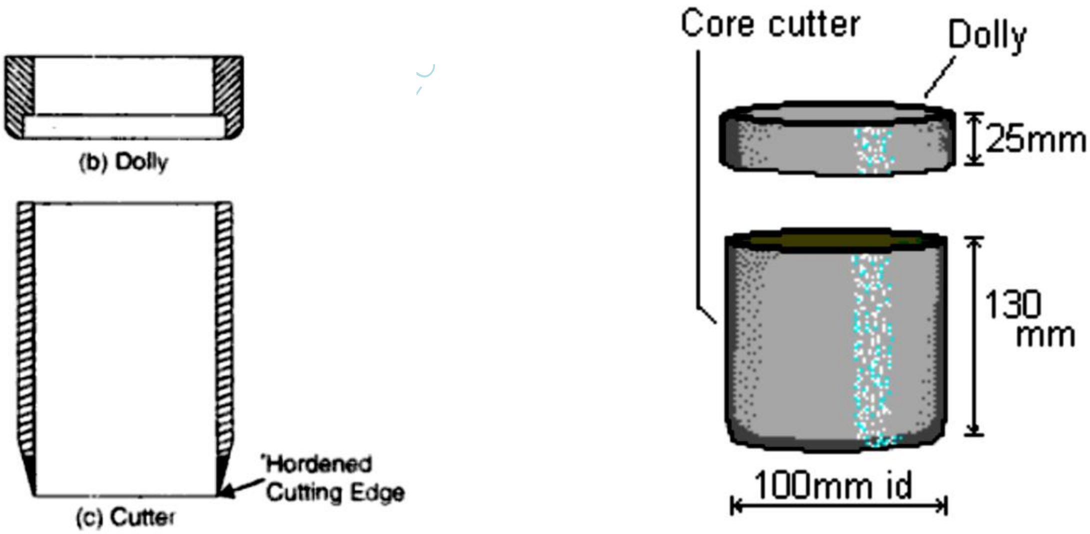
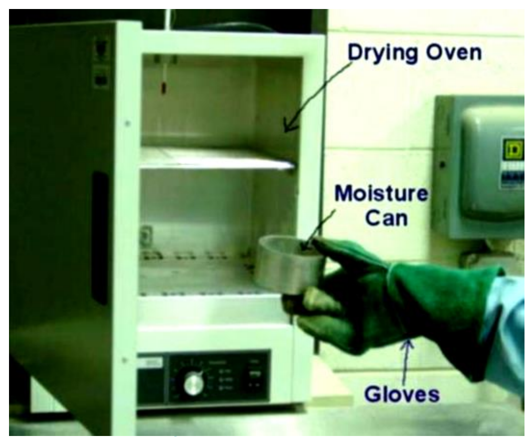


Figure1.1 Core Cutter

Balance



Hot Air Oven

Date: / /

EXPERIMENT NO. 1. CORE CUTTER TEST

AIM

To determine the field or in-situ density or unit weight of soil by core cutter method

APPARATUS

1. **Special:** Cylindrical core cutter, Steel rammer, Steel dolly
2. **General:** Balance of capacity5 Kg and sensitivity of 1 gm, Balance of capacity 200gms and sensitivity of 0.01 gms, Scale, Spade or pickaxe or crowbar, Trimming Knife, Oven, Water content containers Desiccators.

THEORY

1. Field density is defined as the weight of a unit volume of soil present in the site. That is

$$\gamma = \frac{W}{V}$$

Where, γ = Density of soil

W = Total weight of soil

V = Total volume of soil

2. The soil weight consists of a three-phase system that is solids, water, and air. The voids may be filled up with both water and air, or only with air, or only with water. Consequently, the soil may be dry, saturated, or partially saturated.
3. In soils, mass of air is considered to be negligible, and therefore the saturated density is maximum, dry density is minimum and wet density is in between the two.
4. Dry density of the soil is calculated by using an equation.

$$\gamma_d = \frac{\gamma_t}{1+w}$$

Where, γ_d = dry density of soil

γ_t = Wet density of soil

W = moisture content of soil.

OBSERVATION TABLE

	Type 1	Type 2	Type 3	Type 4
Weight of can, W_1 (g)				
Weight of can + wet soil W_2 (g)				
Weight of can + Dry soil W_3 (g)				
Water/Moisture content $w(\%) = \frac{(W_2 - W_3)}{(W_3 - W_1)} X100$				

CALCULATION

	Sample 1	Sample 2	Sample 3
Mass of core cutter, W_1 (g)			
Mass of cutter + soil from field W_2 (g)			
Wet density, (gm/cm^3) $\gamma_b = \frac{W_2 - W_1}{V}$			
Dry density, (gm/cm^3) $\gamma_d = \frac{\gamma_b}{1 + w}$			

PROCEDURE

1. Measure the height and internal diameter of the core cutter.
2. Weight the clean core cutter.
3. Clean and level the ground where the density is to be determined.
4. Press the cylindrical cutter into the soil to its full depth with the help of steel rammer.
5. Remove the soil around the cutter by spade.
6. Lift up the cutter.
7. Trim the top and bottom surfaces of the sample carefully.
8. Clean the outside surface of the cutter.
9. Weight the core cutter with the soil.
10. Remove the soil core from the cutter and take the representative sample in the water content containers to determine the moisture content

PRECAUTIONS

1. Steel dolly should be placed on the top of the cutter before ramming it down into the ground.
2. Core cutter should not be used for gravels, boulders or any hard ground.
3. Before removing the cutter, soil should be removed around the cutter to minimize the disturbances.
4. While lifting the cutter, no soil should drop down

REFERENCE

1. IS: 2720 (Part II) – 1973, Method of Test for soil: Part II

CONCLUSION:

DATE **SIGN**

Figure 2.1 Pycnometer **Bottle and Weigh Balance**

OBSERVATIONS DATA

Specimen Number	Sample 1	Sample 2
Pycnometer bottle number		
W_1 = Mass of empty, clean pycnometer (g)		
W_2 = Mass of empty pycnometer + dry soil (g)		
W_3 = Mass of pycnometer + dry soil + water (g)		
W_4 = Mass of pycnometer + water (g)		
Specific gravity (Gs)		

Date: / /

EXPERIMENT NO. 2 SPECIFIC GRAVITY TEST

AIM

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

APPARATUS

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

THEORY

The specific gravity of a substance, designated as Gs, is defined as the ratio of the density of that substance to the density of distilled water at a specified temperature. Since it is a ratio, the value of Gs does not depend on the system of units used and is a numerical value having no units. In soil mechanics, the specific gravity of soil solids is an important parameter and is a factor in many equations involving weight-volume relationships. Remember that the specific gravity of soil solids refers only to the solid phase of the three-phase soil system, it does not include the water and air phases present in the void space. For soil solids, Gs may be written as:

$$G_s = \frac{\text{Density of Soil solids}}{\text{density of water}} = \frac{\text{mass of soil solids}}{\text{mass of an equal volume of water}}$$

PROCEDURE

1. Clean and dry the density bottle
   - Wash the bottle with water and allow it to drain.
   - Wash it with alcohol and drain it to remove water.
2. Weigh the empty bottle with stopper (W1)

CALCULATION

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

$$= \frac{(W2 - W1)}{(W4 - W1) - (W3 - W2)}$$

$$= \frac{(W2 - W1)}{(W2 - W1) - (W3 - W4)}$$

3. Take about 10 to 20 gm of oven soil sample which is cooled in desiccators. Transfer it to the bottle. Find the weight of the bottle and soil (W2).
4. Put 10ml of distilled water in the bottle to allow the soil to soak completely. Leave it for about 2 hours.
5. Again, fill the bottle completely with distilled water put the stopper and keep the bottle under constant temperature water baths.
6. Take the bottle outside and wipe it clean and dry note. Now determine the weight of the bottle and the contents (W3).
7. Now empty the bottle and thoroughly clean it. Fill the bottle with only distilled water and weigh it. Let it be W4 at temperature.
8. Repeat the same process for 2 to 3 times, to take the average reading of it.

REFERENCE

1. IS: 2720 (Part II) – 1973, Method of Test for soil: Part II: Soil Mechanics and Foundations.

CONCLUSION:

DATE **SIGN**

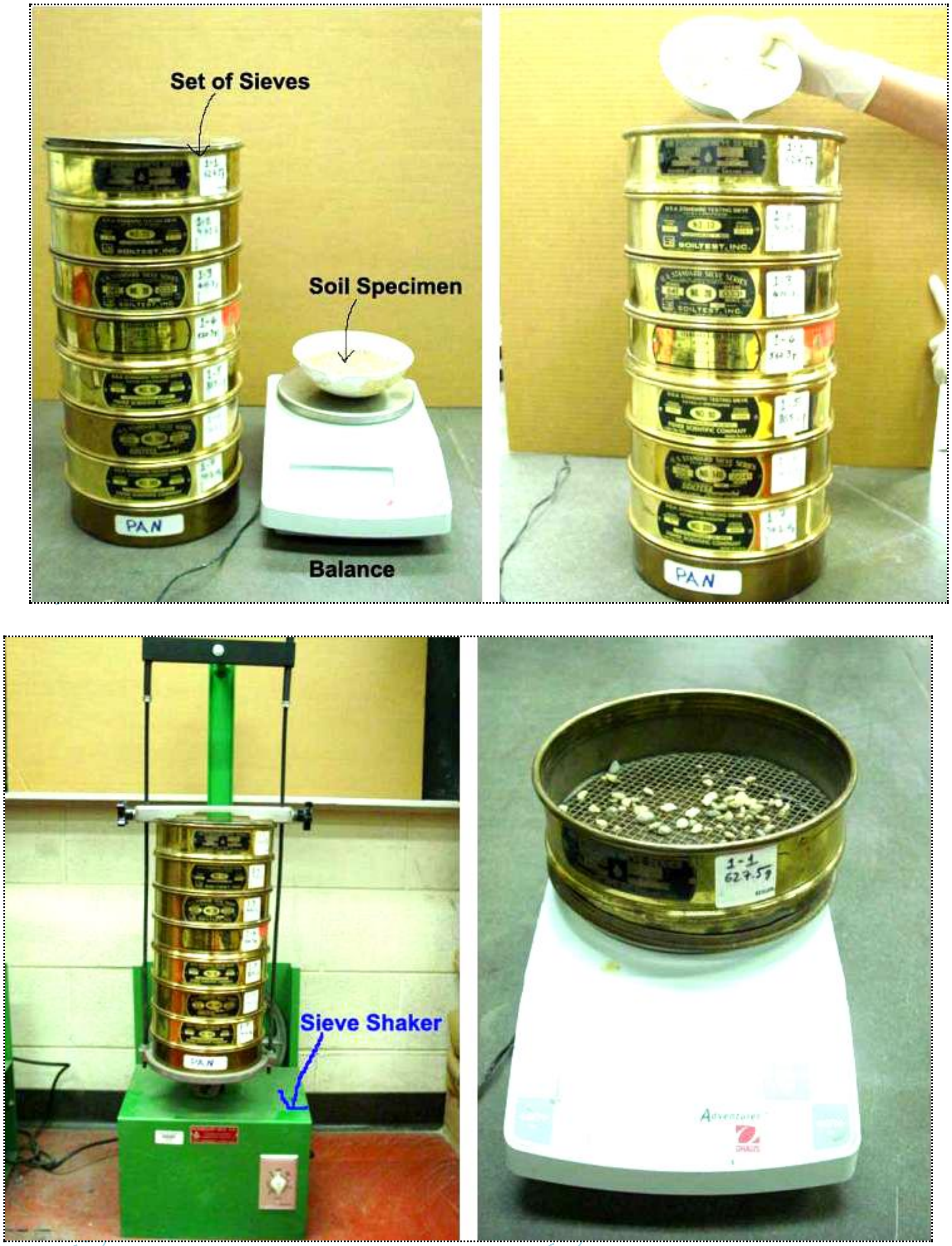


Figure 3.1 Sieve Shaker with Sieve and Weight Balance

Date: / /

EXPERIMENT NO. 3 SIEVE ANALYSIS

AIM

To determine the percentage of various size particles in a soil sample and to classify the coarse-grained soil

APPARATUS

1. 1st set of sieves of size 300 mm, 80 mm, 40 mm, 20 mm, 10 mm, and 4.75 mm.
2. 2nd set of sieves of sizes 2mm, 850 microns, 425 microns, 150 microns, and 75 microns.
3. Balances of 0.1 g sensitivity, along with weights and weight box.
4. Brush.

APPLICATION

The percentage of different size of soil particles coarser than 75 micron is determined. Coarse soils are mainly classified by sieve analysis. The grain size distribution curve gives an idea regarding the gradation of the soil, that is, it is possible to identify whether the soil is well graded or poorly graded. In mechanical soil stabilization, the main principle is to mix a few selected soils in such a proportion that a desired grain size distribution is obtained for the design mix. Hence for proportioning the selected soils, the grain size distribution of each soil is to be first known.

THEORY

1. Soils having particles larger than 0.075mm size are termed coarse-grained soils. In these soils, more than 50% of the total material by mass is larger than 75 microns. Coarse-grained soil may have boulders, cobble, gravel, and sand.
2. The following particle classification names are given depending on the size of the particle:

    i. BOULDER: particle size is more than 300mm.
    ii. COBBLE: particle size in the range of 80mm to 300mm.
    iii. GRAVE (G): particle size in the range of 4.75mm to 80mm.

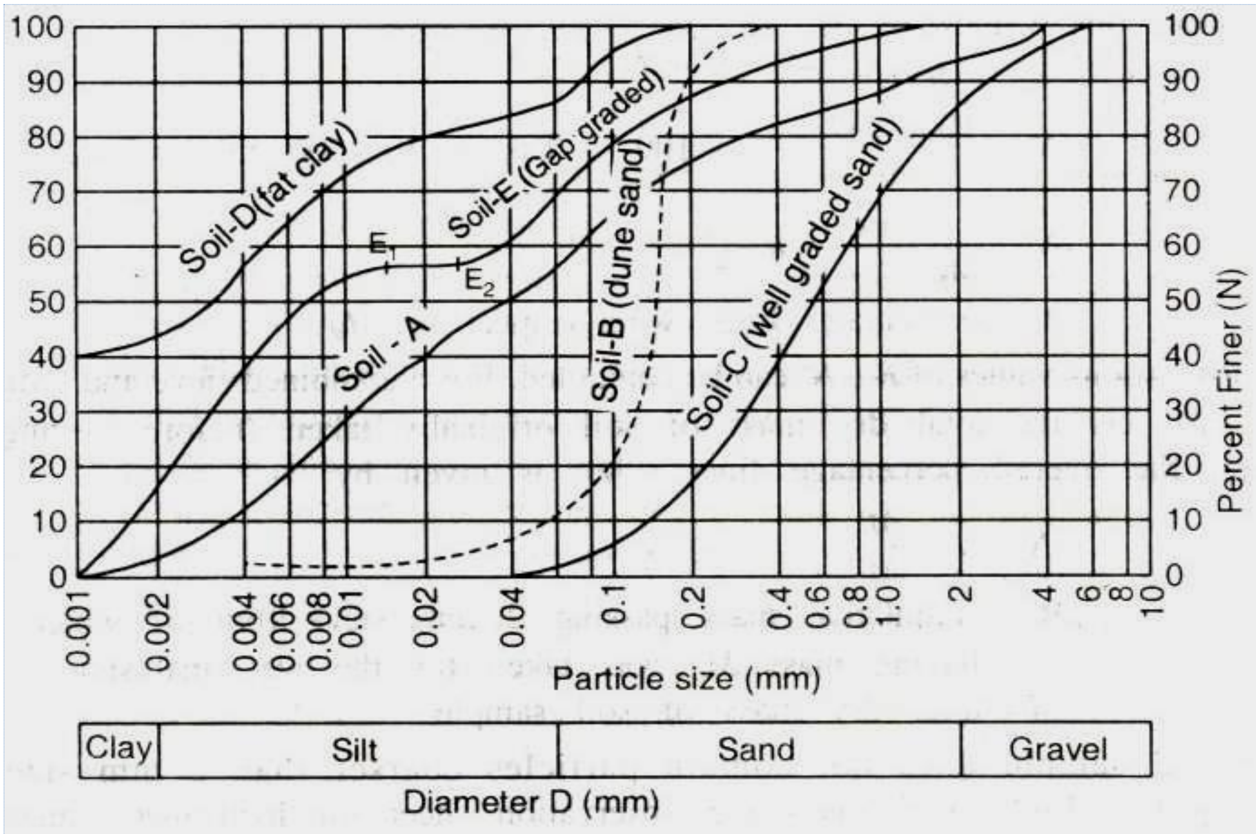
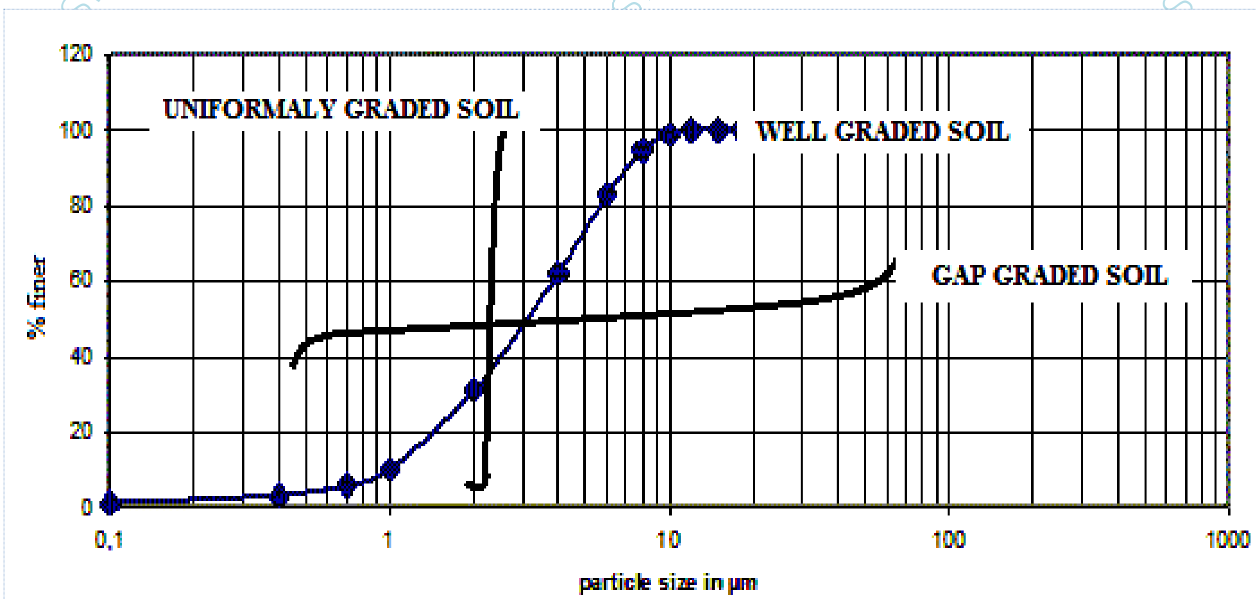


Figure 3.2 Particle Size Distribution Curve



Gravels and sands may be either poorly graded (Uniformly graded) or well graded depending on the value of coefficient of curvature and uniformity coefficient.

a) Coarse Gravel: 20 to 80mm.

b) Fine Gravel: 4.75mm to 20 mm.

iv. SAND (S): particle size in range of 0.075mm to 4.75mm.

   a) Coarse sand: 2.0mm to 4.75mm.
   b) Medium Sand: 0.075mm to 0.425mm.
   c) Fine Sand: 0.075mm to o.425mm.

3. Name of the soil is given depending on the maximum percentage of the above components.
4. Soils having less than 5% particle of size smaller than 0.075mm are designated by the symbols, Example,
   a) GP: Poorly Graded Gravel.
   b) GW: Well Graded Gravel.
   c) SW: Well Graded Sand.
   d) SP: Poorly Graded Sand.

5. Soils having greater than 12% of a particle of size smaller than 0.075mm are designated by the following symbols:
6. Dual symbols are used for the soils having 75 microns passing between 5 to 12%.
7. Dry sieve is performed for cohesionless soils if fines are less than 5%. Wet sieve analysis is carried out if fines are more than 5% and of cohesive nature.

PROCEDURE

1. Weight accurately about 200gms of oven-dried soil sample. If the soil has a large fraction greater than 4.75mm size, then the greater quantity of soil, that is, about 5.0 Kg should be taken. For soil containing some particles greater than 4.75 mm in size, the weight of the soil sample for grain size analysis should be taken as 0.5 Kg to 1.0 Kg.
2. Clean the sieves and pan with a brush and weigh them up to 0.1 gm accuracy. Arrange the sieves in the order as shown in Table. The first set shall consist of sieves of sizes 300 mm, 80mm, 40mm, 20mm, 10mm, and 4.75 mm. While the second set shall consist of sieves of sizes 4.75mm, 2mm, 1.18 mm 600 microns, 300 microns, 150 microns, and 75 microns.
3. Keep the required quantity of soil sample on the top sieve and shake it with mechanical sieve shaker for about 5 to 10 minutes. Care should be taken to tightly fit the lid cover on the top sieve.
4. After shaking the soil on the sieve shaker, weigh the soil retained on each sieve. The sum of the retained soil must tally with the original weight of soil taken.

OBSERVATIONS TABLE

Mass of soil Sample taken for Analysis (M) = 500 gm

Sieve Size (mm)	Mass of Soil Retained (gms)	%Mass of Soil Retained (%) = (x/M)	Cumulative %of Soil Retained (%)	% Finer = (100-p)
Pan				

CALCULATION

Coefficient of curvature (Cc) may be estimated as,

$$Cc = \frac{D_{30}^2}{D_{10} X D_{60}} =$$

Uniformity coefficient (Cu) is given by,

$$Cu = \frac{D_{60}}{D_{10}} =$$

Where, D60 = particle size at 60% finer.

D30 = particle size at 30% finer.

D10 = particle size at 10% finer.

DATA ANALYSIS

1. Obtain the mass of soil retained on each sieve by subtracting the weight of the empty sieve from the mass of the sieve + retained soil, and record this mass as the weight retained on the datasheet. The sum of these retained masses should be

approximately equals the initial mass of the soil sample. A loss of more than two percent is unsatisfactory.

2. Calculate the percent retained on each sieve by dividing the weight retained on each sieve by the original sample mass.
3. Calculate the percent passing (or percent finer) by starting with 100 percent and subtracting the percent retained on each sieve as a cumulative procedure.

PRECAUTIONS

1. During shaking the lid on the topmost sieve should be kept tight to prevent escape of soil.
2. While drying the soil, the temperature of the oven should not be more than 105 c because higher temperatures may cause some permanent change in the 75 fractions.

REFERENCE

1. IS: 2720 (Part II) – 1973, Method of Test for soil: Part II: Soil Mechanics and Foundations.

CONCLUSION:

DATE **SIGN**

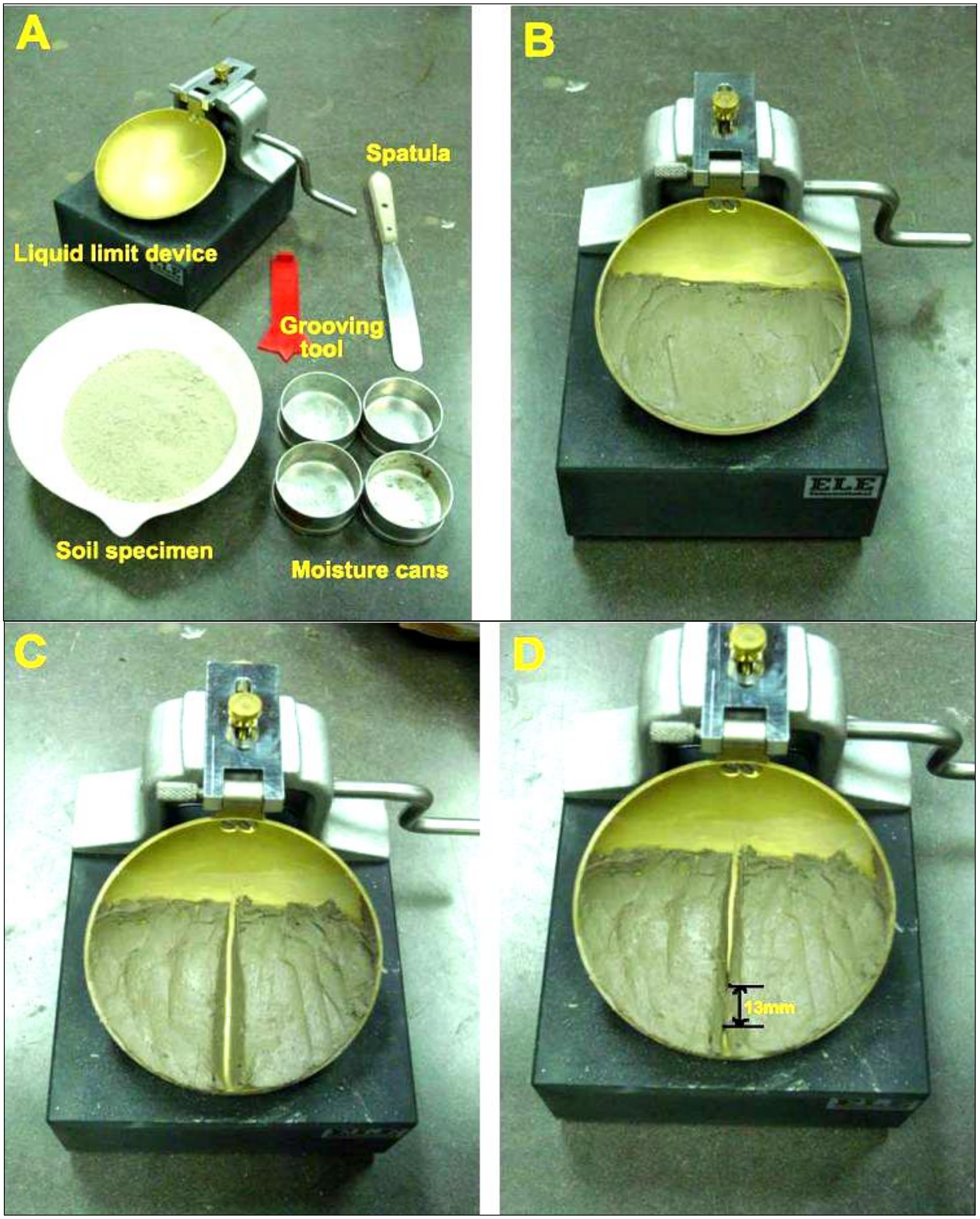


Figure 4.1(a) Casagrade apparatus for Liquid Limit Determination

Date: / /

EXPERIMENT NO. 4 LIQUID LIMIT AND PLASTIC LIMIT TEST

AIM

To determine the liquid and plastic limits of the given soil sample.

APPARATUS

1. FOR LIQUID LIMIT DETERMINATION

The apparatus required are the mechanical liquid limit device, grooving tool, porcelain evaporating dish, flat glass plate, spatula, palette knives, balance, oven wash bottle with distilled water, and containers.

2. FOR PLASTIC LIMIT DETERMINATION

The apparatus consists of a porcelain evaporating dish, about 12 cm in diameter (or a flat glass plate, 10 mm thick and about 45 cm square), spatula, about 8 cm long and 2 cm wide (or palette knives, with the blade about 20 cm long and 3 cm wide, for use with flat glass plate for mixing soil and water), a ground-glass plate, about 20×15 cm, for a surface for rolling, balance, oven, containers, and a rod, 3 mm in diameter and about 10 cm long.

THEORY

The definitions of the consistency limits proposed by Atterberg are not, by themselves, adequate for the determination of their numerical values in the laboratory, especially in view of the arbitrary nature of these definitions. In view of this, Arthur Casagrande and others suggested more practical definitions with special reference to the laboratory devices and methods developed for the purpose of the determination of the consistency limits. In this sub-section, the laboratory methods for determination of the liquid limit, plastic limit, shrinkage limit, and other related concepts and indices will be studied, as standardized and accepted by the Indian Standard Institution and incorporated in the codes or practice.

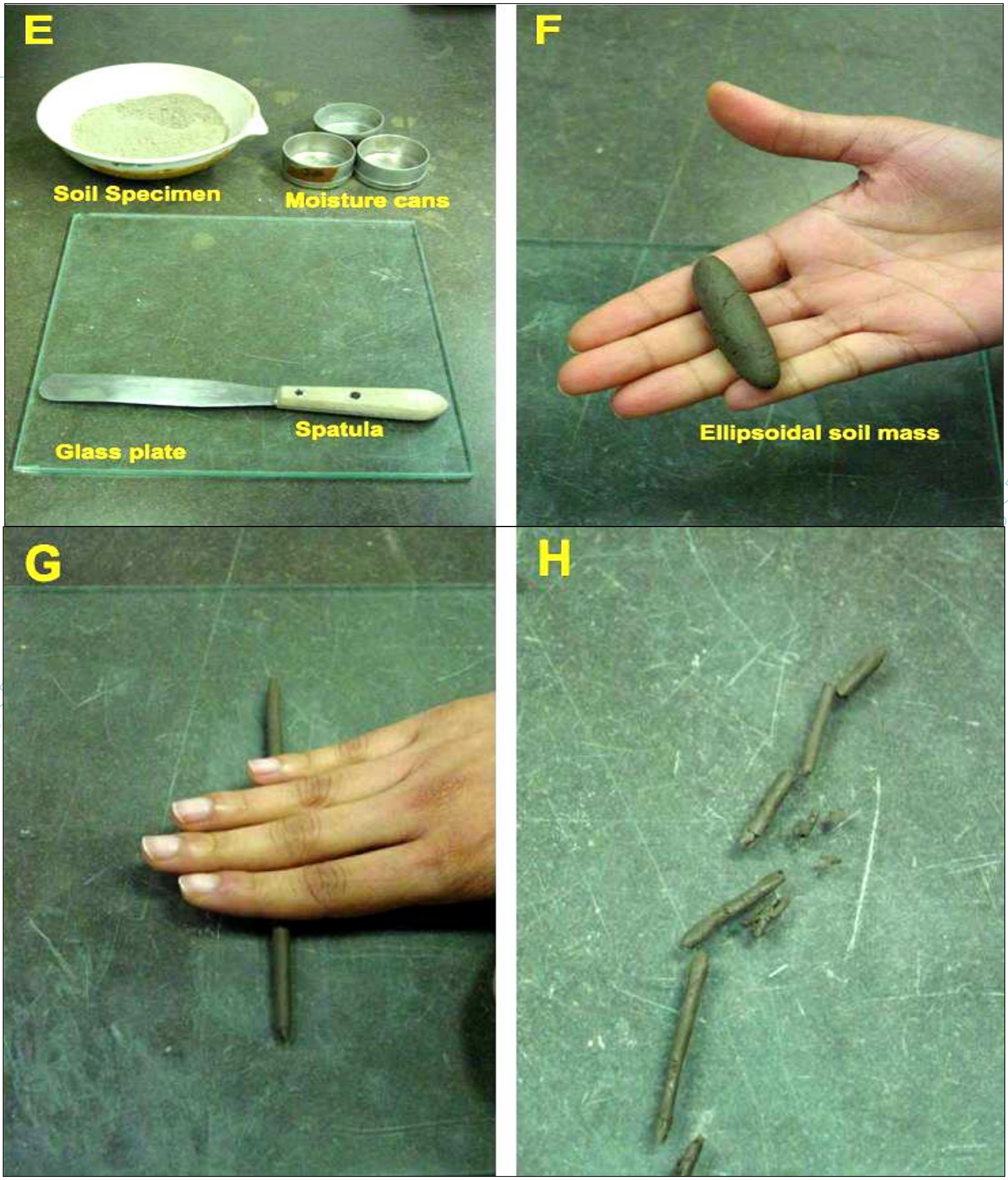


Figure 4.1(b) Casagrande apparatus for Liquid Limit Determination

SHRINKAGE LIMIT

- The shrinkage limit (SL) is the water content where the further loss of moisture will not result in any more volume reduction. The shrinkage limit is much less commonly used than the liquid limit and the plastic limit.

PLASTIC LIMIT

- The plastic limit (PL) is the water content where soil starts to exhibit plastic behavior. A thread of soil is at its plastic limit when it is rolled to a diameter of 3 mm or begins to crumble. To improve consistency, a 3 mm diameter rod is often used to gauge the thickness of the thread when conducting the test. (AKA Soil Snake Test).

LIQUID LIMIT

- Liquid limit (LL) is defined as the arbitrary limit of water content at which the soil is just about to pass from the plastic state into the liquid state. At this limit, the soil possesses a small value of shear strength, losing its ability to flow like a liquid. In other words, the liquid limit is the minimum moisture content at which the soil tends to flow like a liquid.

PROCEDURE

A. FOR LIQUID LIMIT DETERMINATION

1. Take roughly 3/4 of the soil and place it into the porcelain dish. Assume that the soil was previously passed through a No. 40 sieve, air-dried, and then pulverized. Thoroughly mix the soil with a small amount of distilled water until it appears as a smooth uniform paste. Cover the dish with cellophane to prevent moisture from escaping.
2. Weigh four of the empty moisture cans with their lids, and record the respective weights and can numbers on the datasheet.

   Adjust the liquid limit apparatus by checking the height of the drop of the cup. The point on the cup that comes in contact with the base should rise to a height of 10 mm. The block on the end of the grooving tool is 10 mm high and should be used as a gauge. Practice using the cup and determine the Correct rate to rotate the crank so that the cup drops approximately two times per second.
3. Place a portion of the previously mixed soil into the cup of the liquid limit apparatus at the point where the cup rests on the base. Squeeze the soil down to eliminate air pockets and

spread it into the cup to a depth of about 10 mm at its deepest point. The soil pat should form an approximately horizontal surface (See Photo B).

OBSERVATIONS TABLE

A. FOR LIQUID LIMIT DETERMINATION

SAMPLE NO.	1	2	4	5
Moisture can and lid number				
Mc = Mass of empty, clean can + lid (grams)				
M_{CMS} = Mass of can, lid, and moist soil (grams)				
M_{CDS} = Mass of can, lid, and dry soil (grams)				
M_S = Mass of soil solids (grams)				
M_W = Mass of pore water (grams)				
w = Water content, w%				
No. of drops (N)				

B. FOR PLASTIC LIMIT DETERMINATION

SAMPLE NO.	1	2	4	AVG.
Moisture can and lid number				
Mc = Mass of empty, clean can + lid (grams)				
M_{CMS} = Mass of can, lid, and moist soil (grams)				
M_{CDS} = Mass of can, lid, and dry soil (grams)				
M_S = Mass of soil solids (grams)				
M_W = Mass of pore water (grams)				
w = Water content, w%				

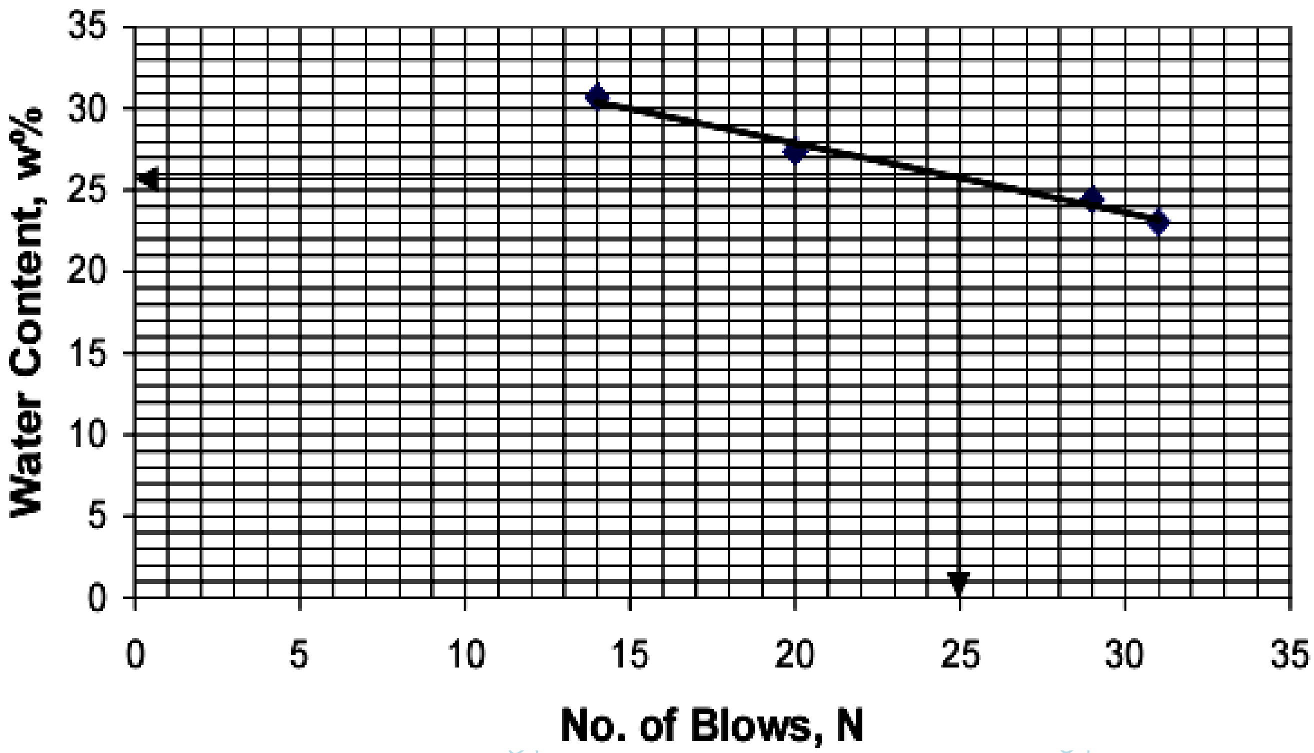
Liquid Limit =

Plastic Limit =

Plasticity Index =

4. Use the grooving tool carefully cut a clean straight groove down the center of the cup. The tool should remain perpendicular to the surface of the cup as groove is being made. Use extreme care to prevent sliding the soil relative to the surface of the cup (See Photo C).
5. Make sure that the base of the apparatus below the cup and the underside of the cup is clean of soil. Turn the crank of the apparatus at a rate of approximately two drops per second and count the number of drops, N, it takes to make the two halves of the soil pat come into contact at the bottom of the groove along with a distance of 13 mm (1/2 in.) (See Photo D). If the number of drops exceeds 50, then go directly to step eight and do not record the number of drops, otherwise, record the number of drops on the datasheet.
6. Take a sample, using the spatula, from edge to edge of the soil pat. The sample should include the soil on both sides of where the groove came into contact. Place the soil into moisture can cover it. Immediately weigh the moisture can containing the soil, record its mass, remove the lid, and place the can into the oven. Leave the moisture can in the oven for at least 16 hours. Place the soil remaining in the cup into the porcelain dish. Clean and dry the cup on the apparatus and the grooving tool.
7. Remix the entire soil specimen in the porcelain dish. Add a small amount of distilled water to increase the water content so that the number of drops required to close the groove decrease. Repeat steps six, seven, and eight for at least two additional trials producing successively lower numbers of drops to close the groove. One of the trials shall be for a closure requiring 25 to 35 drops, one for closure between 20- 30 drops, and one trial for a closure requiring 15 to 25 drops. Determine the water content from each trial by using the same method used in the first laboratory. Remember to use the same balance for all weighing.

LIQUID LIMIT CHART



CALCULATION :

From the graph, liquid limit =

B. FOR PLASTIC LIMIT DETERMINATION

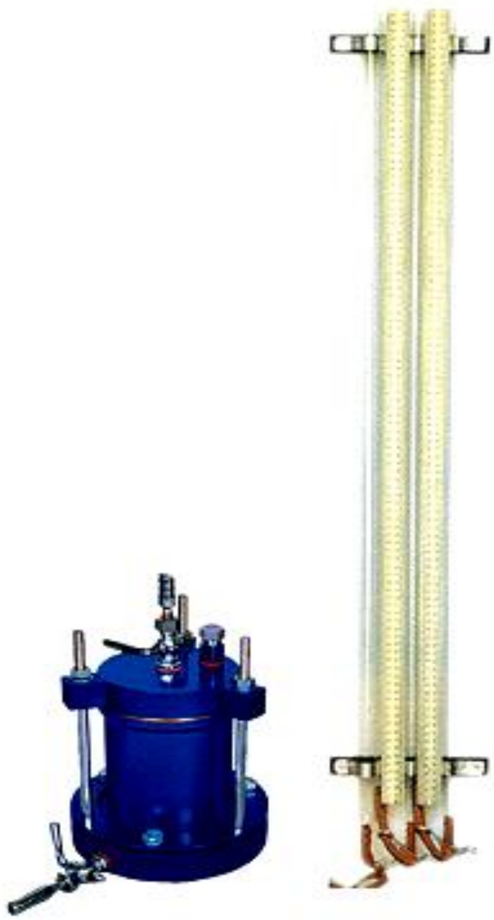
1. Weigh the remaining empty moisture cans with their lids, and record the respective weights and can number on the datasheet.
2. Take the remaining 1/4 of the original soil sample and add distilled water until the soil is at a consistency where it can be rolled without sticking to the hands.
3. Form the soil into an ellipsoidal mass (See Photo F). Roll the mass between the palm or the fingers and the glass plate (See Photo G). Use sufficient pressure to roll the mass into a thread of uniform diameter by using about 90 strokes per minute. (A stroke is one complete motion of the hand forward and back to the starting position.) The thread shall be deformed so that its diameter reaches 3.2 mm (1/8 in.), taking no more than two minutes.
4. When the diameter of the thread reaches the correct diameter, break the thread into several pieces. Knead and reform the pieces into ellipsoidal masses and re-roll them. Continue this alternate rolling, gathering together, kneading and re-rolling until the thread crumbles under the pressure required for rolling and can no longer be rolled into a 3.2 mm diameter thread (See Photo H).
5. Gather the portions of the crumbled thread together and place the soil into a moisture can, and then cover it. If the can does not contain at least 6 grams of soil, add soil to the can from the next trial (See Step 6). Immediately weigh the moisture can containing the soil, record its mass, remove the lid, and place the can into the oven. Leave the moisture can in the oven for at least 16 hours.
6. Repeat steps three, four, and five at least two more times. Determine the water content from each trial by using the same method used in the first laboratory. Remember to use the same balance for all weighing.

REFERENCE

1. The liquid limit and Plastic limit is determined in the laboratory with the aid of the standard mechanical liquid limit device, designed by Arthur Casagrande and adopted by the ISI, as given in IS:2720(Part V)–1985.
2. IS: 2720 (Part II) – 1973, Method of Test for soil

CONCLUSION:

DATE **SIGN**



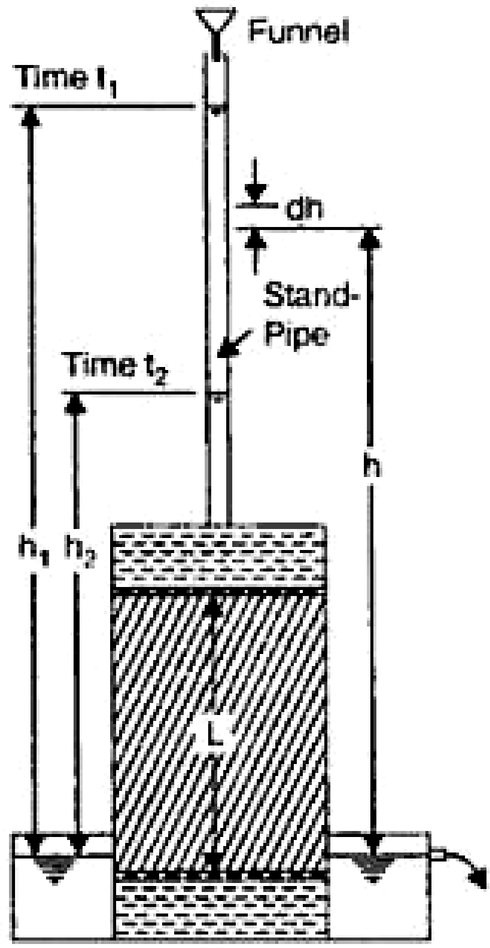


Figure 5.1 Falling Head Permeability Test Apparatus

Date: / /

EXPERIMENT NO. 5 PERMEABILITY TEST

AIM

To determine the coefficient of permeability of a given soil sample by Constant head and Variable head permeability test.

APPARATUS

1. Special
   i. Jodhpur permeameter frame consisting of sand pipe graduated scale, rubber tubing connected to permeameter mold.
   ii. Permeameter mold.
   iii. Accessories of permeameter mold including the cover, base, detachable collar, porous stones, dummy plate, etc.
   iv. Round filter paper.
   v. Dynamic compaction device.
2. General
   i. Stop watch.
   ii. De-aired water.
   iii. IS 4.75 mm sieve
   iv. Grease.

THEORY

Permeability is defined as the property of porous material which permits the passage or seepage of water through its interconnected voids. The coefficient of permeability is finding out following method.

1. Laboratory method:
   i. Variable head test.
   ii. Constant head test.
2. Field method:
   i. Pumping out test.
   ii. Pumping in test.
3. Indirect test:
   i. Computation from grain size or specific surface.
   ii. Horizontal capillarity test.

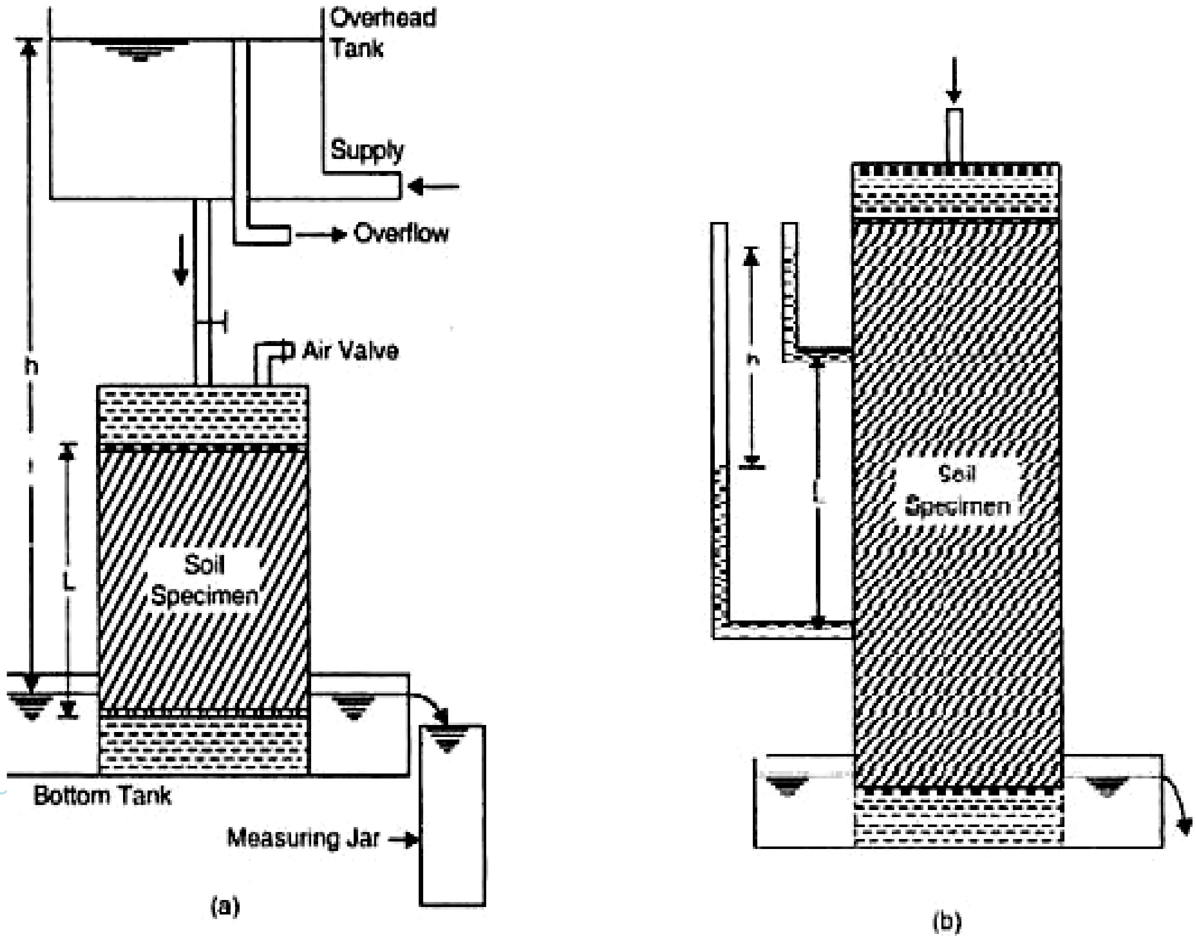


Figure 5.2 Constant Head Permeability Test Apparatus

iii. Consolidation test data.

The derivation of the coefficient of permeability is based on the assumption of the validity of the Darcy's law to the flow of water in soil. The term coefficient of permeability implies the velocity of flow of water through the soil under unit hydraulic gradient, and consequently has the same units as that of velocity.

A. VARIABLE HEAD TEST

The variable head test is used for fine grained soils like silts and silty clays. For the Variable head test the following formula is applicable,

$$k = 2.203\,\frac{\mathrm{axL}}{\mathrm{Axt}}\log_{10}\left(\frac{\mathrm{h1}}{\mathrm{h2}}\right)$$

Where,

k = Coefficient of permeability at T° C (cm/sec).

a = Cross Sectional area of stand pipe (cm2).

L = Length of soil specimen (cm)

A = Cross-sectional area of soil sample inside the mould (cm^2)

t = (t1 – t2) = Time interval for the head to fall from h1 to h2.

h1 = Initial head of water at time t1 in the pipe, measured above the outlet.

h2 = Final head of water at time t2 in the pipe, measured above the outlet.

B. CONSTANT HEAD TEST

The Constant head test is suitable for coarse grained soils like sands, sandy silts. For the Constant head test the following formula is applicable:

$$q = \frac{\mathrm{Q}}{\mathrm{t}} = \mathrm{k\,i\,A}$$

$$k = \frac{\mathrm{Q}}{\mathrm{t}}\frac{1}{\mathrm{i\,A}} = \frac{\mathrm{Q}}{\mathrm{t}}\frac{\mathrm{L}\,1}{\mathrm{h\,A}}$$

Where, k = Coefficient of permeability at To C (cm/sec).

L = Length of soil specimen (cm)

A = Total cross-sectional area of soil sample (cm2)

i = hydraulic gradients.

Q = Quantity of water collected in measuring jar.

t = total time required for collecting 'Q' quantity of water.

h = Difference in the water levels of the overhead and bottom tank.

OBSERVATION TABLE

A. OBSERVATION AND CALCULATION TABLE FOR CONSTANT HEAD PERMEABILITY TEST:

Sr. No	OBSERVATION	1	2	3
1	Diameter of stand pipe (cm) ‘d’			
2	c/s area of stand pipe ‘a = $\pi d^2/4$			
3	Diameter of cylindrical soil sample D			
4	c/s area of soil specimen ‘A = $\pi D^2/4$			
5	Height of soil specimen, L			
6	Hydraulic head ‘h’ (cm)			
7	Time interval ‘t’ (sec)			
8	Coefficient of permeability (cm/sec) $k = \frac{Q}{t}\frac{L}{h}\frac{1}{A}$			

Avg. Coefficient of permeability (cm/sec) = 3.98x10^-4 cm/sec

PROCEDURE

A. PREPARATION OF REMOLDED SOIL SPECIMEN

1. Weight the required quantity of oven dried soil sample. Evenly sprinkle the calculated quantity of water corresponding to the OMC. Mix the soil sample thoroughly.
2. Clean the mould and apply a small portion of grease inside the mould and around the porous stones in the base plate. Weight the mould and attach the collar to it. Fix the mould on the compaction base plate. Keep the apparatus on solid base.
3. The soil sample is placed inside the mould, and is compacted by the standard
4. Proctor compaction tools, to achieve a dry density equal to the predetermine 3d MDD. Weight the mould along with the compacted soil. Saturate the porous stones. Place the filter papers on both ends of the soil specimen in the mould. Attach the mold with the drainage base and cap having saturated porous stones.

B. SATURATION OF SOIL SPECIMEN

1. Connect the water reservoir to the outlet at the bottom of the mold and allow the water to flow in the soil. Wait till the water has been able to travel up and saturate the sample. Allow about 1 cm depth of free water to collect on the top of the sample.
2. Fill the remaining portion of a cylinder with de-aired water without disturbing the surface of the soil.
3. Fix the cover plate over the collar and tighten the nuts in the rods.

C. CONSTANT HEAD TEST:

1. Place the mold assembly in the bottom tank and fill the bottom tank with water up to the outlet.
2. Connect the outlet tube with a constant head tank to the inlet nozzle of the permeameter, after removing the air in flexible rubber tubing connecting the tube.

B. OBSERVATION AND CALCULATION TABLE FOR FOLLING HEAD PERMIABILITY TEST:

Sr. No	OBSERVATION	1	2	3
1	Diameter of stand pipe (cm) ‘d’			
2	c/s area of stand pipe ‘a = $\pi d^2/4$			
3	Diameter of cylindrical soil sample D			
4	c/s area of soil specimen ‘A = $\pi D^2/4$			
5	Height of soil specimen, L			

Sr. No	Initial Head (h1) cm	Final Head (h2) cm	Time required (t) sec	Permeability, $k = 2.203 \frac{axL}{Axt} \log_{10}(\frac{h1}{h2})$
1				
2				
3				

3. Adjust the hydraulic head by either adjusting the relative height of the permeameter mould and constant head tank or by rising or lowering the air intake tube with in the head tank.
4. Start the stop watch and at the same time put a bucket under the outlet of the bottom tank, run the test for same convenient time interval and measure.
5. Repeat the test twice more, under the same head and for the same time interval.

D. VARIABLE HEAD PERMEABILITY TEST METHOD:

1. Disconnect the water reservoir from the outlet at the bottom and connect the standpipe to the inlet at the top plate.
2. Fill the standpipe with water. Open the stop cock at the top and allow water to flow out so that all the air in the cylinder is removed.
3. Fix the height h1 and h2 on the standpipe from the center of the outlet such that (h1 – h2) is about 30 cm to 40 cm.
4. When all the air has escaped, close the stop clock and allow the water from the pipe to flow through the soil and establish a steady flow.
5. Record the time interval, t, for the head to drop from h1 to h2.
6. Take about five such observations by changing the values of h1 and h2.
7. Measure the temperature of the water.

CONCLUSION:

DATE **SIGN**

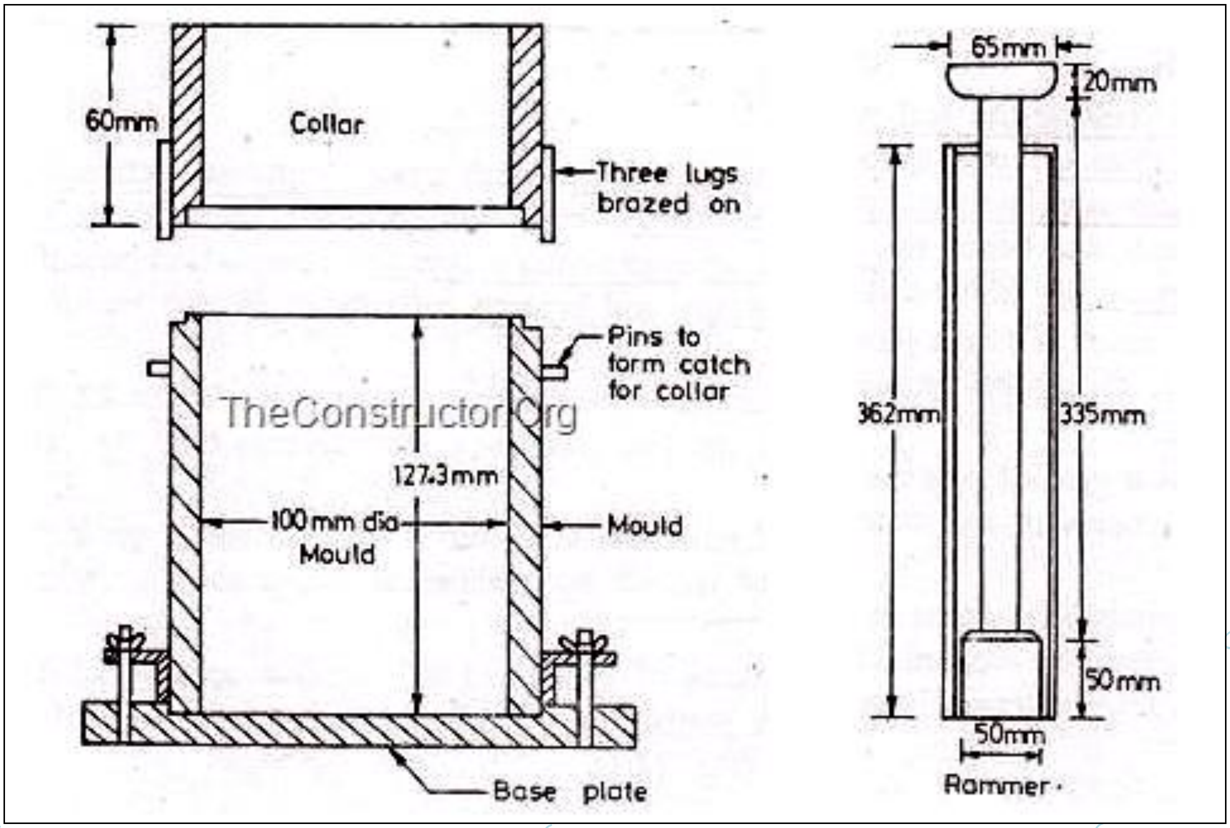


Figure No: 6.1 Standard Proctor test Apparatus

OBSERVATION AND CALCULATION TABLE:

i. Diameter of mold, D (cm):
ii. Height of mold, h (cm):
iii. Volume of mold, V (cc):

SAMPLE NO	1	2	3	4	5
Weight of empty mold + Baseplate (w_1),kg					
Weight of compacted soil + Baseplate (w2) ,kg					
Bulk unit weight of compacted soil γ (gm/cc)					
Water content (w)					
Dry unit weight $\gamma d = \gamma / (1 + w)$, (gm/cc)					

Date: / /

EXPERIMENT NO. 6 PROCTER COMPACTION TEST

AIM

To determine the optimum moisture content and maximum dry density of soil by standard proctor compaction test.

APPARATUS

A) Special:

i. Proctor mold (capacity 1000.0 cc, internal diameter 100mm, and effective height 127.3 mm.
ii. Rammer for light compaction (2.6Kg, with free drop of 310 mm).
iii. Mould accessories including detachable base plate, removable Collar.
iv. I.S. sieve 4.75 mm.

B) General:

i. Balance of capacity 10 kg, and sensitivity of 1 gm.
ii. Balance of capacity 200 gms and sensitivity of 0.01 gm.
iii. Drying oven.
iv. Desiccators.
v. Containers for water content.
vi. Graduated Jar.
vii. Trimming knife.
viii. Large mixing tray

THEORY

- Compaction is the process of densification of the soil mass by reducing air voids. The purpose of the laboratory compaction test is to determine the proper amount of water at which the weight of the soil grains in a unit volume of the compacted is maximum, the amount of water is thus called the Optimum Moisture Content (OMC). In the laboratory, different values of moisture contents and the resulting dry densities, obtained after compaction are plotted both to arithmetic scale, the former as abscissa and the latter as ordinate. The points thus obtained are joined together as a curve. The maximum dry density and the corresponding OMC are read from the curve.
- The wet density γ_t of the compacted soil is calculated as below,

$$\gamma_t = \frac{W_1 - W_2}{V}$$

Where,

W$_1$ = Weight of mould with moist compacted soil.
W$_2$ = Weight of empty mould.
V = Volume of mould.

- The dry density of the soil shall be calculated as follows,

$$\gamma_d = \frac{\gamma_t}{1 + w}$$

Where,

γ_t = wet density of the compacted soil.

w = moisture content

Typical OMC vs. MDD GRAPH

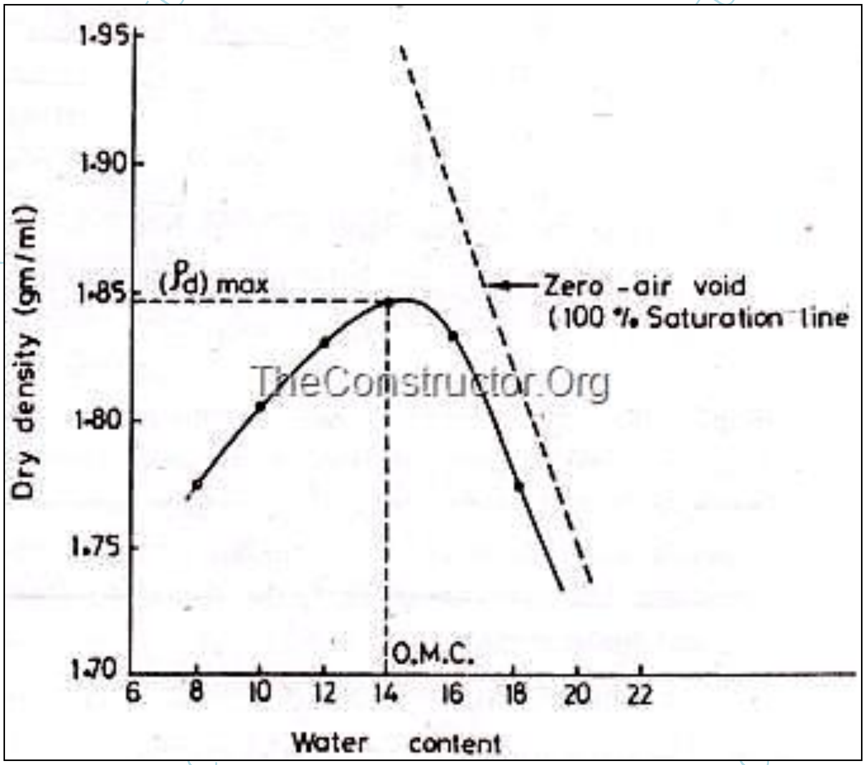


Figure No: 6.2: OMC Vs MDD

PROCEDURE

i. Take about 20 kg of soil and sieve it through 20 mm and 4.75 mm.

ii. A 100 mm diameter Proctor mould is to be used if the soil fraction that passes 4.75 mm sieve is greater than 80% by weight.

iii. Take about 2.25 kg of the soil sample and add water to get the moisture content round 8%. Leave the mix to mature for few minutes.

iv. Clean and grease gently the inside surface of the mould, and the base plate.

v. Take the weight of empty mould with the base plate.

vi. Fir the collar and place the mould on a solid base.

vii. Place first batch of soil inside the mould and apply 25 blows of Standard rammer, so that the compacted layer thickness is about one-third height of the mould Scratch the top of the compacted soil before the second layer is placed Place the second batch of wet soil and follow the same procedure In all the soil is compacted in three layers, each given 25 blows of the standard rammer weighing 2.6 Kg and having a drop of 310 mm.

viii. Remove the collar, and trim of the excess soil with trimming knife. Clean the mould, and weight the mould with the compacted soil and the base plate.

ix. Take a representative sample from the mould and determine its water content.

x. Repeat the above procedure for water content values of 13%, 17%, 20%, 22% and 25%.

PRECAUTIONS

i. Adequate period is allowed to mature the soil after it is mixed with water.

ii. The rammer blows should be uniformly distributed over the surface with spatula before next layer is placed.

iii. To avoid stratification each compacted layer should be scratched with spatula before next layer is placed.

iv. At the end of compaction test, the soil should not penetrate more than 5mm into the collar.

CALCULATION:

Attach the OMC Vs. AMD Graph Paper :

FROM GRAPH OMC= ______% and MDD=_____________ gm/cc

CONCLUSION:

DATE **SIGN**

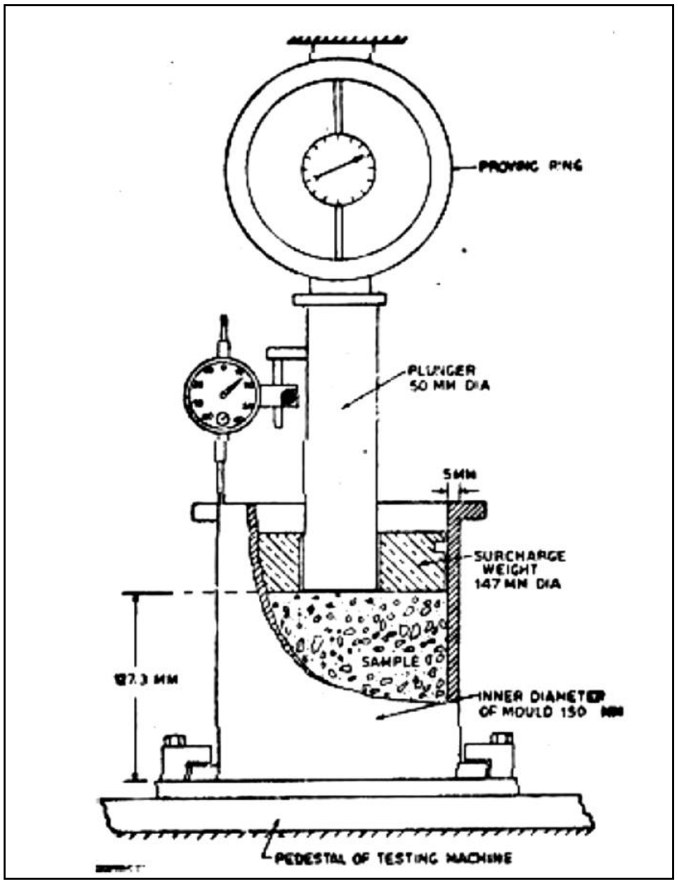


Figure No: 7.1 CBR Test Apparatus.

Date: / /

EXPERIMENT NO. 7 CALIFORNIA BEARING RATIO TEST

AIM

To determine the California Baring Ratio (C.B.R.) value of a given soil sample.

APPARATUS

Loading machine which can be operated at a constant rate of 1.25mm per minute, cylindrical molds of 150mm diameter i.e., 175mm height provided with a collar of about 50mm length and detachable perforated base are used for this purpose, Compaction Rammer.

THEORY

The California Bearing Ratio (C.B.R.) test was developed by the California Division of Highways as a method of classifying and evaluating soil subgrade and base course materials for flexible pavements. The test is empirical and the results cannot be related accurately to any fundamental property of the material. The C.B.R. is a measure of the resistance of a material to penetration of a standard plunger under controlled density and moisture conditions.

The C.B.R. test may be conducted in re-molded or undisturbed specimens in the laboratory. The test is simple and has been extensively investigated for field correlations of flexible pavement thickness requirements. The test is conducted by causing a cylindrical plunger of some diameter to penetrate a pavement component material at 1.25mm/minute. The loads, for 2.5mm and 5mm are recorded. This load is expressed as a percentage of the standard load value at a respective deformation level to obtain the C.B.R. value. The values are given in the table below.

Table 1 Load corresponding to Penetration.

Penetration, mm	Standard Load, kg	Unit Standard Load, kg/cm^2
2.5	1370	70
5.0	2055	105
7.5	2630	134
10.0	3180	162
12.5	3600	183

As per IRC recommendation, the minimum value of C.B.R. required for a subgrade should be 8%. The procedure is standardized by the Indian Standards Institution in two different categories. The first is

Test of Soils in the laboratory, determination of C.B.R., IS 2720 part XVI. The second is Methods of Test for soils, field determination of C.B.R., IS 2720 XXXI.

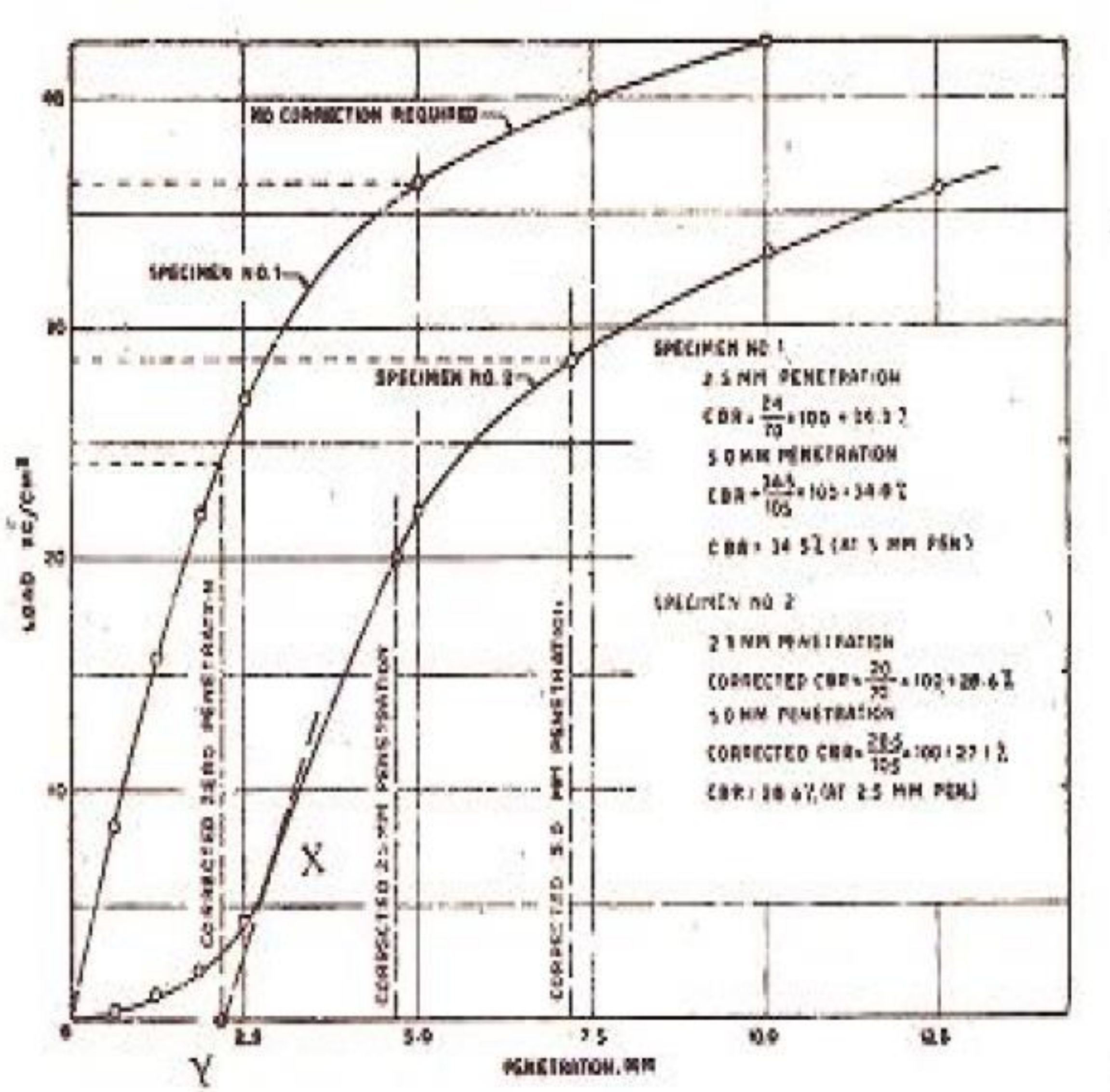


Figure 7.2 Typical Graph Plotted In CBR Test

PROCEDURE

1. Each batch of soil is (of at least 5.5kg for granular soils and 4.5 to 5kg weight for fine-grained soils) mixed with water up to the optimum moisture content or the field moisture content if specified so.
2. The spacer disc is placed at the bottom of the mold over the base plate and coarse filter paper is placed over the spacer disc.
3. The moist soil sample is to be compacted over this in the mold by adopting either the I.S. light compaction or the I.S. heavy compaction.
4. After compacting the last layer, the collar is removed and the excess soil above the top of the mold is evenly trimmed off by means of straight edges.
5. The clamps are removed and the mold with the compacted soil is lifted leaving below the base plate and the spacer disc is removed.
6. A filter paper is placed on the base plate, the mold with compacted soil is inverted and placed in position over the base plate, and the clamps of the base plate are tightened.
7. Weights of 2.5 to 5kg are placed over the soil sample in the mold. Then the whole mold is placed in a water tank for soaking.
8. A swelling measuring device consisting of the tripod and the dial gauge are placed on the top edge of the mold and the spindle of the dial gauge is placed touching the top of the sample.
9. The initial dial gauge reading is recorded and the test setup is kept undisturbed in the water tank to allow soaking of the soil specimen for four full days or 96 hours.
10. After 96 hours of soaking, the mould with the specimen is clamped over the base plate and the same surcharge weights are placed on the specimen centrally such that the penetration test can be conducted
11. The mold with the base plate is placed under the penetration plunger of the loading machine.
12. The penetration plunger is seated at the center of the specimen and is brought in contact with the top surface of the soil sample by applying a seating load of 4.0kg.
13. The dial gauge for measuring the penetration values of the plunger is fitted in position. The dial gauge of the proving ring and the penetration dial gauge are set to zero.
14. The load is applied through the penetration plunger at a uniform rate of 1.25mm/minute.
15. The load readings are recorded at penetration readings of 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 7.5, 10.0, 12.5 mm penetration.

OBSERVATION TABLE

Load at 2.5 mm penetration =_____________ = _______ kg
Load at 5.0 mm penetration = _____________= _______ kg

CALCULATIONS:

1. CBR at 2.5 mm penetration =
2. CBR at 5 mm penetration =

The C.B.R. value of the given soil sample is __________%.

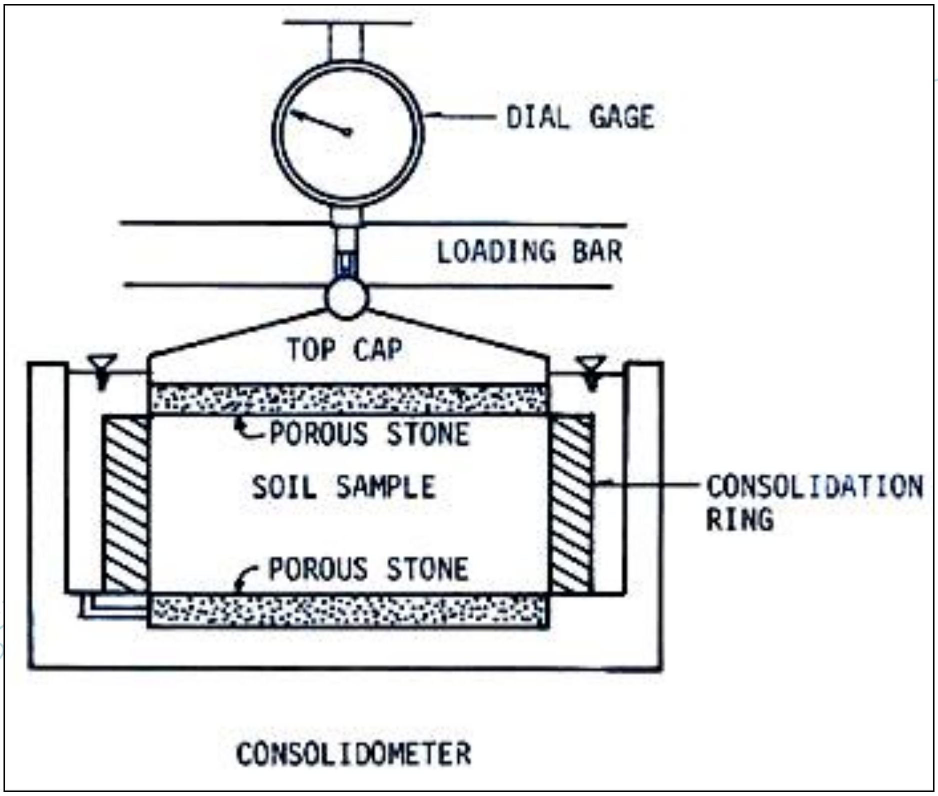
16. The maximum load value and the corresponding penetration value are recorded.
17. After the final reading, the load is released and the mould is removed from the loading machine.
18. The proving ring calibration factor is noted so that the load dial values can be converted into load in kg.
19. The load values noted for each penetration level are divided by the area of the loading plunger (19.635 cm^2) to obtain the pressure.
20. A graph is plotted by penetration in mm on x-axis and the pressure in kg/cm2 on y-axis.
21. Then the unit pressure values corresponding to 2.5 and 5.0mm penetration values are found in the graph.
22. Then the C.B.R. value is calculated from the formula:

$$\left[\frac{\text{Unit pressure carried by soil sample at defined penetration level}}{\text{Unit pressure carried by standard crushed stones at above penetration level}}\right] x100$$

23. C.B.R. (%) =
24. The C.B.R. values at 2.5mm and 5.0mm penetrations are calculated for each specimen from the corresponding graphs. Generally, the C.B.R. value at 2.5mm penetration if higher, and the value are adopted. However, if a higher C.B.R. value is obtained at 5.0mm penetration, the test is to be repeated to verify the results. If the value at 5.0mm penetration is again higher, this is adopted as the C.B.R. value of the soil sample.

CONCLUSION:

DATE **SIGN**



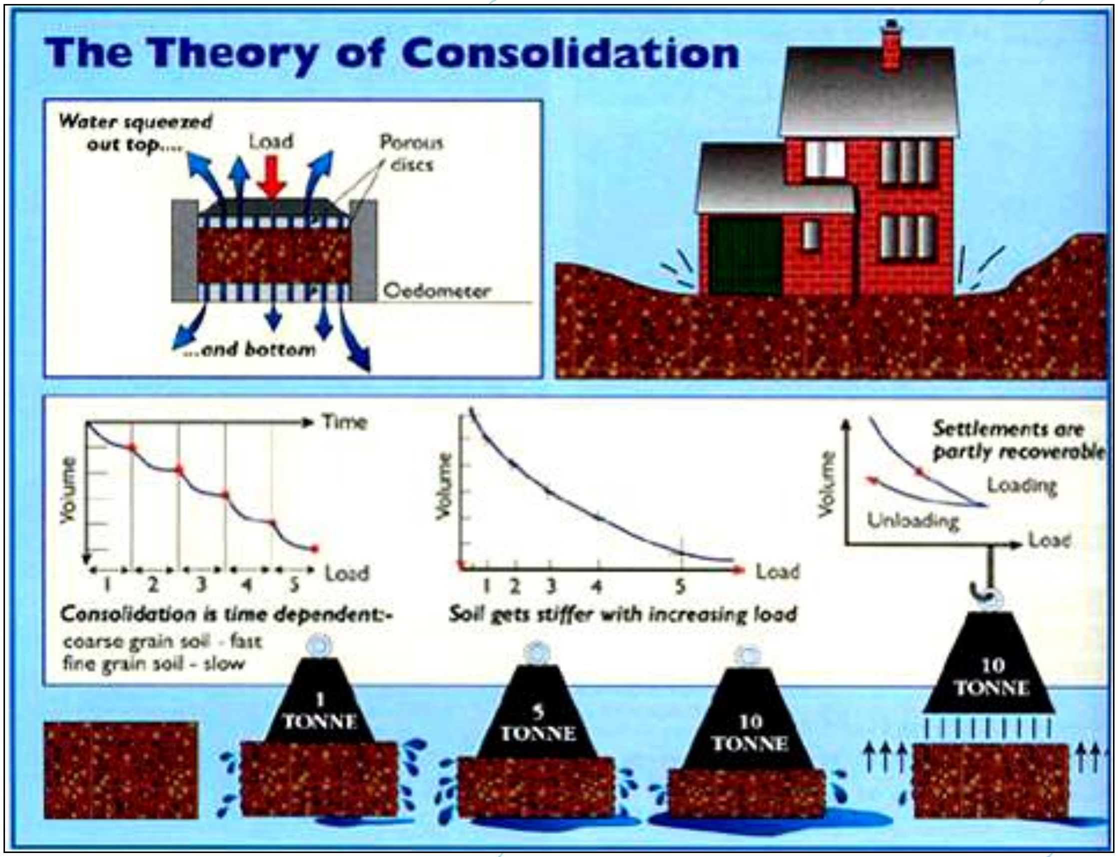


Figure No:.8.1 Consolidometer Apparatus

Date: / /

EXPERIMENT NO. 8 CONSOLIDATION TEST

AIM

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

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

APPARATUS

i. Consolidometer consisting essentially; A ring of diameter = 60mm and height = 20mm, Two porous plates or stones of silicon carbide, aluminum oxide or porous metal, Guide ring, Outer ring, Water jacket with base, Pressure pad, Rubber basket.
ii. Loading device consisting of frame, lever system, loading yoke dial gauge fixing device and weights.
iii. Dial gauge to read to an accuracy of 0.002mm.
iv. Thermostatically controlled oven.
v. Stopwatch to read seconds.
vi. Sample extractor.
vii. Miscellaneous items like balance, soil trimming tools, spatula, filter papers, sample containers.

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 void filled with incompressible water, decrease in volume or compression can take place when water is expelled out of the voids. Such a compression resulting from a long time static load and the consequent escape of pore water is termed as consolidation.
- Then the load is applied on the saturated soil mass, the entire load is carried by pore water in the beginning. As the water starts escaping from the voids, the hydrostatic pressure in water gets gradually dissipated and the load is shifted to the soil solids which increases effective on them, as a result the soil mass decrease in volume. The rate of escape of water depends on the permeability of the soil.
- Major problem in the soil is the soil subsidence caused by pressure or weight of construction trucks on the surface, which may be divided into three categories.
    i. Elastic Deformation
    ii. Primary Consolidation
    iii. Secondary Consolidation

OBSERVATION AND CALCULATION TABLE

Pressure Intensity (kN/m2)							
Elapsed Time in min	**Dial gauge reading**						
0							
0.25							
0.50							
1							
2							
4							
8							
15							
30							
60							
120							
180							
1440							

OBSERVATION SHEET FOR PRESSURE VOIDS RATIO

Applied pressure σ' (kN/m^2)	Final dial reading	Dial change ΔH	A_v in m^2/kN	C_v	t_{90}	Void Ration $e = \frac{H - H_s}{H_s}$

PROCEDURE

i. Preparation of the soil specimen:

a) From undisturbed soil sample:

From the sample tube, eject the sample into the consolidation ring. The sample should project about one cm from outer ring. Trim the sample smooth and flush with top and bottom of the ring by using a knife. Clean the ring from outside and keep it ready from weighing.

b) From remolded or disturb sample:

- Choose the density and water content at which sample has to be compacted from the moisture density relationship.
- Calculate the quantity of soil and water required to mix and compact.
- Compact the specimen in compaction mould in three layers using the standard rammers.
- Eject the specimen from the mould using the sample extractor.

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

iii. Assemble the Consolidometer, with the soil specimen and porous stones at top and bottom of specimen, providing a filter paper between the soil specimen and porous stone. Position the pressure pad centrally on the top porous stone.

iv. Mount the mould assembly on the loading frame, and center it such that the load applied is axial.

v. Position the dial gauge to measure the vertical compression of the specimen. The dial gauge holder should be set so that the dial gauge is in the begging of its releases run, allowing sufficient margin for the swelling of the soil, if any.

vi. Connect the mould assembly to the water reservoir and the sample is allowed to saturate. The level of the water in the reservoir should be at about the same level as the soil specimen.

vii. Apply an initial load to the assembly. The magnitude of this load should be chosen by trial, such that there is no swelling. It should be not less than 50 g/cm2 (5 kN/m^2) for ordinary soils & 25 g/cm2 (2.5 kN/m2) 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.

viii. Note the final dial reading under the initial load. Apply first load of intensity 0.1 kg/cm^2 (10 kN/m^2) start the stop watch simultaneously. Record the dial gauge readings at various time intervals (and fill in the table). The dial gauge readings are taken until 90% consolidation is reached. Primary consolidation is gradually reached within 24 hrs.

ix. At the end of the period, specified above take the dial reading and time reading. Double the load intensity and take the dial readings at various time intervals. Repeat this procedure fir successive load increments.

x. The usual loading intensity are as follows: 0.1, 0.2, 0.5, 1, 2, 4 and 8 kg/cm2

xi. After the last loading is completed, reduce the load to half (1/2) of the value of the last load and allow it to stand for 24 hrs. Reduce the load further in steps of 1/4th the previous intensity till an intensity of 0.1 kg/cm2 is reached. Take the final reading of the dial gauge.

xii. Reduce the load to the initial load, keep it for 24 hrs and note the final readings of the dial gauge. Quickly dismantle the specimen assembly and remove the excess water on the soil specimen in oven, note the dry weight of it.

CALCULATION

1. **Height of solids (H_s)** is calculated from the equation, where Md is 96.98 gm, G= 2.68,

$$H_s = \frac{M_d}{G\,A\,\rho_w}$$

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

$$e = \frac{H - H_s}{H_s}$$

3. **Coefficient of consolidation:**

The Coefficient of consolidation at each pressures increment is calculated by using the following equations:

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

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

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

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

4. **Compression Index:**

To determine the compression index, a plot of voids ratio (e) Vs log t is made. The initial 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 = 0.435 Cc/Avg. pressure for the increment
   - Where Cc = Coefficient of compressibility
6. **Coefficient of permeability.** It is calculated as follows
   - K = Cv. av *(unit weight of water)/ (1+e).

PRECAUTIONS

i. While preparing the specimen, attempts has to be made to have the soil strata orientated in the same direction in the consolidation apparatus.
ii. During trimming care should be taken in handling the soil specimen with least pressure.
iii. Smaller increments of sequential loading have to be adopted for soft soils.

APPLICATION

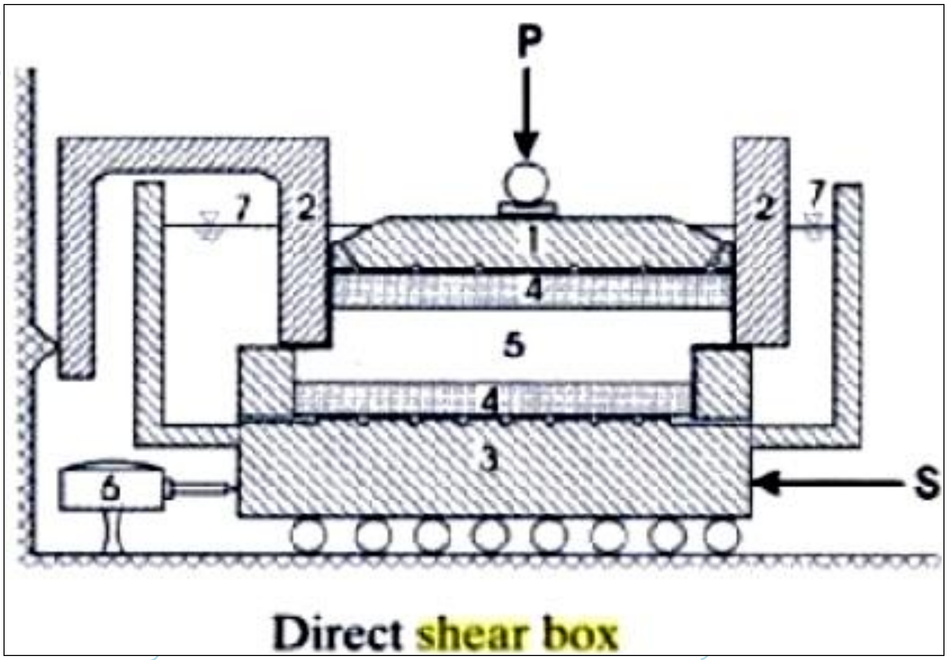
The test is conducted to determine the settlement due to primary consolidation. To determine:

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

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

CONCLUSION

DATE **SIGN**



1. Piston
2. Fixed half
3. Movable half
4. Filter Stone
5. Specimen
6. Strain gauge
7. Water Level

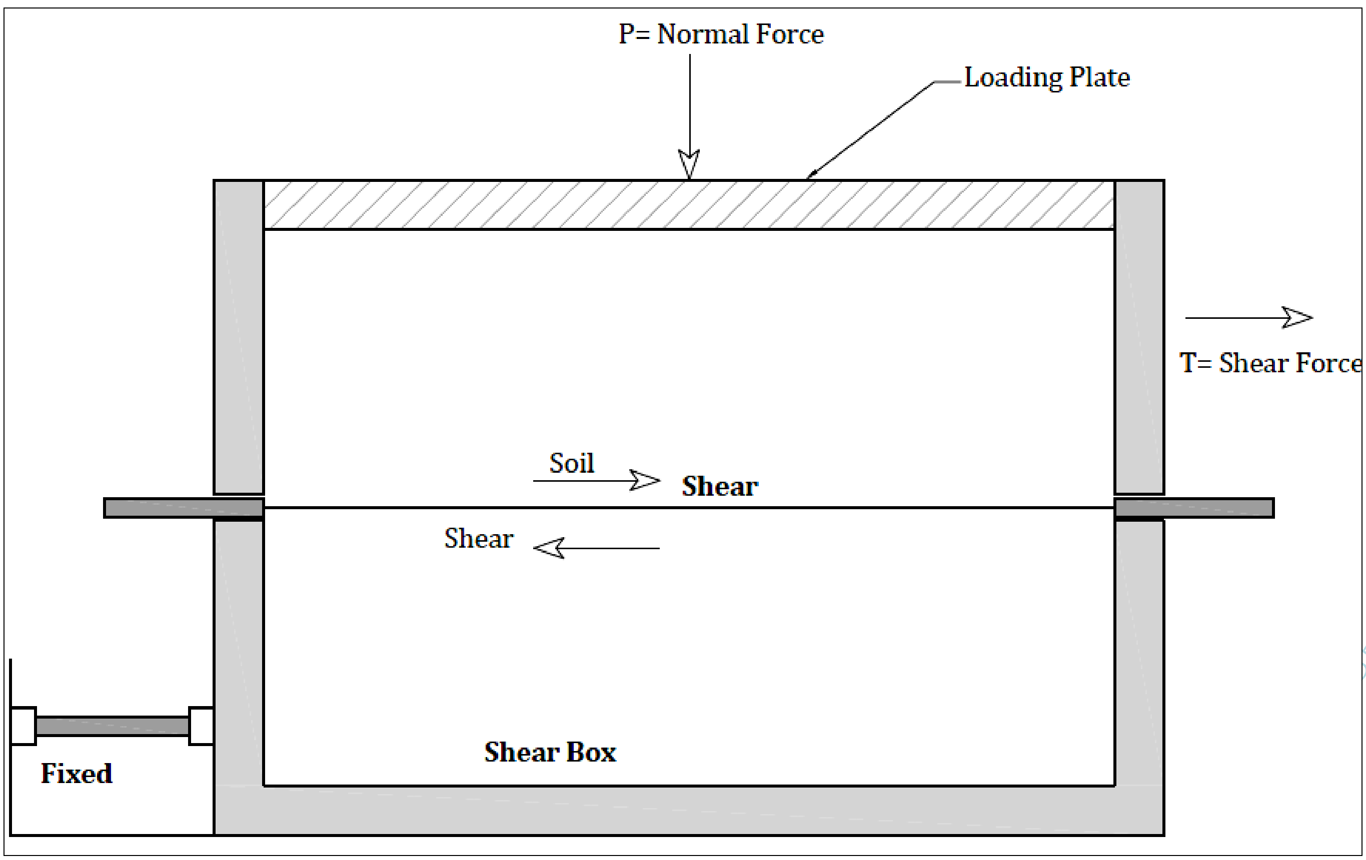


Figure No: 9.1 Direct Shear Arrangements

Date: / /

EXPERIMENT NO. 7 DIRECT BOX SHEAR TEST

AIM

To determine shear strength parameters of the given soil sample by Direct Shear Test.

APPARATUS

A) Special:

Shear test frame housing the motor, loading yoke, Shear box of internal dimension 60 mm x 60 mm x 25 mm, Water jacket for shear box, Metallic Grid plates, Baseplate, Porous stones, Loading pad, Proving ring of capacity 200 Kgf, Slotted weights to impart appropriate normal stress on a soil sample.

B) General:

Balance of capacity 1 Kg and sensitivity 0.1 gms, Scale, Dial Gauge of sensitivity 0.01 mm

THEORY

The shear strength of a soil is the maximum resistance to shearing stress at failure on the failure plane. Shear strength is composed of:

i. Internal friction which is the resistance due to friction between individual particles at their contact points and interlocking of particles. This interlocking strength is indicated through parameter φ.

ii. Cohesion which resistances due to inter-particle force which tends hold the particles together in a soil mass. The indicative parameter is called Cohesion intercept (c).

Coulomb has represented the shear strength of soil by the equation:

$$\tau_f = c + \sigma_n \tan\varphi$$

Where,

τ_f = shear strength of soil = shear stress at failure.

C = Cohesion intercepts.

σ_n =Total normal stress on the failure plane

φ = Angle of internal friction or shearing resistance

The graphical representation of the above equation gives a straight line called Failure envelope. The parameters c and are not constant for a given type of soil but depends in its degree of saturation, drainage conditions and the condition of laboratory testing.

In direct shear test, the sample is sheared along the horizontal plane. This indicates that the failure plane is horizontal. The normal stress, on this plane is the external vertical load divided by the corrected area of the soil sample. The shear stress at failure is the external lateral load divided by the corrected of soil sample.

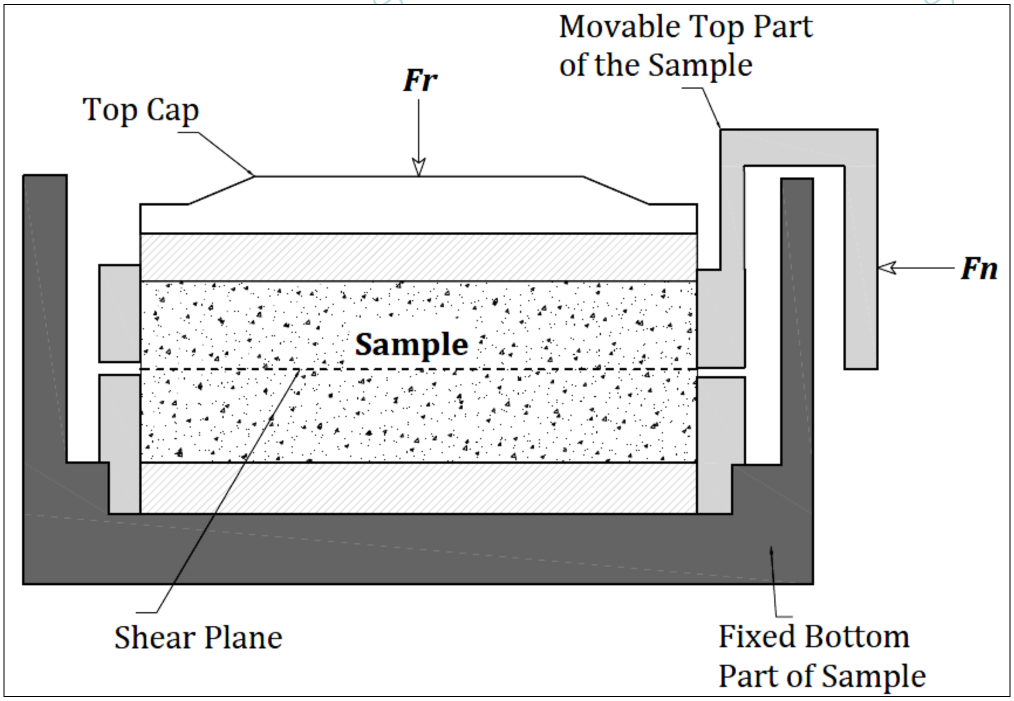


Figure No: 9.2 Schematic Presentation of a direct Shear box apparatus

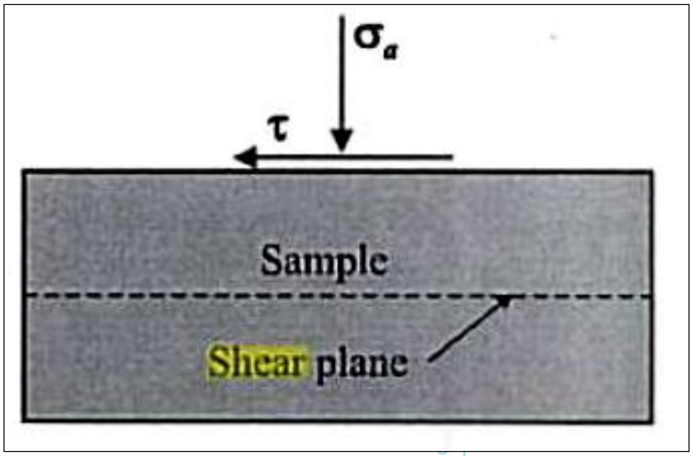


Figure No: 9.3 Stresses acting on a sample in a direct shear box

PROCEDURE

i. Prepare a soil specimen of size 60 mm * 60mm* 25 mm either from undisturbed soil sample or from compacted or remolded sample. Soil specimen may also be directly prepared in the box by compaction.
ii. Fix the upper part of the box to the lower box by fixing screws. Attach the base plate to the lower part.
iii. Place the porous stone in the box.
iv. Transfer the soil specimen prepared into the box.
v. Place the upper grid, porous stone, and loading pad in the order on soil specimen.
vi. Place the box inside the container and mount it on loading frame.
vii. Bring the upper half of the box in contact with the proving ring assembly. Contact is observed by the slight movement of proving ring dial gauge needle.
viii. Mount the loading yoke on the ball placed on the loading pad.
ix. Put the weight on the loading yoke to apply a given value of normal stress intensity. Add the weight of the yoke also in the estimation of normal stress intensity.
x. Remove the fixing screws from the box and raise slightly the upper box with the help of the spacing screws. Remove the spacing screws also.
xi. Adjust the entire dial gauge to read zero.
xii. Shear load is applied at constant rate of strain.
xiii. Record the readings of proving ring and dial readings at a fixed interval.
xiv. Continue the observations till the specimen fails.
xv. Repeat the test on the identical specimen under increasing normal stress and record the corresponding reading.

PRECAUTIONS

i. Before starting the test, the upper half of the box should be brought in proper contact with the proving ring.
ii. Before subjecting the specimen to shear, the fixing screws should take out.
iii. Spacing screws should also be removed before shearing the specimen.
iv. No vibrations should be transmitted to the specimen during the test.
v. Do not forget to add the self weight of the loading yoke in the vertical loads.

APPLICATION

The purpose of direct shear test is to get the ultimate shear resistance, peak shear resistance, cohesion, angle of shearing resistance and stress-strain characteristics of the soils.

Shear parameters are used in the design of earthen dams and embankments. These are used in calculating the bearing capacity of soil-foundation systems. This parameter is helps in estimating the earth pressures behind the retaining walls. The values of these parameters are also used in checking the stability to natural slopes, cuts and fills.

OBSERVATION AND CALCULATION TABLE

1. Size of box (mm) = 60X60 = 36 cm^2
2. Area of box (cm^2) = 36 cm^2
3. Volume of box (cm^3) = 109.08
4. Mass of soil (gm) =
5. Density of soil (kg/cm^3) =
6. Least count of displacement dial gauge (mm/div.) =________
7. Proving ring constant (kg/div.) = ________kg/div.

Normal stress: 0.5kg/cm^2

Horizontal dial reading (Div)	**Horizontal displacement** (mm)	Shear strain	Load dial reading (Div)	**Horizontal shear force** (kg)	**Shear stress** (kg/cm^2)

Normal stress: 1kg/cm^2

Horizontal dial reading (Div)	**Horizontal displacement** (mm)	Shear strain	Load dial reading (Div)	**Horizontal shear force** (kg)	**Shear stress** (kg/cm^2)

Normal stress: 1.5kg/cm^2

Horizontal dial reading (Div)	**Horizontal displacement** (mm)	Shear strain	Load dial reading (Div)	**Horizontal shear force** (kg)	**Shear stress** (kg/cm^2)

NOTE

Draw Graph for the Normal Stress Vs Maximum Shear Stress.

Cohesion (kg/cm^2) =

The angle of shearing resistance (Φ) =

CONCLUSION:

DATE **SIGN**

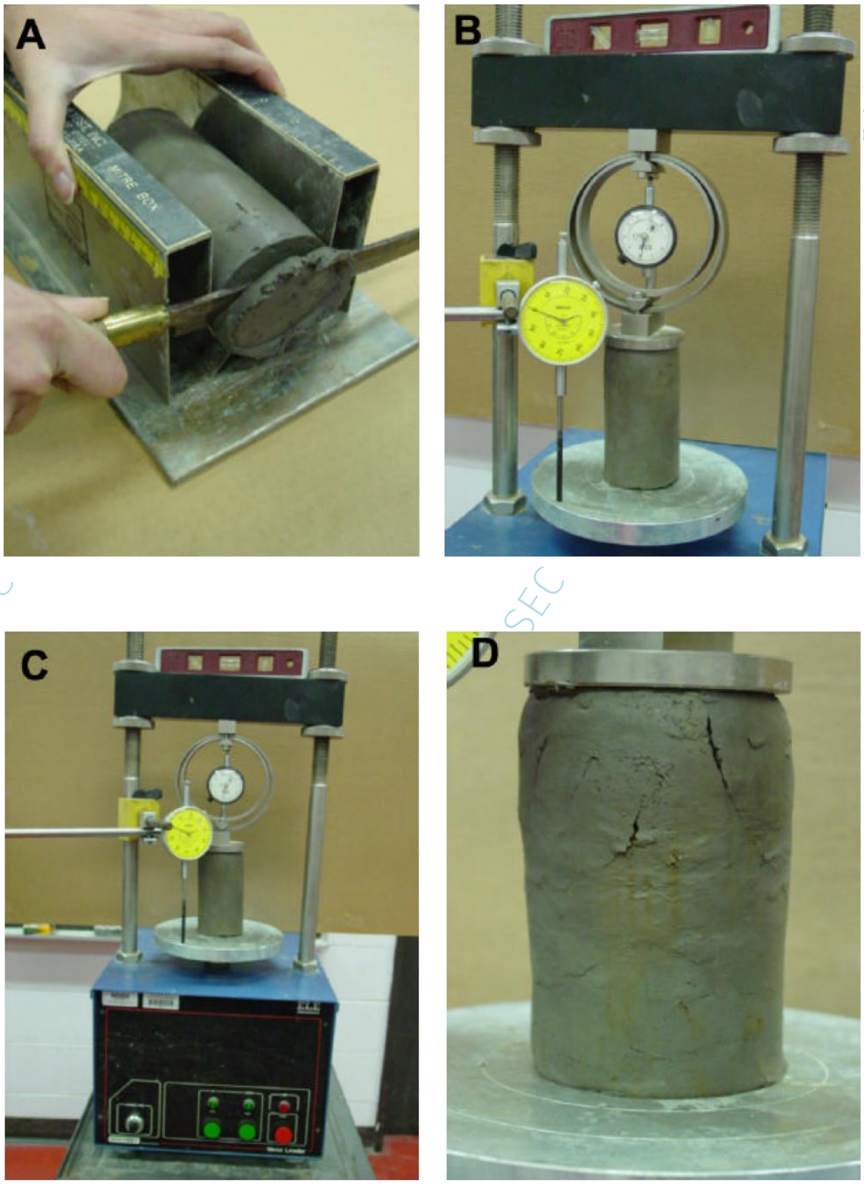


Figure No: 10.1 Unconfined compression Test Arrangements

Date: / /

EXPERIMENT NO. 8 UNCONFINED COMPRESSION TEST

AIM

To determine the shear parameter of the clay under unconfined conditions.

APPARATUS

Compression devise, Load and deformation dial gauges, Sample trimming equipment, Balance, Moisture can.

MATERIAL

Cohesive soil sample, Water.

THEORY

The unconfined compressive strength (qu) is defined as the compressive stress at which an unconfined cylindrical specimen of soil will fail in a simple compression test. In addition, in this test method, the unconfined compressive strength is taken as the maximum load attained per unit area, or the load per unit area at 15% axial strain, whichever occurs first during the performance of a test.

For soils, the undrained shear strength (su) is necessary for the determination of the bearing capacity of foundations, dams, etc. The undrained shear strength (su) of clays is commonly determined by an unconfined compression test. The undrained shear strength (su) of cohesive soil is equal to one-half the unconfined compressive strength (qu) when the soil is under the $\phi = 0$ condition (ϕ = the angle of internal friction). The most critical condition for the soil usually occurs immediately after construction, which represents undrained conditions, when the undrained shear strength is basically equal to the cohesion(c). This is expressed as:

$$Su = C = \frac{q_u}{2}$$

Then, as time passes, the pore water in the soil slowly dissipates, and the intergranular stress increases, so that the drained shear strength (s), given by s = c'+ σ'tan ϕ', must be used.

Where

s' = intergranular pressure acting perpendicular to the shear plane;

s' = (s - u),

s = total pressure,

u = pore water pressure; c' and ϕ of are drained shear strength parameters.

OBSERVATIONS AND CALCULATIONS

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

Proving ring constant (kg/div.) =

Type of specimen: Undisturbed/ Re-moulded

The initial length of the specimen, L_0 (mm) =

The initial diameter of the specimen, D_0 (mm) =

The initial area of the specimen, A_0 (cm^2) =

Elapsed time (min)	Vertical deformation (ΔL)		Vertical strain $\xi = \frac{\Delta L}{L_0}$	**Corrected area** $A = \frac{A_0}{1 - \xi}$ (mm^2)	**Compressive load**		**Compressive stress** (N/mm^2)
	(div.)	(mm)			(div.)	(N)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8) = (7)/(5)
0.5							
1							
1.5							
2							
3							
4							
5							
6							
8							
10							

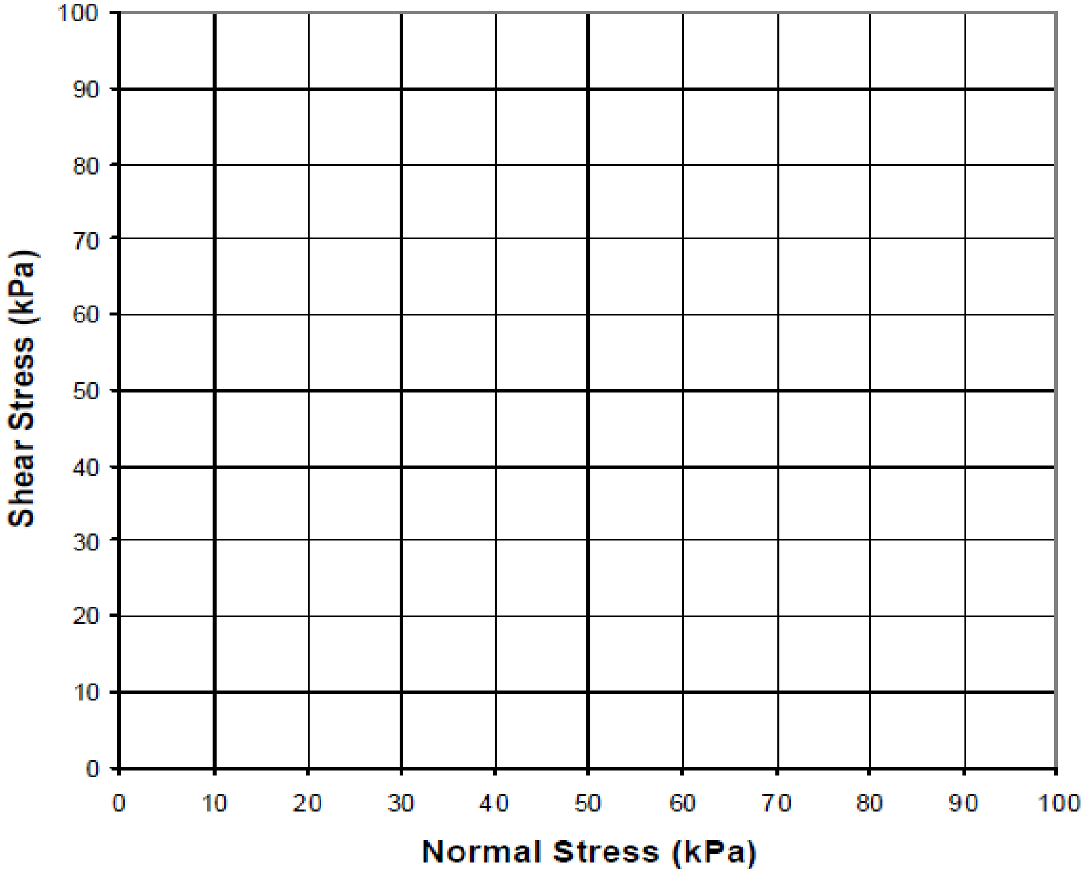
PROCEDURE

1. Extrude the soil sample from the Shelby tube sampler. Cut a soil specimen so the ratio (L/d) is approximately between 2 and 2.5. Where L and d are the length and diameter of soil specimen, respectively.
2. Measure the exact diameter of the top of the specimen at three locations 120° apart, and then make the same measurements on the bottom of the specimen. Average the measurements and record the average as the diameter on the datasheet.
3. Measure the exact length of the specimen at three locations 120° apart, and then average the measurements and record the average as the length on the datasheet.
4. Weigh the sample and record the mass on the datasheet.
5. Calculate the deformation (ΔL) corresponding to 15% strain (e).

$$\text{Strain (e)} = \frac{\Delta L}{L_o}$$

   Where L_o= Original specimen length (as measured in step 3).

6. Carefully place the specimen in the compression device and center it on the bottom plate. Adjust the device so that the upper plate just makes contact with the specimen and set the load and deformation dials to zero.
7. Apply the load so that the device produces an axial strain at a rate of 0.5% to 2.0% per minute, and then record the load and deformation dial readings on the data sheet at every 20 to 50 divisions on deformation the dial.
8. Keep applying the load until (1) the load (load dial) decreases on the specimen significantly, (2) the load holds constant for at least four deformation dial readings, or (3) the deformation is significantly past the 15% strain that was determined in step 5.
9. Draw a sketch to depict the sample failure.
10. Remove the sample from the compression device and obtain a sample for water content determination.



RESULTS

From the stress-strain curve and Mohr’s circle:

Unconfined compressive strength (qu) = _____________ N/mm2

Cohesion (c) = qu/2 = ____________ N/mm^2

CONCLUSION

DATE **SIGN**

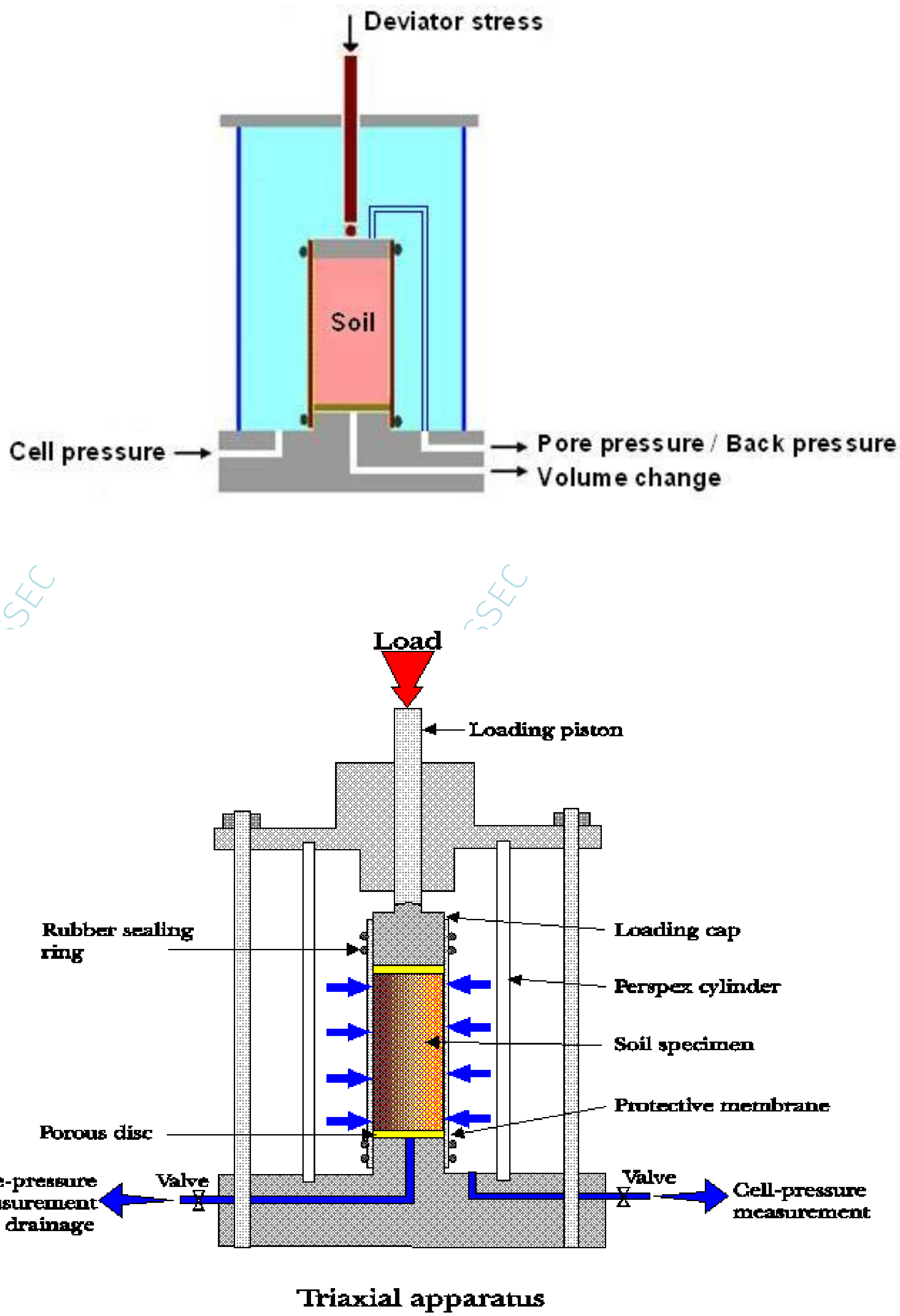


Figure No. 11.1 Typical Triaxial Apparatus

Date: / /

EXPERIMENT NO. 11 STUDIES OF TRIAXIAL TEST

AIM

Determination of shear strength parameters of soils under triaxial loading conditions.

APPARATUS

Triaxial cell, Compression machine, Cell pressure application system, Pore pressure measuring device, Volume change measuring device, Proving ring, Deformation dial gauge, Split mold, Trimming knife, Rubber membrane, Membrane stretcher, Rubber ‘O' rings, Balance, Apparatus for moisture content determination.

THEORY

The triaxial test is carried out in a cell on a cylindrical soil sample having a length to diameter ratio of 2. The usual sizes are 76 mm x 38 mm and 100 mm x 50 mm. Three principal stresses are applied to the soil sample, out of which two are applied water pressure inside the confining cell and are equal. The third principal stress is applied by a loading ram through the top of the cell and is different to the other two principal stresses. A typical triaxial cell is shown.

The soil sample is placed inside a rubber sheath which is sealed to a top cap and bottom pedestal by rubber O-rings. For tests with pore pressure measurement, porous discs are placed at the bottom, and sometimes at the top of the specimen. Filter paper drains may be provided around the outside of the specimen in order to speed up the consolidation process. Pore pressure generated inside the specimen during testing can be measured by means of pressure transducers.

The triaxial compression test consists of two stages:

First stage: In this, a soil sample is set in the triaxial cell and confining pressure is then applied.
Second stage: In this, additional axial stress (also called deviator stress) is applied which induces shear stresses in the sample. The axial stress is continuously increased until the sample fails.

During both the stages, the applied stresses, axial strain, and pore water pressure or change in sample volume can be measured.

OBSERVATIONS AND CALCULATIONS

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

Proving ring constant (kg/div.) =

Confining cell pressure, σ_3 (kg/cm^2) =

Initial diameter of specimen, D_0 (mm) =

Initial length of specimen, L_0 (mm) =

Deformation dial reading (ΔL)		Vertical strain $\xi = \frac{\Delta L}{L_0}$	**Burette reading** (DV) (cm^3)	**Pore pressure change** (Du) (kg/cm^2)	**Proving ring dial reading**		**Corrected area for undrained test** $A = \frac{A_0}{1 - \xi}$ (cm^2)	**Corrected area for drained test** $A = \frac{V_0 - \Delta V}{L_0 - \Delta L}$ (cm^2)	**Deviatoric stress** $(\sigma_1 - \sigma_3)$ (kg/cm^2)
(div.)	(mm)				(div.)	(kg)			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10) =(7)/A

RESULTS

Water content (%) =

Cohesion (kg/cm^2) =

Angle of shearing resistance (°) =

Test Types

There are several test variations, and those used mostly in practice are:

UU (unconsolidated undrained) test: In this, cell pressure is applied without allowing drainage. Then keeping cell pressure constant, deviator stress is increased to failure without drainage.

CU (consolidated undrained) test: In this, drainage is allowed during cell pressure application. Then without allowing further drainage, deviator stress is increased keeping cell pressure constant.

CD (consolidated drained) test: This is similar to CU test except that as deviator stress is increased, drainage is permitted. The rate of loading must be slow enough to ensure no excess pore water pressure develops.

In the UU test, if pore water pressure is measured, the test is designated by UU. In the CU test, if pore water pressure is measured in the second stage, the test is symbolized as CU.

PROCEDURE

1. Prepare a test specimen of necessary diameter and length, and measure its weight. Place a rubber membrane around the specimen using the membrane stretcher.

2. De-air the outlet line at the pedestal of the triaxial base, place on its top a saturated porous stone with a filter paper disc, and then position the soil specimen with the membrane stretcher around it. Put a loading cap on the specimen top, and seal the membrane on to the bottom pedestal and the top cap with ‘O' rings.

3. Assemble the triaxial cell with the loading ram initially clear of the top cap. Fill the cell with water, raise the water pressure to the desired value, and maintain the pressure constant. Raise the platform of the compression machine to bring the ram in contact with the seat on the top cap.

4. Set both the proving ring dial gauge and the deformation dial gauge to zero, select an axial strain rate, and verify that the cell pressure remains constant.

5. For undrained shearing of saturated samples, either close the outlet valve at the base of the cell or connect it to a pore pressure transducer. For drained shearing of saturated samples, connect the outlet to a burette for volume change measurements.

6. Apply axial compression load and take readings of the proving ring at intervals of 0.20 mm vertical deformation till the peak load has been passed, or till the strain reaches 20% of the specimen length. Record also burette or pore pressure readings, as applicable.

7. Remove the axial load, drain the water from the cell, remove the specimen, make a sketch of the failure pattern, and take soil samples for water content determination.

8. Repeat the test on identical soil specimens under different cell pressures.

SIGNIFICANCE OF TRIAXIAL TESTING

the first stage simulates in the laboratory the in-situ condition that soil at different depths is subjected to different effective stresses. Consolidation will occur if the pore water pressure which develops upon application of confining pressure is allowed to dissipate. Otherwise, the effective stress on the soil is the confining pressure (or total stress) minus the pore water pressure which exists in the soil.

During the shearing process, the soil sample experiences axial strain, and either volume change or development of pore water pressure occurs. The magnitude of shear stress acting on different planes in the soil sample is different. When at some strain the sample fails, this limiting shear stress on the failure plane is called the shear strength.

The triaxial test has many **advantages** over the direct shear test:

• The soil samples are subjected to uniform stresses and strains.

• Different combinations of confining and axial stresses can be applied.

• Drained and undrained tests can be carried out.

• Pore water pressures can be measured in undrained tests.

• The complete stress-strain behavior can be determined.

CONCLUSION

DATE **SIGN**

GOVERNMENT OF GUJARAT

Shantilal Shah Engineering College, Bhavnagar