



University of Technology
Building & Const. Eng. Dept.
Highway & Bridges Branch



LABORATORY SOIL TESTS

Supervised by

Dr. Mahmood Rasheed

Lec. Kawther Yaly Hussain

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EXPERIMENT NO.1
SPECIFIC GRAVITY OF SOIL SOLIDS
ASTM D-854

1. AIM

To determine the specific gravity of soil solids using pycnometer .

2. APPARATUS:

Pycnometer , Balance capacity 500g accuracy 0.1g, Vacuum pump, Water bath, Oven

3. PROCEDURE:

3.1 Collect about 500g of represent active soil sample, oven dry the sample by keeping it in oven maintained at $110^{\circ}\text{C} \pm 5^{\circ}\text{C}$ at least for 12 hours.

3.2 Record the weight (W_1) of a clean and dry pycnometer .

3.3 Place about 100g of soil sample in the pycnometer and determine its weight (W_2).

3.4 Fill the Pycnometer to half its height and boil it gently in water bath with occasional rolling for the removal of air entrapped in the voids. This can also be done by keeping the Pycnometer on water bath and applying vacuum. Add more water and fill up the Pycnometer . dry the Pycnometer from outside and weight it (W_3).

3.5 Empty the Pycnometer , clean it and fill with distilled water. Dry the Pycnometer from outside and weight it (W_4).

3.6 Repeat the test at least 3 time accurate determination of specific gravity

4. CALCULATIONS

Calculate the specific gravity of soil using ,

$$GS = \frac{\text{Dry weight of soil}}{\text{Weight of equal volume of water}}$$
$$= \frac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_2)}$$

5. RESULTS

Fond the average specific gravity of soil sample.

6. DATA SHEET

Sr.	Details	Trial	Trial	Trial
No.		1	2	3
1	Pycnometer No.			
2	Wt. of empty Pycnometer W1			
3	Wt. of Pycnometer + dry soil W2			
4	Wt. of Pycnometer + dry soil + water W3			
5	Wt. of Pycnometer + water W4			
6	Specific gravity of soil GS			

EXPERIMENT NO. 2
SIEVE ANALYSIS
ASTM D-422

1. AIM:

To determine particle size distribution of soil sample using sieve analysis.

2. APPARTUS :

Balance (capacity 1 kg accuracy 1g), set of standard sieve, Brush, Sieve shaker

3. PROCEDURE:

3.1 Take about 500g of representative soil sample, the sample should be oven dry.

3.2 Note the weight of sample

3.3 Arrange a stack of clean and standard sieve for a sandy soil the recommended set of sieve are:

ASTM NO. 10, 20, 40, 60, 100 and 200

3.4 Place the set of sieve with cover at top and pan at the bottom on a sieve Shaker, operate the shaker for 5 to 10 minutes ,if the sieve shaker is not available , perform the sieving operation by hand .

3.5 Remove the stack of sieve from the shaker and measure the weight of soil retained on each sieve

4. CALCULATION:

% retained on each sieve is calculated as:

$$RS = \frac{\text{Wt.of soil retained}}{\text{Total Wtof soil sample}} \times 100$$

Cumulative % retained = Sum of % retained up to that sieve .

% finer = 100 – cumulative % retained

5. RESULTS

Plot graph of % finer vs. log. Particle .

Determine uniformity coefficient

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

And coefficient of curvature

$$C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$$

6. CHECKLIST:

1. For hand sieving change the mode of shaking so that grains are continuously moved on the screen of sieve .
2. If the recommended sieve size are not available select the nearest available size .
3. This analysis is valid for soils having % finer on sieve No. 200 less than 10 to 12%.
4. Check that the loss in weight of residue is less than 2%.

7. DATA SHEET:

Weight of soil sample =

Sieve analysis

Sr. No.	Sieve NO.	Sieve opening	Wt. of soil retained	%Retained	Cumulative % retained	% finer
	10					
	20					
	40					
	60					
	100					
	200					
	pan					

Total

EXPERIMENT NO. 3
HYDROMETER ANALYSIS
ASTM D-422

1. AIM

To determine grain size distribution of soil, which contains appreciable quantity of soil passing ASTM 200 sieve (0.075 mm).

2. APPARATUS:

Standard hydrometer

Two graduated cylinders (capacity 1000 cc)

Balance (capacity 100g accuracy 0.1 g)

Drying oven

High speed stirrer

Thermometer (range to 50 °c , accuracy 0.1 °c)

Stop watch

ASTM sieve No. 200 (0.075 mm)

3. PROCEDURE:

3.1 Record area of cross section of cylinder A, volume of hydrometer V_h , length of the bulb of hydrometer L_2 , the reading of hydrometer R and the corresponding length from the top of the bulb , from these observations calibrate the hydrometer . the readings of hydrometer R varies from – 5 to 30 for a hydrometer calibration from 0.995 to 1.030.

3.2 Record the height of meniscus rise on stem of hydrometer .

3.3 Take about 50g oven dry soil passing through ASTM sieve No. 200 .

3.4 Prepare solution of dispersing agent by adding 40g of sodium hexametaphosphate to 1000 cc of distilled water.

3.5 Add 125 cc of the solution prepared in 3.4 to the soil sample.

3.6 Transfer the mixture to high speed stirrer and add some more distilled precaution not to lose any soil .

3.7 Operate the stirrer for 3 to 5 minutes then transfer the mixture from stirrer cup to graduated cylinder , called as , sedimentation jar. Rinse the cup thoroughly to transfer all the soil to the sedimentation jar.

3.8 Add some more distilled water to make the volume of suspension equal to 1000 cc .

3.9 Fill a graduated cylinder by 1000 cc of distills water. This cylinder is called as , control jar.

- 3.10 Cover the sedimentation jar either by rubber stopped or by palm of hand and agitate the solution by moving the jar upside down for about 30 sec.
- 3.11 Insert hydrometer in the sedimentation jar and start the stop watch. Take the hydrometer readings at total elapsed time of 1/2 , 1 ,2 , and 4 minutes without removing the hydrometer.
- 3.12 Repeat the steps 3.10 and 3.11 till the initial reading agree.
- 3.13 After agreement of initial readings continue to take readings at elapsed times of 9, 16, 25,36,49,64, and 121 minutes. Afterwards the readings are taken at elapsed when the reading in the sedimentation jar becomes nearly equal to that in the control jar . After each reading beyond 2 minutes remove the hydrometer from suspension and store it in the control jar . before each insertion of the hydrometer , dry the stem.
- 3.14 Take the temperature reading in the control jar corresponding hydrometer reading.

4. CALCULATIONS:

The effective length of hydrometer , L is calculated for two situation as :

- (i) Without immersion correction ,

$$L = L_1 + \frac{1}{2}L_2$$

- (ii) With immersion correction

$$L = L_1 + \frac{1}{2} \left(L_2 \frac{V_h}{A} \right)$$

Where , L_1 = the distance of hydrometer reading R from the starting of stem portion .

L_2 = the distance of hydrometer bulb.

V_h = volume of hydrometer

A = area of cross section of sedimentation jar .

Diameter of particle size Dis. Given as ,

$$D = K \sqrt{\frac{L}{t}}$$

D in mm.

Where k = for known G & T value taken from table

L= effective length in cm.

t= elapsed time in min .

% finer of soil , N at any elapsed time is given as:

$$N = \frac{G}{G - 1} \cdot \frac{\gamma_w}{W_s} (R - R_w) \times 100$$

Where ,

G = specific gravity of solids

W_s = wt of dry soil

γ_w = unit weight of water at temperature of hydrometer calibration, see the table.

R= hydrometer reading in sedimentation jar.

R_w = hydrometer reading in control jar

$N = a (R - R_w)$

Where a= constant

$$N = \frac{G}{G - 1} \cdot \frac{\gamma_w}{W_s} 100$$

5. RESULTS:

Plot the calibration curves on a graph between hydrometer reading R vs. effective length L for two cases vise.

1-Without immersion correction and

2- With immersion correction. From this graph effective length for subsequent hydrometer reading can be directly obtained.

Plot another graph between diameter of particle vs. % finer on semi log scale. From this find % clay , silt and fine sand in the soil sample.

6. CHECKLIST

- 6.1 before each insertion of hydrometer , check that the stem is dry.
- 6.2 practice insertion of hydrometer and recording of reading before starting the experiment.
- 6.3 check that the temperature in sedimentation jar and control jar are same during the entire period of test .

7. DATA SHEET:

Hydrometer No.

Length of bulb $L_2=$

Volume of hydrometer , $V_h=$

Area of sedimentation jar , $A =$

Meniscus correction , $c_m=$

Wt . of dry soil passing ASTM 200 sieve $w_s=$

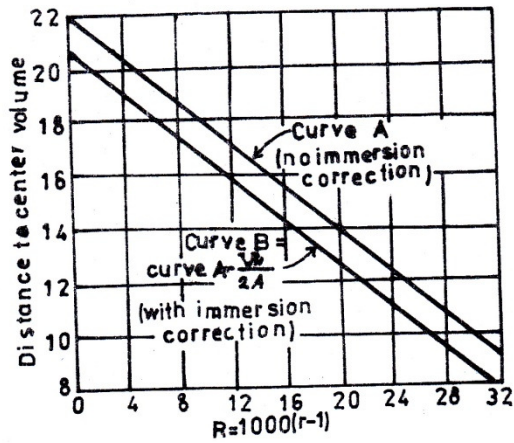
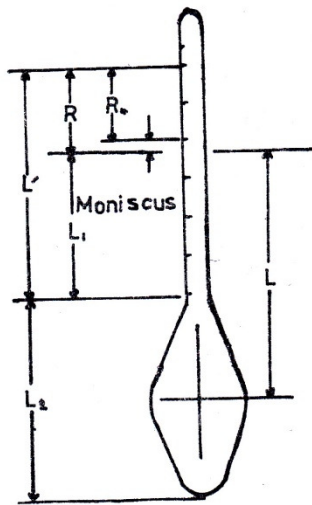
a- Calibration of hydrometer :

Sr. hydrometer No. reading	Hydrometer reading corrected for meniscus $R_C=R+C_m$	Length L_1 in cm.	Effective length $L = L_1 + \frac{L}{2} L_2$	Effective length with immersion correction $L = L_1 + \frac{L}{2} (L_2 - \frac{v_h}{A})$
1				
2				
3				

Date	Time	Elapsed time in min	Hydrometer reading (R) in sedi- mentation jar	Hydrometer reading R_w in control jar	$R - R_w$	Tempera- ture T in $^{\circ}C$	Const- ant a	Constant K	Effective length, L in cm.	$\frac{L}{t}$	Particle diameter D in mm.	finer N

Table 6-4 Values of K for Use in Eq. (6-8a) for Several Unit Weights of Soil Solids and Temperature Combinations

Temp (°C)	UNIT WEIGHT OF SOIL SOLIDS (g/cm ³)							
	2.50	2.55	2.60	2.65	2.70	2.75	2.80	2.85
16	0.0151	0.0148	0.0146	0.0144	0.0141	0.0139	0.0137	0.0136
17	0.0149	0.0146	0.0144	0.0142	0.0140	0.0138	0.0136	0.0134
18	0.0148	0.0144	0.0142	0.0140	0.0138	0.0136	0.0134	0.0132
19	0.0145	0.0143	0.0140	0.0138	0.0136	0.0134	0.0132	0.0131
20	0.0143	0.0141	0.0139	0.0137	0.0134	0.0133	0.0131	0.0129
21	0.0141	0.0139	0.0137	0.0135	0.0133	0.0131	0.0129	0.0127
22	0.0140	0.0137	0.0135	0.0133	0.0131	0.0129	0.0128	0.0126
23	0.0138	0.0136	0.0134	0.0132	0.0130	0.0128	0.0126	0.0124
24	0.0137	0.0134	0.0132	0.0130	0.0128	0.0126	0.0125	0.0123
25	0.0135	0.0133	0.0131	0.0129	0.0127	0.0125	0.0123	0.0122
26	0.0133	0.0131	0.0129	0.0127	0.0125	0.0124	0.0122	0.0120
27	0.0132	0.0130	0.0128	0.0126	0.0124	0.0122	0.0120	0.0119
28	0.0130	0.0128	0.0126	0.0124	0.0123	0.0121	0.0119	0.0117
29	0.0129	0.0127	0.0125	0.0123	0.0121	0.0120	0.0118	0.0116
30	0.0128	0.0126	0.0124	0.0122	0.0120	0.0118	0.0117	0.0115



EXPERIMENT NO.4
FIELD DENSITY BY SAND
REPLACEMENT METHOD
ASTM D-1556

1. AIM

To determine field density of soil and water content of soil.

2. APPARATUS:

Sand replacement apparatus.

Digging tools

Balance (capacity 25kg accuracy 10 g)

Balance (capacity 200g accuracy 0.01g)

uniformly graded medium sand .

3. PROCEDURE

(i) calibration of equipment :

3.1 Take empty weight of calibration jar , & its size.

3.2 Fill the cylinder of sand replacement apparatus with uniformly graded medium sand .

3.3 Run the sand from the apparatus to fill the calibration jar. Make the surface on sand level to the top of jar by straight edge. Record the weight of sand in the jar.

3.4 Keep the apparatus on flat surface and allow the sand to fill the cone of the apparatus. Record the weight of sand filled in the cone of the apparatus.

3.5 Find the volume of calibration jar.

3.6 Find the bulk density of sand.

(ii) field work :

3.7 Take the empty weight of sand replacement apparatus.

3.8 Fill the cylinder of the apparatus with valve closed by calibrated sand and again take the weight of the apparatus.

3.9 Clean and level the state where field density is desired. Keep the template with central hole on the leveled ground. Excavate the soil from the hole by digging tools. Collect all the excavated soil in a tray.

3.10 Keep the sand replacement apparatus with valve in closed position on the hole of the template.

3.11 Open the valve and allow the sand run down.

3.12 When running of sand stops completely close the valve.

(iii) laboratory work

3.13 Record the weight of excavated soil

3.14 Record the weight of sand replacement apparatus with left over sand in the cylinder from this; find the weight of sand used in the field.

3.15 Find the weight of sand used to fill the excavated hole.

3.16 From the bulk density of sand and weight of sand determine the volume of the excavated soil.

3.17 Take at least two sample of the excavated soil and determine water content

3.18 Determine the field density, water content and dry density of soil

4. DATA SHEET:-

(i) calibration of equipment :-

1- Wt. of calibration jar , W1

2- Vol. of calibration jar , V1

3- Wt. of jar + sand ,W2

4- Wt. of sand to fill the jar , $W3 = W2 - W1$

5- Wt. of sand to fill cone of the apparatus , W4

6- bulk density of sand , γ_b

ii-Water content determination :

	Trial 1	Trial 2
1- Can No.		
2- Empty Wt. of can		
3- Wt. of can + wet soil		
4- Wt. of can + dry soil		
5- Wt. of water		
6- Wt. of dry soil		
7- Water content , W%		

(iii) field density determination :

1. Empty Wt. of apparatus , W5

2. Wt. of apparatus + sand , W6

3. Wt. of apparatus + sand, after running down sand , W7.

4. Wt. of sand used in field , $W8 = W6 - W7$

5. Wt. of sand used to fill the excavated hole $W9 = W8 - W4$

6. Wt. of excavated soil , W₁₀
7. Volume of excavated soil , V₂
8. Field density of soil γ_{rfield}
9. Water content of soil , W%
10. Dry density of soil , γ_{dry}

5. CALCULATIONS

First calculation the bulk density of sand as :-

$$\gamma_b = \frac{\text{Wt. of sand to fill the calibration jar}}{\text{Volume of calibration jar}} \quad \frac{W_3}{V_1}$$

To find the density of soil make the calculation as :

Wt. of sand used to fill the excavated hole

= total Wt. of sand used in the field – Wt. of sand used to fill the cone of the apparatus.

$$\text{I . e. } W_g = W_8 - W_4$$

$$\text{Volume of excavated soil , } V_2 = \frac{W_g}{\gamma_b}$$

$$\text{Field density of soil , field} = \frac{\text{Wt. of soil , } W_{10}}{\text{Vol. of soil , } V_2}$$

Determine the water content of soil , W%

Find dry density of soil , using the law as,

$$\gamma_{\text{dry}} = \frac{\gamma_{\text{field}}}{1 + \frac{W}{100}}$$

6. RESULTS:

Report the values of field density water content and dry density of field soil sample .

EXPERIMENT NO.5
FIELD DENSITY BY BALLOON METHOD
ASTM D-2167

1. AIM

To determine the field density of soil by rubber balloon method.

2. APPARATUS :-

Balloon density apparatus, balance 0.01g sensitivity, oven, chisel ,containers , density plate .

3. PROCEDURE

3.1 remove base from the density apparatus removing the four socket head screws with hexagon wrench .

3.2 pass the neck of the balloon through hole in base and then stretch it over the lip around the hole. Fit wire around the balloon under the lip twist ends together and fold ends down .

3.3 replace the base and fit socket screws and tighten .

3.4 remove the hexagon headed filler cap . fill unit through the aperture with clean water until the level is coincident with the top of sighting window.

Replace filler cap , and tighten in position .

3.5 stand the apparatus on a smooth, flat surface and check for air and water tightness by pressurizing the system slightly.

3.6 position the density plate on a smooth flat surface and set the apparatus into the recess.

3.7 pressurize the system and continue pump until the water level in the graduated cylinder reaches its lowest point Record the volume shown . this is initial based reading .

3.8 release the pump and invert the pump to suck the balloon into the cylinder .

3.9 put the density plate on the surface of the material to be tested and dig through the hole in the plate to the desired depth .

3.10 retain all the material which is removed from the hole . record the weight of excavated material .

3.11 set the apparatus in the recess of the density plate , and pump the balloon into the hole .

3.12 record the lowest point (final reading) reached by the water in the cylinder .

3.13 reverse the air pump and by suction , pump the balloon back into the cylinder .

3.14 take sample of excavated soil and determined its moisture content .

4. CALCULATION

4.1 subtract the initial based reading from the final reading . this will give the volume of the hole in cubic centimeters .

4.2 make density calculation based on volume of the test hole and weight of soil excavated .

4.3 calculated moisture and dry density .

5. RESULTS :-

Report the values of water content dry density and field density of soil .

6. DATA SHEET :-

Initial volume reading

Final volume reading

Volume of soil excavated

Weight of soil excavated

Moisture content determination

	Trial 1	Trial 2
Can NO.		
Wt. of can + soil		
Wt. of can + dry soil		
Wt. of can		
Moisture content		
Av. Value		

EXPERIMENT NO. 6
LIQUID LIMIT AND PLASTIC LIMIT
ASTM D-4318

1. AIM :-

To determine the liquid limit and plastic limit of soil .

2. APPARATUS :-

Liquid limit device , grooving tool , glass plate balance (0.01g sensitivity), oven , spatula , wash bottle ASTM sieve No. 40 (0.425 mm)

3. PROCEDURE:-

3.1 liquid limit determination

3.1.1 Check the height of fall of the L.L. device . grooving tool has end block of size 1 cm . it can be used to check the height of fall .

3.1.2 Take a bout 200g of soil passing ASTM sieve No. 40 in aporcetain dish . add distilled water to soil and mix it thoroughly to form uniform paste .

3.1.3. Place the soil in the cap of liquid limit device to a maximum depth of 13mm and level the surface.

3.1.4. Draw the grooving tool through the sample to set asymmetrical groove in the centre of the cup.

3.1.5 Turn the crank at a rate of two revolutions per second , and count the blows necessary to close the groove for a distance of 13mm , preferably observe the no. of blows , must be between 10 and 40 .

3.1.6 Take approximately 10 g of soil from near the closed groove for water content determination.

3.1.7. Remove the sample from the cup and clean the cup .

3.1.8. By altering the water content of soil and repeating steps 3.1.2. to 3.1.5. Obtain four water content determination and their respective number of blows.

3.2 plastic limit determinations:-

3.2.1 Mix thoroughly a bout 20g of soil .

3.2.2. Roll the soil on a glass plate with the palm until it is a uniform tread of 3 mm diameter .

3.2.3. If the soil rolls into thread of less than 3mm diameter, make it a lump again and reroll it until a thread of 3mm diameter shows signs of crumbing .

3.2.4. Take some of the crumbling material obtained in step 3.2.3. for a water content determination .

3.2.5. Repeat steps 3.2.2. to 3.2.4. obtain three determinations which can be averaged to give the plastic limit .

4. CALCULATIONS

In both the experiments of L.L. and P.L. the calculation are made for water content determination. To find the L.L. plot a graph between no. of blows on log scale on x – axial and water content on y- axis as shown in fig (a) find the water content corresponding to 25 blows. This will give the liquid limit of soil.

From the L.L. & P.L. values calculated the P.I as

$$PI = L.L. - P.L$$

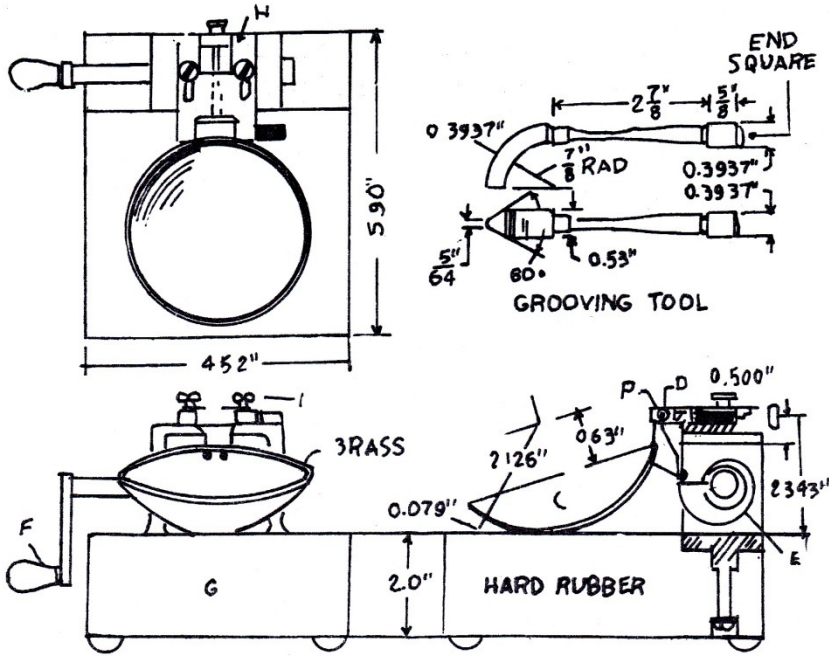
5. RESULTS :-

Report the values of L.L. , P.L. and P.I of soil

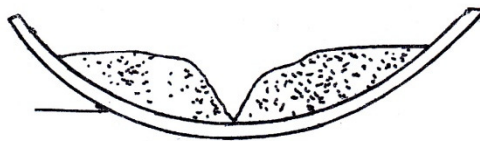
6. DATA SHEET

Liquid limit :-

NO	1	Trial No. 1	2	3	4
1	Number of blows N				
2	Wt. of wet soil + can w1				
3	Wt. of dry soil + can w2				
4	Wt. of can w3				
5	Wt. of dry soil w2-w3				
6	Wt. of moisture w1-w2				
7	Water content W% (w1-w2) / (w2 – w3)				



Divided soil coke before test



Soil coke after test

LIQUID LIMIT TEST

EXPRIMENT NO.7

SHRINKAGE LIMIT

1. AIM:

To determine shrinkage limit of soil sample .

2. APPARATUS:-

Shrinkage dish (circular flat bottom diameter about 44.5 mm and height about 13 mm).

Evaporating dish

Spatula

Volume measuring apparatus .

Balance 500g capacity and 0.1g accuracy .

Oven.

ASTM sieve no.40 (0.425 mm)

3. PROCEDURE:-

3.1 Take about 40g of soil passing ASTM sieve No.40 (0.425) .In the evaporating dish .

3.2 Add water to the soil such that soil will become saturated, or the consistency of soil becomes slightly above liquid limit .

3.3 Apply a light coat of petroleum jelly or oil to the inside of shrinkage dish such coat prevent the soil sticking to the dish.

3.4 Take the weight of empty dish record it .

3.5 Fill the dish with wet soil in the three layer . After each layer top the dish gently on a firm base so that the soil flows all over the dish to remove air bubbles .

3.6 After the final layer, make the top surface of the dish level using spatula clean outside surface of the dish .

3.7 Take the weight of dish filled with wet soil .

3.8 Air dry the dish by placing the dish in the laboratory for about 24 hrs .

3.9 After air drying keep the dish in oven for drying After 24 hours record the weight of dish with dry sample .

3.10 Make the volume measuring apparatus in working condition by checking the level electrical contact, and amount of mercury .

3.11 Remove the air bubbles trapped in the instrument by lowering the cage 2-3 times .

- 3.12 Adjust the micrometer until the bubble just up .Record the reading of the micrometer .
- 3.13 Place the oven dried soil pat in the cage and lower it .
- 3.14 Adjust the micrometer once again after removing trapped air bubbles ,until the bulb just light up . Record the micrometer reading .

4. CACULATION :-

- 4.1 Calculation the volume of wet soil equal to volume of shrinkage dish (V_1)
- 4.2 From the initial wet weight and final dry weight of soil , W_d demine the water content of soil (W_1).
- 4.3 From the micrometer reading of the volume measuring apparatus calculate the dry volume of soil sample (V_d) .
- 4.4 Using the following relationship determine the shrinkage limit of soil sample W_s as :

$$W_s = W_1 \frac{(v_1 - v_d) \gamma_w}{W_d} 100$$

5. RESULT :-

Report the value of shrinkage limit of soil sample .

6. CHECKLIST :-

- 6.1 Avoid direct skin contact with mercury as it a harmful substance .
- 6.2 If the soil pat cracks into pieces on oven dry repeat the test .

7. DATA SHEET :-

Dimension of shrinkage dish .

Diameter of height

Volume

Wt. of shrinkage dish (W_1)

Wt. of shrinkage dish

Wet soil (W_2)

Wt. of shrinkage dish

Oven dried soil (W_3)

Wt. of wet soil ($W_2 - W_1$)

Wt. of dry soil , $W_d = (W_3 - W_1)$

Initial water content , W_1
Micrometer reading , initial
Micrometer reading , final
Volume of dry soil , V_d
Shrinkage limit , W_s

EXPERIMENT NO.8
STANDARD PROCTOR TEST
ASTM D-698

1. AIM :

To determine the relationship between dry density and water content to obtain maximum dry density and optimum moisture water content for a soil.

2. APPARATUS :-

Standard Proctor mould with base plate and collar.

Rammer weight 2.5 kg with fall of 30 cm .

ASTM sieve NO.4(0.425) .

Sample extruder

Tray for mixing soil .

Measuring cylinder 500 ml capacity

Balance (capacity 15kg .accuracy 1g)

Balance (capacity 200g accuracy 0.01g)

3. PROCEDURE :-

3.1 Take about 3 kg of air dry soil passing ASTM NO.4 sieve .

3.2 Weight empty with base plate but without collar .

3.3 Determine the volume of mould by measuring its diameter and height .

3.4 Add about 4 % water by weight i.e. about 120g (120 ml) to the soil .
mix the water thoroughly with soil .

3.5 Compact the soil in the proctor mould . The compaction is done in 3 layers, and each layer is given 25 blows of rammer .the third layer should be about 6 mm .above the top of mould projecting into collar after compaction .

3.6 Remove the collar and termite top compacted soil level to top of the mould by straight edge .

3.7 Recode the weight of the mould with its base plate and compacted soil (W₂).

3.8 Remove the soil from the mould , of necessary by using soil extruder .
collect two samples for water content determination .

3.9 Break the soil into small pieces . Add again about 4 % water by weight to the soil and mix it thoroughly .

3.10 Repeat step 3.5. TO 3.9 till weight of mould with compacted soil decreases .

4. CALCULATIONS :-

From the wet weight (W₂ –W₁) and volume if soil (equal to volume of mould) wet density , γ_{wet} of soil can be calculated as :-

$$\gamma_{wet} = \frac{W_2 - W_1}{V}$$

V : Further dry density of soil calculated using the relationship ,

$$\gamma_{dry} = \frac{\gamma_{wet}}{1 + w}$$

5. RESULTS :-

Plot a graph between moisture content on X -axis and dry density on Y-axis . From the graph the maximum dry density and corresponding optimum moisture content .

6. CHECKLIST

- 3.10 After adding water to sold , mixing of soil is done thoroughly .
- 3.11 Rammer ,while compacting should be moved on the entire surface of in the mould .
- 3.12 After compacting 1 st and 2nd layer make some scratches on the surface of soil for good bond .

7. DATA SHEET :-

Mould dimension :

Volume :

Height:

(i) Moisture content determination :

Sr.No	Trial No.		1	2	3	4	5	
.								
1	Can No.							
2	W _t of empty can							
3	W _t of can + wet soil							
4	W _t of can + dry soil							
5	W _t of moisture							
6	W _t of dry soil							
7	% Moisture content							
8	% Av . Moisture content							

(ii) Density determination :

Sr.No.	Trial No.	1	2	3	4	5
1	W_c of empty mould = W_1					
2	W_c of mould + wet soil = W_2					
3	W_c of wet soil = $W_2 - W_1$					
4	Wet density of soil = γ_{wet}					
5	Moisture content = W					
6	Dry density of soil = γ_{dry}					

EXPERIMENT NO. 9
CONSTANT HEAD PERMEABILITY TEST
ASTM D-2434

1. AIM

To determine the coefficient of permeability of sand sample by constant head permeability test .

2. APPARATUS :-

Permeameter
Constant head reservoir
Stand pipes
Source of water supply
Stop clock (watch)
Measuring jar
Spatula
Slide calipers, scale

3. PROCEDURE

- 3.1 Measure the inner diameter of permeameter and the vertical distance between intake point for piezometer observations .
- 3.2 Open the water supply and fill up the permeameter by letting water in through constant head reservoir .
- 3.3 See that there is no air entrapped in the leads from piezometric in take points in the permeameter .Shut down the flow of water into permeameter .
- 3.4 Deposit through water a layer clean well graded coarse filter material at the bottom of the permeameter . Speared it and gently compact it with a spatula or a rod . The top of filter material should be below the level of bottom intake point for piezometric observation .
- 3.5 Deposit a few spoons full of sand through standing water in the permeameter . The sand must have been washed before ,boiled , cooled and kept submerged in water . Compact the sand using spatula or rod to the required extent . The sample inside permeameter is built up in layer and should extend a little beyond the level of top intake point for piezometric observations .

- 3.6 Deposit a layer of filter material at the top of sample . It must be built up to level to allow the cover at the top to rest on the filter and the permeameter .
- 3.7 Place the cover at the top and tight it with screws
- 3.8 Open the valve slightly to allow flow of water into permeameter . The water allows through soil and comes out at the top . The water level in stand pipe also rises and register pressure at intake point . Watch for the reading in stand pipe to stabilize .Collect the water from top in a measuring jar for a fixed time interval . Record the observation for quantity of water collected and reading on the stand pipe. Repeat the observation for quantity of water collected and the reading on the stand pipe .Repeat the observation till reading are consistent . While making the observation constant head must be maintained in water reservoir . This will be evident by continuous flow water in the overflow pipe .
- 3.9 Repeat step 3 .8 three or four time by varying the discharge of water through soil . This can be controlled by keeping the valve open at different positions .

4. CACULATIONS

Head loss h_1 in col. (5) is $h_1 = H_1 - H_2$. K in col (6) is calculated from :

$$K = \frac{QL}{h_1 A_T}$$

Report the average value of coefficient of permeability of sand sample

5. CHECK LIST

- Ensure that there is no air enterapped in the leads from piezometer intake points .
- There must be continuous overflow of water in the over flow pipe to maintain constant head .
- There must be no leaking in the permeameter .

6. DATA SHEET

Inner diameter of permeameter (D) :

Area of soil sample ($A = \frac{\pi D^2}{4}$)

Distance between bottom and top intake point for piezometric

observations (L) :

Elapsed time	Discharge Q	Reading in stand pipe		Head loss	K
(1)	(2)	bottom	top	(5)	(6)
		(3)	(4)		

EXPERIMENT NO.10

VARIABLE HEAD PERMEABILITY

1. AIM

To determine the coefficient of permeability of soil by variable head test .

2. APPARATUS :

Permeameter mould
stand pipe
vacuum supply
stop clock (watch)
spatula

3. PROSEDURE

- 3.1 Measure the inside diameter of the stand pipe , and the height and inner diameter of permeameter . weight and record the empty weight of permeameter
- 3.2 Fill the permeameter soil sample and trim both ends. Determine the weight of the permeameter with the soil sample . From trimmings at the ends determine the water content of soil .
- 3.3 Place the cover at top and the wire gauze at the bottom and fix the permeameter to its base .
- 3.4 Keep the bottom of permeameter slightly below water level in a tray filled with water .
- 3.5 Through top of permeameter mould apply vacuum for about 20-30 min. to saturate soil sample .
- 3.6 Remove vacuum supply and connect the stand pipe to permeameter . Water must be at sufficient level in stand pipe. It must be ensured that no air gets entrapped in stand – pipe or in the permeameter .
- 3.7 Record the difference in the levels of water in stand pipe and water in the tray .
This is the initial head loss in the soil sample . Start the stop watch .At different elapsed times record the difference in the two water levels .
- 3.8 Remove the soil from permeameter and determine its moisture water content .

4. CALCULATIONS :

4.1 Compute coefficient of permeability in cool 1.4 of data sheet from :

$$K = \frac{aL}{At} \text{Ln} \frac{h_{11}}{h_{12}}$$

a : area of stand pipe

A : area of soil sample

L : length of soil sample (mould)

t : elapsed time

h_{11}, h_{12} head loss in the beginning and end of elapse time

4.2 For saturated soil determine K from :

$$\frac{K_{unsat}}{K_{sat}} = \frac{S}{100} \quad 3.5$$

Where K_{unsat} = K for un saturated soil at degree of saturation

K_{sat} = K for saturated soil .

5. RESULTS

Report the average value of coefficient of permeability .

6. CHECKLIST

No air must be entrapped in stand pipe and permeameter .

7. DATA SHEET

Inner diameter of stand pipe (d) :

Area of stand pipe ($a = \frac{\pi d^2}{4}$) :

Inner diameter of permeameter (D) :

Area of soil sample ($A = \frac{\pi D^2}{4}$) :

Empty weight of permeamter (W_1) :

Length of permeameter (L) :

Volume of permeameter (V) :

Weight of permeameter with soil (W_2)

Total unit weight of sample ($\sigma_c = \frac{W_2 - W_1}{V}$)

Initial moisture water content (W_i)

Initial degree of saturation (S_i)

Moisture water after test (W_f)

Degree of saturation after test (S_f)

Time (1)	Elapse time,t (2)	Head loss, h_1 (3)	K (4)	

EXPERIMENT NO.11
CONSOLIDATION TEST
ASTM D-2435

1. AIM :

To determine the consolidation characteristics of a given soil sample .

2. APPRATUS :

Consolidation unit , specimen trimmer and accessories . Device (sensitivity) ,Oven, Descater Timer , moisture content cans Evaporating dish .

3. PRUSEDURE

3.1- Specimen preparation :-

- 1- Measure the height and inner diameter of the consolidation ring . Also measure the combined thickness of the upper porous stone and cover .
- 2- Determine the weight of those parts which lie on the top of the specimen to add it to computed scale load required to give the desired pressures .
- 3- Trim the test specimen by using a special sample trimmer.
- 4- From the soil trimmings obtain at least three representative specimen for water content determination .
- 5- Place the trimmed specimen in the container carefully .
- 6- Trim the top and bottom faces of the specimen by means of a wire sawer knife .
- 7- Place the specimen and the container on the porous stone which has been soaked in water on the base of the unit , and then raise the water level above the porous stone .
- 8- Place the specimen and the container on the porous stone and carefully place the ring seal , porous stone and cover on top o the soil specimen .

3.2 Compression Test :

1. Mount the container with specimen in the loading unit .
2. Screw the holder with vertical deflections dial in place and adjust it in such a way that dial is the beginning of its release run .
3. Apply the load to give a pressure intensity of 0.1 kg/cm^2 on the soil specimen , and start taking time and vertical deflection reading .

Compression reading should be taken at total elapsed times of $0, \frac{1}{4}, 1, 2, \frac{1}{4}, 4, 6, \frac{1}{4}, 9, 12, \frac{1}{4}, 16, \frac{1}{4}, 20, \frac{1}{4}, 25$ minutes etc . until 90% consolidation has been reached . This point can be determined by the square root fitting method .

4. At the end of 24hr , a compression and time reading should be made and then the load increased to 0.25 kg/cm^2 and step 3.2.3 is repeated . Like wise the following further load increments are made on the soil sample :
 $0.5 \text{ kg/cm}^2, 1 \text{ kg/cm}^2, 2 \text{ kg/cm}^2, 4 \text{ kg/cm}^2$ and 8 kg/cm^2 .
5. After the 8 kg/cm^2 load has been on for 24hr , the load is decreased to 2 kg/cm^2 and then 0.1 kg/cm^2 rebound loads .
6. After the final reading has been taken for the 0.1 kg/cm^2 load . quickly dismantle the apparatus dry the surface water of the soil specimen and weight .
7. Place the weight specimen in the oven to dry for water content determination .

4. CALCULATION :-

The calculation of the consolidation test result are shown in the columns of the data sheet which is as follows :

Col . a- The pressures to which the specimen is to be subjected

b. Its obtain by adding the tare weight to the product of the specimen area and the desired pressure intensity .

c. The final vertical dial reading for each load .

d. The change in final dial readings is the compression for load increment and is found by subtracting successive numbers in column (CA) .

e. Computed 2H values by means of the Δ dial value form column d .

f. The void weight found by subtracting the height of solids , $2H_o$, from the specimen height, 2H, read from col(2) The of $2H_o$ is found from ,

$$2H_o = \frac{W_s}{G_{sw} A}$$

Where W_s = weight of solids

G = specific gravity

A = The area of sample

g. The void ratio e , is equal the void height divided by height of solids .

$$e = \frac{V_v}{V_s} = \frac{A(2H-2H_0)}{A2H_0}$$

h. In this column are listed the time for 90% of primary compression if the square root fitting method is used or the time for 50% of primary compression if the log the fitting method is used .

I. The coefficient of consolidation C_v is computed from the following equation :

a. Square root fitting method $L:C_v = \frac{0.848 H^2}{t_{90}}$

b. Log fitting method $C_v = \frac{0.197 H^2}{t_{50}}$

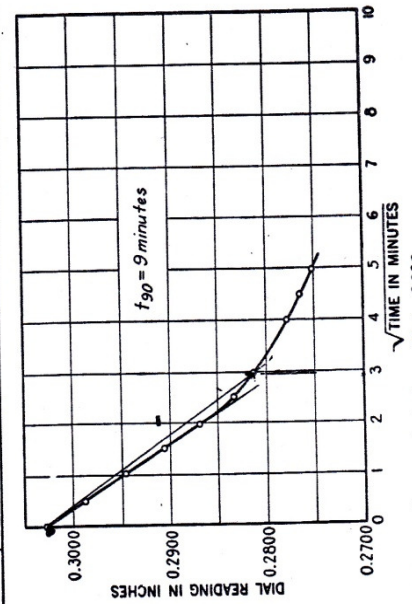
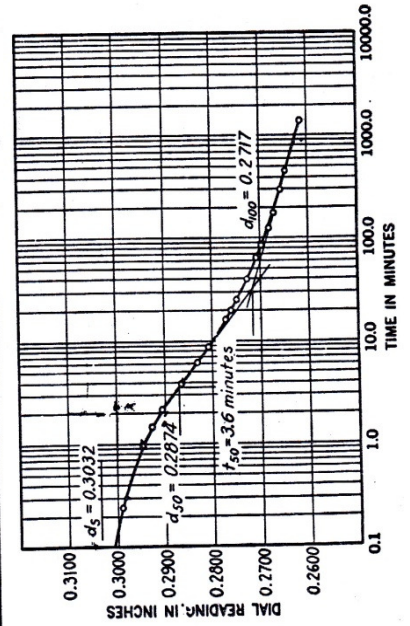
In Eqs , 1&2 H is the average thickness . it is found by dividing the sum of the $2H$ value (col.e) for boundary loads of the increment by four .

SOIL MECHANICS LABORATORY
CONSOLIDATION TEST

TEST NO. C-2 TESTED BY HPA PRESSURE INCREMENT FROM 2 kg./sq. cm. TO 4 kg./sq. cm.

DATE	TIME	ELAPSED TIME, t IN min.	\sqrt{t} IN $\sqrt{\text{min.}}$	COMPRESSION DIAL IN in.
		43		.27245
		68		.27070
		93		.26995
	12:00	130		.26838
	1:00 P.M.	190		.26707
	2:54 P.M.	304		.26562
	5:42 P.M.	472		.26438
Dec. 5, '50	10:00 A.M.	1450		.26176

DATE	TIME	ELAPSED TIME, t IN min.	\sqrt{t} IN $\sqrt{\text{min.}}$	COMPRESSION DIAL IN in.
Dec. 4, '50	9:50 A.M.	0	0	.30280
		0.25	0.5	.29870
		1.00	1.0	.29435
		2.25	1.5	.29037
		4.00	2.0	.28660
		6.25	2.5	.28339
		9.00	3.0	.28090
		12.25	3.5	—
		16.00	4.0	.27738
		20.25	4.5	.27607
		25.00	5.0	.27496



REMARKS: Temperature varied from 20 to 23°C

SOIL MECHANICS LABORATORY
CONSOLIDATION TEST

TEST NO. C-2
DATE Nov. 30, 1950
TESTED BY H.P.A.
DEGREE OF SATURATION IN %
TEST START 65.2
TEST END 100.0

APPLIED LOADS
SIDE FRICTION ALLOWANCE IN % 0
1 kg./sq. cm. = 202 lbs. SCALE LOAD
TARE IN lbs. 4.4

APPARATUS MEASUREMENTS
CONTAINER HEIGHT, $Z_1 - Z_2$ cm. 1.263 in.
CONTAINER DIAMETER 10.8 cm. 4.25 in.
CONTAINER AREA, A, IN sq. cm. 91.8
STONE + COVER THICKNESS, $Z_2 - Z_1$ cm. 0.847 in.

LOCATION Union Falls, Maine
BORING NO. Pit-A-3 SAMPLE DEPTH 3
SPECIFIC GRAVITY, G_s , 2.83
SOLIDS HEIGHT, $2H_0 = \frac{W_s}{G_s \cdot 1.4}$ = 1.71 cm. 0.673 in.

WATER CONTENT

SPECIMEN LOCATION	BEGINNING OF TEST			END OF TEST			REMARKS:
	TOP	BOTTOM	SIDE	ENTIRE	ENTIRE	ENTIRE	
CONTAINER NO.	F 4	F 29	F 9	B 11			Sample had fine silt lenses running in horizontal direction.
WT. CONTAINER + WET SOIL IN g	23.900	28.168	24.421	70.47			
WT. CONTAINER + DRY SOIL IN g	21.740	24.800	22.230	59.25			
WT. WATER, W_w , IN g	2.160	3.368	2.191	11.22			
WT. CONTAINER IN g	13.184	13.294	13.146	147.9			
WT. DRY SOIL, W_s , IN g	8.556	11.506	9.084	444.6			
WATER CONTENT, w , IN %	25.2	29.5	24.1	25.2			

APPLIED PRESSURE IN kg./sq. cm.	SCALE LOAD IN lbs.	FINAL DIAL IN in.	DIAL CHANGE IN in.	Z_3 IN in.	SPECIMEN HEIGHT $2H = Z_1 - Z_2 + Z_3$ IN in.	2 H FROM DIAL CHANGE IN in.	VOID HEIGHT, $2H - 2H_0$, IN in.	VOID RATIO, $e = \frac{2H - 2H_0}{2H_0}$	FITTING TIME IN sec.		COEF. OF CONSOL., c_v IN sq. cm./sec.
									t_{90}	t_{50}	
0	41.0	34000	0.0713			1.262	0.587	0.870	316	59	$848 H^2 / t_{90}$.197 H ² / t ₅₀
1/2	94.5	33287	0.0427			1.255	0.580	0.860	276	66	.00683 .00777 .00782
1	145.0	32880	0.0836			1.250	0.575	0.852	284	58	.00725 .00860
2	246.0	32024	0.1744	0.825	1.241	1.242	0.567	0.840	264	95	.00790 .00510
4	446.0	30280	0.4104	0.768	1.184	1.225	0.550	0.815	540	216	.00368 .00214
8	652.0	26176	0.5414	0.768	1.184	1.184	0.509	0.795	516	201	.00354 .00212
2	1662.0	20762	0.0417			1.129	0.454	0.673			
0.1	448.0	21179	0.2216			1.133	0.458	0.679			
	64.2	23395				1.155	0.480	0.711			

EXPERMINT NO .12
DIRECT SHEAR TEST
ASTM D-3080

1. AIM

To conduct a direct shear test on a dry sand specimen to determine its shear strength parameter .

2. APPARATUS

Direct shear box and accessories – a metal box in two halves , bottom plate ,metal plates with serration , locking pins , loading cap , spacing screws .

Direct shear machine – with facilities to apply normal and shear load on the shear and vertical displacement of the soil sample slide calipers .

Balance – 2 Kg capacity accuracy 1g

3. PROCEDURE

- a. Measure the plan dimension of the shear box .
- b. Insert the bottom plate .
- c. Secure the two halves of the shear box together with the locking pins .
- d. Measure the average thickness of serrated plates .
- e. Insert a serrated plate and make it rest on the bottom plate such that the serrations are at right angle to the movement of the box .
- f. Measure the average height available inside the box for preparation of soil sample .
- g. Measure the empty weight of the shear box with bottom plate , locking pins and serrated plate .
- h. Place sand inside the shear box in little quantities and and compact each layer uniformly with a tin rod .
- i. Build up the sand sample till it reaches thickness 10 to 12 mm inside the top half of the shear box .
 - 1-Level up the surface of sand .
 - 2-Insert another serrated plate on top and make it rest firmly on the sand . The serration must at right angle to the direction of shear displacement . The average thickness and weight of the serrated plate should have been measured earlier .

- 3-Measure the average height inside the box above the top serrated plate .
- 4-Weight the shear box at this stage .
- 5-Place the loading cap at top and place the shear box in the container in the direct shear machine .
- 6-Place the loading yoke on the loading cap and apply a predetermined value of vertical load on the soil sample .
- 7-Adjust the machine such that initially there is on shear load on the soil but will start building up immediately after the machine is suited on .
- 8-Using the spacer the two halves of the shear box slightly to eliminate the contact friction at the inter face .
- 9-Set the horizontal dial gauge to measure the shear displacement and the vertical displacement of the sample .
- 10-Set rate of movement . For dry sand use a rate of displacement of *mm/minute* .
- 11-Note the initial reading in the horizontal , proving ring and vertical dial gauges .
- 12-Remove the locking pins .
- 13-Switch on the machine and record the proving ring and vertical dial gauge reading at regular intervals of horizontal dial reading .
- 14- Continue the observations until failure is reached or until the shear displacement equals 15% of the length of the sand sample .

Repeat the test for three or more normal load on the sample.

4. CACULATION

In data sheet col. 1,2 and 3 are observed. Shear displacement in Col. 4 is obtained from col. 1 and least count of horizontal dial gauge . shear load is entered on Col. 5 from reading in Col.6 is calculation as $\tau = \text{shear load in col.5} / (L \times B)$. Vertical displacement (Δh) in col. 7 is obtained from vertical dial gauge reading in col. 3 and its least count value . +ve sign is used for compression and -ve for expansion – volumetric strain in Col 8 is obtained as $\frac{\Delta h}{h} \times 100$. Where h is the thickness of sand sample.

From result the maximum value for shear stress , τ_{max} , can be observed . The angle of shearing resistance , ϕ is computed as

$$\phi = \tan^{-1}(\tau_{max}/\sigma)$$

Where σ = normal load intensity .

5. RESULTS

- 1- Plot shear displacement vs .shear stress and displacement vs . volumetric strain curve as shown in Figure DS 1 .
- 2- Plot the failure envelope as shown in Figure DS 2 .

6. CHECKLIST

- 1-See whether all the data for calculation of density have been entered before shearing the sample
- 2- Remove locking pins before applying shear load .
- 3- While repeating the test for different normal loads it must be ensured that all the sample have nearly the same density.

7. DATA SHEET

DIRECT SHEAR TEST

Plan dimension of Shear box (LxB) :

Height available for preparation

Of soil sample (h_1) :

DS Machine No.:

Proving ring No. :

LC of horizontal dial gauge :

Weight of empty shear box (w_1) :

LC of vertical dial gauge :

Thickness of top serrated plate (t)

Height of box above the serrated plate at top (h_2) :

Thickness of soil sample ($h = h_1 t - h_2$) :

Weight of shear box with sand (w_2) :

Weight of sand ($w = w_2 - w_1$) :

Density of sand ($\gamma = w / (h \times l \times b)$) :

Normal pressure on soil sample :

Shear displacement dial gauge	Proving ring reading	Vertical dial gauge reading (3)	Shear Displacement	Shear load	Shear stress τ	Vertical displacement Δh	Volume strain
(1)	(2)		(4)	(5)	(6)	(7)	(8)

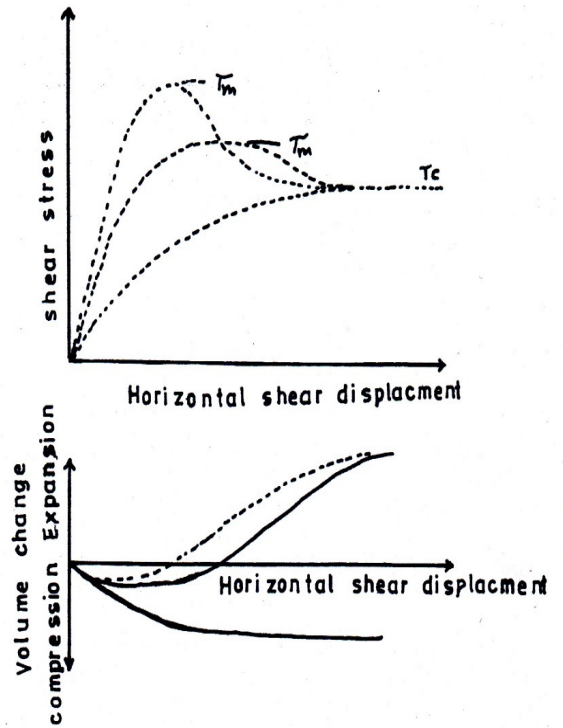


FIG DS1

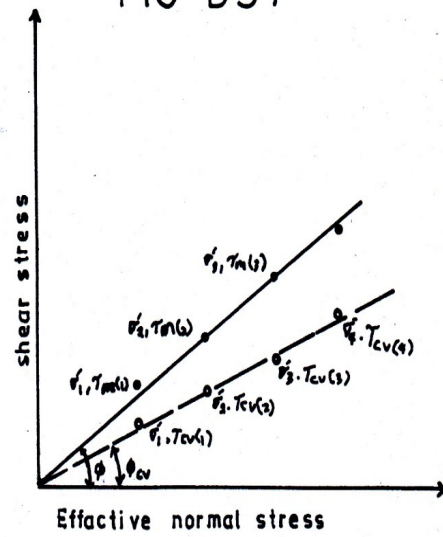


FIG DS2

EXPERIMENT NO.13
Unconfined Compression Test
ASTM D-2166

1-AIM

To Carry out unconfined compression test on a soil sample and determine its compressive strength or undrained shear strength.

2- APPARATUS

Unconfined compression testing machine with proving ring.

Triaxial cell

Weighing balance – 200 gms capacity accuracy 0.01 g.

Moisture cans

Oven

Desiccators

Perspex or impervious disc

Perspex or impervious loading cap

3-PROCEDURE

3.1 Prepare a soil specimen of standard dimensions, 38 mm diameter and 76 mm long.

3.2 Collect the trimmings from the ends of the soil sample and determine the moisture content.

3.3 Weigh the soil sample

3.4 Place an impervious disc on the pedestal of the triaxial cell base.

3.5 Place the soil sample on the impervious disc.

3.6 Place an impervious loading cap at the top of the sample.

3.7 Place the triaxial cell over the base and tighten the screws.

3.8 Transport the cell with the soil sample to the load frame.

3.9 Adjust the load frame such that the proving ring and the ram of the cell are in contact with each other without exerting axial load on the soil sample .

3.10 Set the rate of displacement. For unconfined confined compression test, rate of displacement can be computed on the basis of reaching 15% axial strain in 20 to 30 minutes.

For a standard sample of 76 mm length, the rate of displacement varies from 0.38 mm/min to 0.57 m/m min

3.11 Set the vertical displacement measuring dial gauge.

3.12 Note down the initial reading in the vertical displacement dial gauge and in the proving ring dial gauge.

3.13 Switch on the machine and record the proving ring reading at regular intervals of vertical displacement dial gauge reading.

3.14 Switch off the machine when the soil sample has failed or when the axial strain has reached a value of 15 %

4. CALCULATIONS:

COI.1 and 2 in data sheet are recorded observations. Vertical displacement ΔL in col.3 is obtained from reading in col. 1 and the least count of vertical displacement dial gauge. Compute axial strain as $\epsilon_1 = \Delta L / L_0$ and enter in col . 4. Corrected area in col . 5 is calculated from

$A_1 = A_0 / (1 - \epsilon_1)$ where A_0 is the initial area of the soil sample.

Axial load P_a in col .6 is obtained from readings in col . 2 and the calibration chart of the proving ring. Compute axial stress using the equation .

$$\sigma_1 = P_a / A_1$$

And enter in col . 7.

5. RESULTS

Plot σ_1 vs . ϵ_1 curve as shown in fig UC1

Plot the Mohr's circle as shown in fig UC2

Compute the undained shear strength (S_u) from,

$$S_u = \frac{\sigma_1 f}{2}$$

6. CHECKLIST

- 6.1 Check whether the ram of the cell falls freely due to its own weight
- 6.2 Do not touch the ram of the cells
- 6.3 While placing the cells on the base hold the ram up so that it does not disturb the soil sample.
- 6.4 Where brittle failure is expected keep a constant watch on proving and vertical displacement dial gauge to record the failure load and displacement.

7. DATA SHEET

Initial dimensions of soil sample:

Diameter (D_o): π

Length (L_o): π

Area = $\pi D_o^2 / 4$

(A_o)

Volume ($V_o = \pi D_o^2 L_o$)

Weight (W_o):

Machine No:

Proving ring No:

LC of vertical dial gauge:

LC of proving ring dial gauge:

Moisture Content Measurements:

Can No:

Weight of can :

Can + Wet soil:

Can + dry soil:

Moisture Content (W): -----

Unit weights of soil Sample :

Total unit weight ($\gamma_t = W_o / V_o$):-----

Dry unit weight ($\gamma_d = \gamma_t / (1+w)$):-----

Vertical displacement dial gauge Reading (1)	Proving ring reading (2)	Vertical displacement (ΔL) (3)	Axial Strain ϵ_1 (4)	Corrected Area A_1 (5)	Axial Load Pa (6)	Axial Stress σ_1 (7)

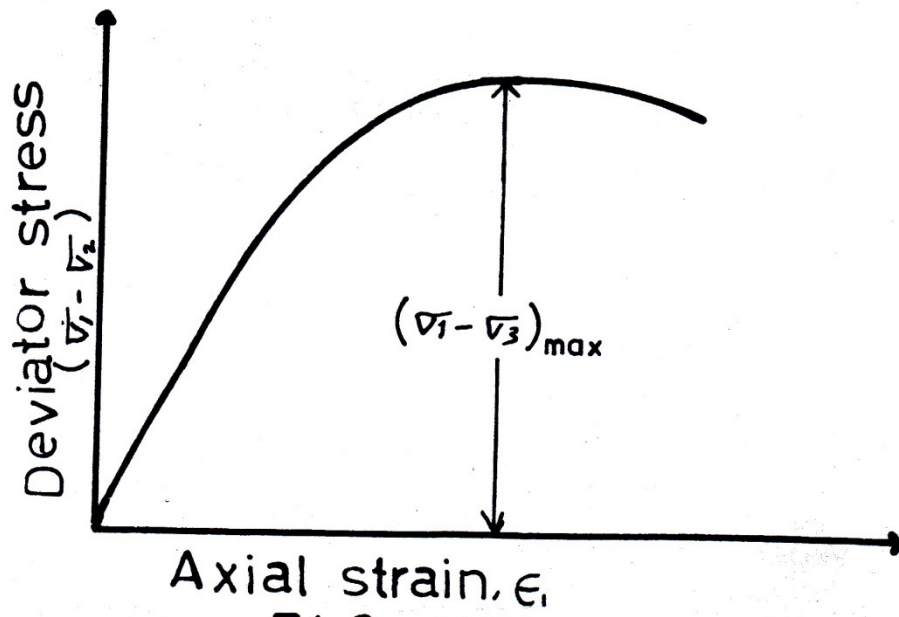


FIG UC1

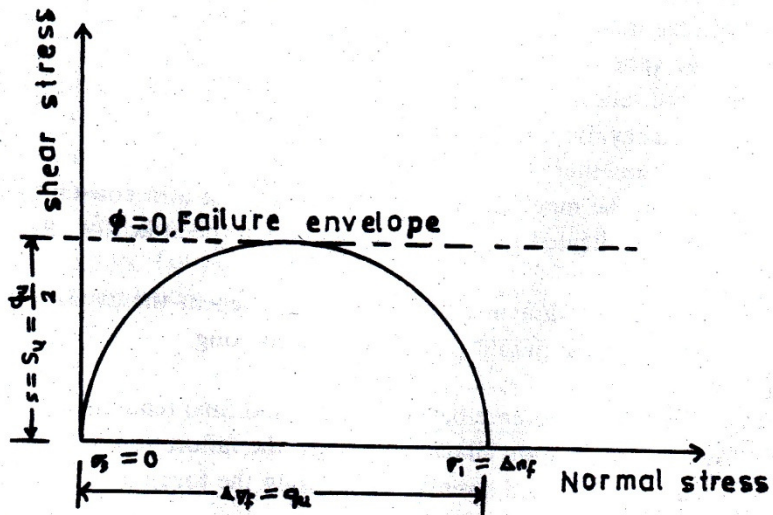


FIG. UC2

EXPEIMENT NO. 14

VANE SHEAR TEST

ASTM D-2166

1. AIM

To conduct vane shear test in the laboratory to determine the undrained strength of soil.

2. APPARATUS:

Laboratory vane shear apparatus with vanes and rotating mechanism
Moulds for soil Sample

Weighing balance (capacity , accuracy)

Oven

Slide calipers

Moisture cans

Spatula

3. PROCEDURE

3.1 Measure inner diameter and height of mould.

3.2 Record empty weight of mould. Measure dimensions of vane.

3.3 Prepare a soil sample in the mould and trim both ends. Weight the mould with soil.

3.4 Place the mould in the van shear apparatus and secure it in position.

3.5 Fix the vane to the shear apparatus.

3.6 Insert the vane in to the soil sample to sufficient to ensure shear in soil at both ends cylinder formed by vanes.

3.7 Record the initial reading in the indicator.

3.8 Switch on the machine which rotates the vane at a constant rate.

3.9 Failure is indicated by a constant reading in the indicator. Record this final reading.

3.10 Take out the vane and after cleaning it repeat the experiment from other end of the mould if it is sufficiently long.

4. CALCULATIONS

4.1 Calculate the difference between initial and final readings in indicator.

4.2 Use the calibration chart and obtain the failure torque, T .

4.3 Calculate untrained strength S_u , using the formula,

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

5. RESULTS:

Report the un drained strength of soil.

6. CHECKLIST:

6.1 Insert the vane sufficiently into the soil to ensure shear failure at both ends of cylinder formed by vanes.

6.2 Select the torsional spring consistent with the stiffness of soil sample.

7. DATA SHEET

Dimensions of mould:

Diameter: -----

Height: -----

Date; -----

Volume: -----

Diameter of vane (D) -----

Height of vane(H) -----

Moisture content of soil:

Weight of empty can: -----

Can +Wet soil:-----

Can + dry soil:-----

Moisture content (W): -----

Unit weight of soil:

Empty weight of mould:-----

Mould + wet soil:-----

Total unit weight:-----

Dry unit weight:-----

Initial reading in indicator: -----

Final reading in indicator: -----

Difference:-----

Failure Torque:-----

Undrained strength: -----

Spring No:-----

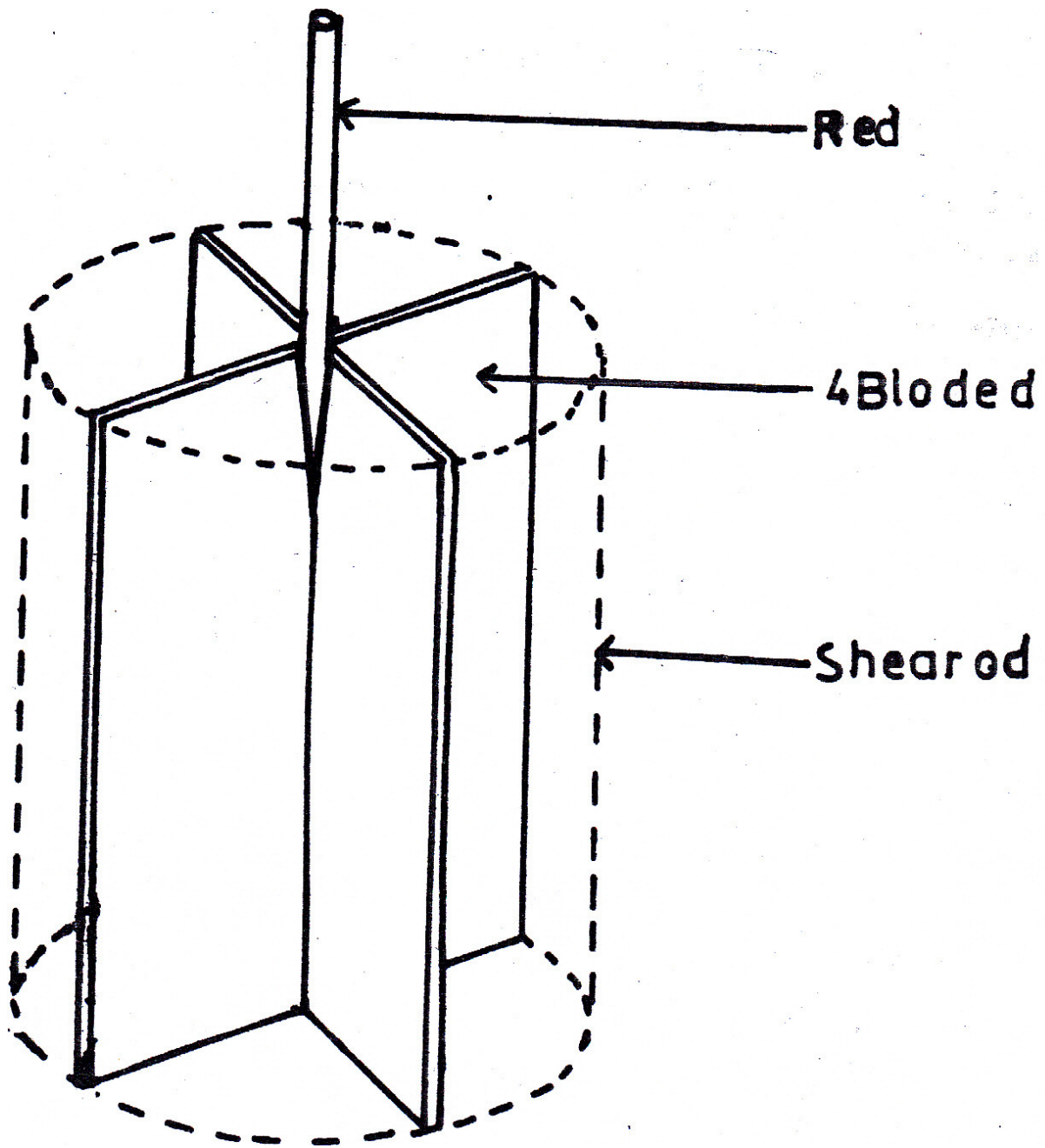


FIG VS1

EXPERIMENT NO. 15
UNCONSOLIDATED UNDRAINED TEST
ASTM D-2850

1. AIM

To determine the shear strength parameters of soil under unconsolidated undrained situations.

2. APPARATUS:

Loading frame with proving ring
Triaxial cell
Constant cell pressure application system
Weighing balance – 200 gm capacity
Moisture cans
Rubber membrane. O – rings,
Membrane stretcher
Perspex or impervious disc
Perspex or impervious loading cap
Oven
Desiccators

3. PROCEDURE:-

- 3.1- Prepare a soil of standard dimensions, 38 mm diameter and 76 mm long. Weigh the sample.
- 3.2- Collect the trimmings from the ends of the soil sample and determine the moisture content.
- 3.3- Place an impervious disc on the pedestal of the triaxial cell base.
- 3.4- Place the soil sample on the impervious disc. and place an impervious Loading cap at top of the sample.
- 3.5- Stretch the rubber membrane over the soil sample, pedestal and loading cap using rubber membrane stretcher.
- 3.6- Place O- rings on the membrane, two at bottom on the pedestal and two at top on the loading cap.
- 3.7- Place the triaxial cell over the base and tighten the screws.
- 3.8- Transport the cell with the soil sample to the loading frame.

- 3.9- Connect the hose from de-aired water reservoir to the inlet valve at the base of the triaxial cell. Open the inlet valve and fill the cell with water.
- 3.10- Develop the required pressure in the constant pressure system and transfer it slowly to the triaxial cell.
- 3.11- Record the proving ring reading while it hangs free.
- 3.12- Adjust the load frame such that proving ring and the ram of the cell are in contact with each other.
- 3.13- Lower the ram of the cell till it comes into contact with the loading cap. The proving ring reading will increase in the beginning of downward movement, then the reading will become constant. When the ram comes into contact with the loading cap the proving ring reading increase again. Stop at this stage.
- 3.14- Set the rate of displacement. For unconsolidated undrained test., rate of displacement can be computed on the basis of reaching 15% axial strain in 20 to 30 minutes. For a standard sample of 76 mm length, the rate of displacement ranges from 0.38 mm/min to 0.57 mm/min.
- 3.15- Set the vertical displacement measuring dial gauge.
- 3.16- Note down the initial reading in the vertical displacement dial gauge and in the proving ring gauge.
- 3.17- Switch on the machine and record the proving ring reading regular intervals of vertical displacement dial gauge reading.
- 3.18- Switch off the machine when the soil sample has failed or when the axial strain reaches a value of 15%.
- 3.19- Release the load on the proving ring and make it free. Release the cell pressure and empty the water in the cell. Remove the soil sample.
- 3.20- Repeat the test at two or more cell pressures.

4.CALCULATION:

Col.1 and 2 in data sheet are recorded observations. Vertical displacement ΔL in col. 3 is obtained from reading in Col. 1 and the Least count of vertical displacement dial gauge. Compute axial strain as $\epsilon_1 = \Delta L / L_0$ and enter in Col. 4 Corrected area in Col. 5 is calculated from $A_1 = A_0 / (1 - \epsilon_1)$. Axial Load P_a in col. 6 is obtained from readings in Col. 2 and the calibration chart of proving ring. Deviator load P_d in col. 7 is obtained as, $P_d = P_a - (p_3 \times A_r)$, where A_r is the area of ram. Compute deviator stress using the equation,

$$\sigma_1 - \sigma_3 = Pd/A1$$

and enter in Col,8.

5. RESULTS:

Plot $(\sigma_1 - \sigma_3)$ Vs. ϵ_1 curve as shown in fig. UU1 plot the Mohr's circles and the failure envelope as shown in fig UU2. Compute the undrained strength (Su) as

$$Su = Cu = \frac{(\sigma_1 - \sigma_3)}{2}$$

For $\phi_u = 0^\circ$ conditions.

6. CHECKLIST:

- 6.1- Check for punctures in the rubber membrane.
- 6.2- Check whether the ram of the cell falls freely due to its own weight.
- 6.3- Do not touch the ram of the cell.
- 6.4- While placing the cell on the base, hold the ram up so that it dose not disturb the soil sample.

7. DATA SHEDT:

UNCONSOLIDATEP UNDRAINED TEST

Initial dimensions of soil sample:

Diameter (D_o):-----

Length (L_o):-----

Area (A_o = $\pi D_o^2 / 4$):

Volume (V_o = $\pi D_o^2 L_o$):-----

Weight (W_o):-----

Machine No: -----

Proving ring No: -----

L C of vertical

Moistur Content measurements:

Can No: -----

Weight of can:-----

Can + wet soil:-----

Can +dry soil:-----

Moisture content (W): -----

Dial gauge: -----

L C of proving

Ring dial gauge: -----

Cell pressure(σ_3):

Proving ring

Reading while free: -----

Unit weight of soil sample:

Total unit weight ($\gamma_t = W_o / V_o$):

Dry unit weight, $\gamma_d = \gamma_t / (1 + w)$:

Diameter of ram(Dr): -----

Rate of displacement: -----

Vertical displace ment reading	Proving Ring Reading	Vertical Displace- Ment	Axial Strain	Corrected Area	Axial Load	Deviator Load	Deviato Stress ($\sigma_1 - \sigma_3$)
(1)	(2)	(ΔL) (3)	ϵ_1 (4)	A1 (5)	Pa (6)	Pd (7)	(8)

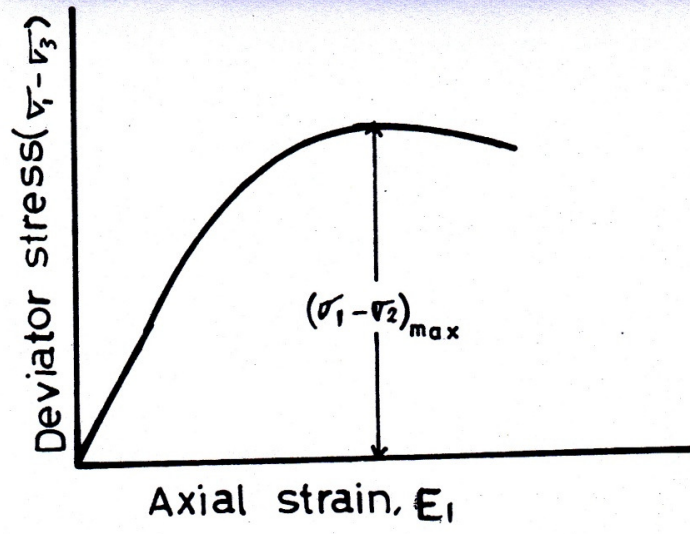


FIG UU1

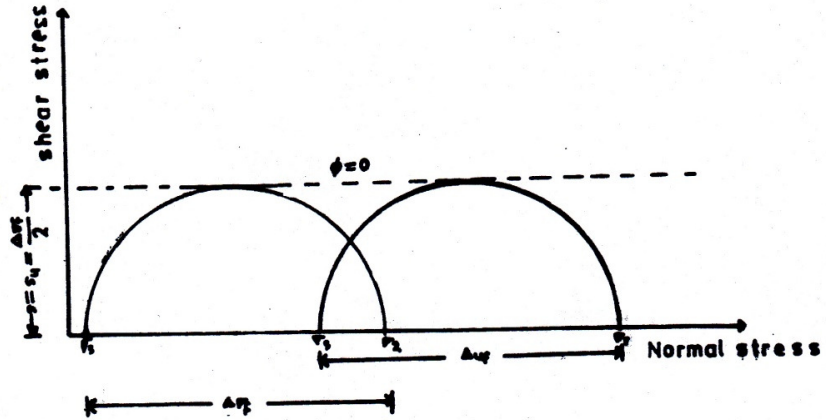


FIG. UU 2

EXPERIMENT NO. 16
CONSOLIDATED DRAINED TEST ON SAND
ASTM D-422

1. AIM

To determine the shear strength parameters of sand under drained conditions of loading.

2. APPARATUS:

Loading frame with ring

Triaxial (cell)

Constant cell pressure application system

Split sampler

Porous discs

Rubber membrane

O – rings

Burette

Perspex or impervious loading cap

Weighing balance

Oven

Spoon

Thin rod – 3 mm diameter, fitted with rubber

Cushion at one end.

Slide calipers

3. PROCEDURE

3.1- Measure the depth of the pedestal of the cell base, the thickness of porous disc and the thickness of the impervious loading cap

- 3.2- Stretch a rubber membrane over the pedestal – of the cell .. place two O-rings on the membrane.
- 3.3- Place the split sampler on the base around the pedestal enclosing the rubber membrane.
- 3.4- Stretch the rubber membrane over the split sampler.
- 3.5- Connect a burette with water to one of the two valves in the base which leads to one of the two openings in the pedestal. Open and shut this valve a few number of times to remove the air in the opening.
- 3.6- Open and shut the other valve in the base which loads to the other opening in the pedestal , a few number of times. This drains out some water from the split sampler and de- airs the other opening.
- 3.7- Fill up the split sampler with water.
- 3.8- Keep all the valves in the base shut.
- 3.9- Insert a porous disc through split sampler and place it on the pedestal.
- 3.10- Take sand using a spoon from a container , in which the preboiled sand is kept immersed in water , and place it in side the split sampler.
- 3.11- After placing a few spoons of sand compact the sand using a rubber sheathed thin rod.
- 3.12- When the sampler reaches to the top of the sampler, make the surface level. Place the loading cap and gently press it slightly into the split sampler.
- 3.13- Using wash bottle wash off the sand particles on the membrane at the top of the sampler.
- 3.14- Stretch the membrane over the loading cap and place two O- rings.
- 3.15- Take the burette down by about 1 m. It can be kept on the floor.
- 3.16- Open the valve connecting the burette to the sand sample.
- 3.17- Remove the split sampler.
- 3.18- Wash the sand sampler and the base of the cell to remove sand particles outside.

- 3.19- Measure the average initial diameter of the sample, by taking measurements near the top, middle and bottom of the soil sample.
- 3.20- Measure the height from top of loading cap to bottom of pedestal.
- 3.21- Place the triaxial cell over the base and tighten the screws
- 3.22- Close the valve connecting the burette to the sand sample.
- 3.23- Transport the cell with the sand sample, and the burette to the loading frame.
- 3.24- Connect the hose from de-aired water reservoir to the inlet valve at the base of the triaxial cell.
- 3.25- Open the inlet valve and fill the cell with water.
- 3.26- Keep the burette at the same level as the cell and open the valve to the burette.
- 3.27- Adjust the burette such that the water level in the burette is approximately at the mid – level of the sample.
- 3.28- Close the valve to the burette ,. Note down the reading in the burette.
- 3.29- Develop the required pressure in the constant pressure system and transfer it slowly to the triaxial cell.
- 3.30- Open the valve to the burette.
- 3.31- Wait until the water level in the burette stabilises and record the reading.
- 3.32- Record the proving ring reading while it hangs free.
- 3.33- Adjust the load frame such that the proving ring and the ram of the cell are in contact with each other.
- 3.34- Lower the ram of the cell till comes into contact with the loading cap. The proving ring reading will increase in the beginning of downward movement, then the reading will become constant.

When the ram comes into constant with the loading cap the proving ring reading will increase again.

Stop at this stage.

3.35- Set the rate of displacement. For drained test on sand, the rate of displacement can be computed on the basis of reaching 15 % axial strain in 30 minutes.

3.36- Set the vertical displacement measuring dial gauge.

3.37- Note down the initial readings in the vertical displacement dial gauge in the proving ring , and in the burette.

3.38- Switch on the machine and record the proving ring reading and burette reading at regular intervals of vertical displacement dial gauge reading.

3.39- Switch of the machine when the soil sample has failed or when the axial strain reaches a value of 15 %.

3.40- Release the load on the proving ring and mak it free.

3.41- Release the cell pressure and empty the water in the cell.

3.42- Remove the soil sample and keep it in the oven to dry.

3.43- Weigh the dry sand.

3.44- Repeat the test at two or more cell pressures.

4. CALCULATIONS:

Col . 1,2 and 3 in data sheet are recorded observations. ΔL in Col . 4 is obtained from reading in Col . 2 and the least count of vertical displacement dial gauge. Compute axial strain ϵ_1 as $\epsilon_1 = \Delta L / L_{oc}$ and enter in Col . 5 . obtain Volume charge ΔV in Col . 6 from burette reading in Col . 1 . Use +ve sign for ΔV for expansion of the sample and – ve sign for contraction compute corrected area A_1 from the formula.

$$A_1 = \frac{A_{oc}(1 \pm \Delta V, V_{oc})}{(1 - \epsilon_1)}$$

And enter in Col . 7 . Axial load P_a in Col . 8 in obtained from reading in Col . 3 and the calibration chart of proving ring . Deviator load P_d in Col .9 is obtained as $P_d = P_a (\sigma_3 \times A_r)$, where A_r is the area of ram . compute deviator stress using the equation.

$$\sigma_3 = P_d / A_1$$

and enter in Col . 10 .Obtain axial stress σ_1 ($= \sigma_1$) in Col . 11 . by adding σ_3 to values in Col . 10 . σ_1 / σ_3 ($= \sigma_1 / \sigma_3$) values are entered in Col . 12 .

Volumetric strain (%) in Col . 13 is calculate as $(\frac{\Delta V}{V_{oc}} \times 100)$. Use + ve sign for expansion and – ve sign

For contraction.

5. RESULTS:

Plot $(\sigma_1 - \sigma_3)$ Vs ϵ_1 curves as shown in Fig CD1 plot (σ_1 / σ_3) Vs ϵ_1 curves as shown in Fig CD2 Plot the Mohr's circles and the failure envelopes as shown in Fig CD3

Determine the effective stress shear strength parameters.

6. CHECKLIST:

6.1 Check for punctures in the rubber membrane

6.2 Check that the burette is free of air bubbles

6.3 Check whether the ram of the cell falls freely due to its own weight

6.4 Do not touch the ram of the cell

6.5 While placing the cell on the base , hold the ram up so that it does not disturb the soil sample.

6.6 Ensure the capacity of the proving ring . the load to cause failure of the soil sample can be computed from,

$$P_f = \sigma_3 A_r + 2 \sigma_3 \left(\frac{\sin \phi}{1 - \sin \phi} \right) A_{oc}$$

Where σ_3 = cell pressure

A_r = area of ram

ϕ = an assumed value of ϕ = for sand

A_{oc} = post – consolidation area of sample

The capacity of the proving ring should be in the range of 1.5 P_f to 2 P_f .

7. DATA SHEET:

CONSOLIDATED DRAINED TEST

PRE – SHEAR DATA

Initial dimensions of sample:

Diameter (D_o):

Coll pressure (σ_3):

Length (L_o):

Initial burette

Area ($A_o = \pi D^2 / 4$):

Reading:

Volume ($V_o = \pi (D_o^2 / 4)$):

Burette reading

After consolidation:

Post Consolidation dimensions

Of soil sample:

Consolidation volume

Diameter (D_{oc}):

Change (ΔV_c):

Length(l_{oc}):

Area (A_{oc}):

Volume (V_{oc}):

Initial unit weight of soil sample:

Dry weight of soil sample (W_d):

Dry unit weight ($\gamma_d = W_d / V_o$):

$$D_{oc} = D_o \left(1 - \frac{\Delta V_c}{3 V_o} \right)$$

$$L_{oc} = D_o \left(1 - \frac{\Delta V_c}{3 V_o} \right)$$

$$V_{oc} = V_o - \Delta V_c$$

CONSOLIDATED TEST

SHEAR DATA

Cell pressure (σ_3) -----

proving ring no -----

Proving ring reading-While free

lc of dial gauge -----

vertical

Diameter of ram (D_r) -----

lc of proving ring D_{Gi} -----

Rate of displacement -----

1. Burette reading	
2- Vertical dial gauge	
3- proving ring d. g.	
4- Vert . displacement Δl	
5- Axial strain ϵ_l	
6- Volume load Δv	
7- Corrected area A_l	
8- Axial load P_a	
9- Deviator load P_d	
10- Deviator stress σ_1 $-\sigma_3$	
11- Axial stress σ_1	
12- σ_1 / σ_3	
13- Volumetric strain ϵ_v	

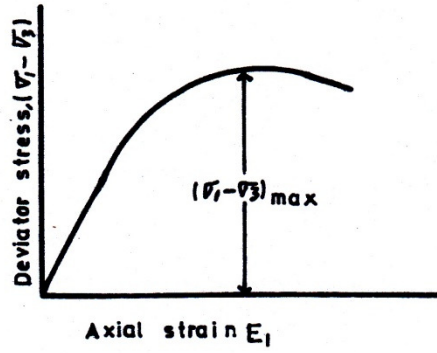


FIG. CD1

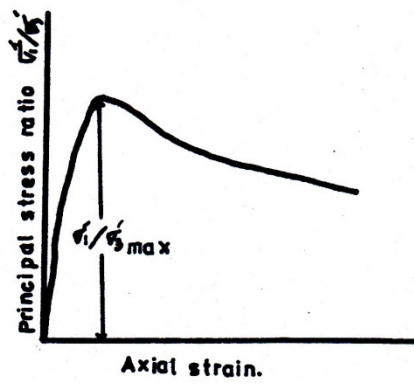


FIG. CD2

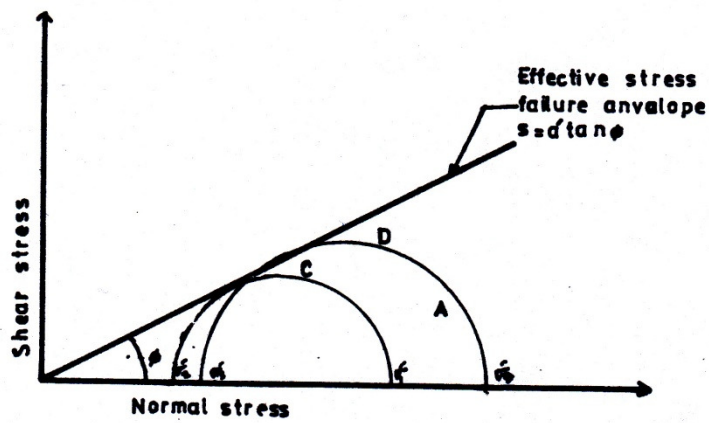


FIG CD3