

Contents

Name of experiment	Page
1. How to Prepare a Laboratory Report.....	1
2. 'Water content' test by oven dry method.....	2
3. Determining 'specific gravity' of soil.....	4
4. Determination of 'water content' by Pycnometer method.....	8
5. 'Sieve analysis' test.....	10
6. 'Hydrometer' analysis.....	14
7. 'Liquid Limit' Determination using Cassa Grande apparatus.....	22
8. Determination of Liquid limit using cone penetration method.....	24
9. Determination of Plastic limit.....	28
10. 'Proctor compaction' test	30
11. 'Consolidation' test.....	35
12. Constant head 'Permeability' test.....	42
13. 'Unconfined compression' test.....	45
14. Laboratory Vane shear Test.....	50

oil Mechanics Laboratory Manual

How to Prepare a Laboratory Report

The laboratory report should include the following items

- Course title and No
- Partners' name
- Experiment No
- Experiment title
- Date of performance
- Objective of the experiment(not more than two lines)
- Brief introduction (theory of about six lines)
- Procedural performance in passive voice with out the use of personal pronouns
- Row data (in tabular form, if any)
- Sample calculations.
- Results including tables, graphs and all necessary explanations with the respective Naming of the graph / table.
- Conclusion drawn from the result by referring previous results from handbooks, etc.
- Engineering significance of the test(not the result)

- N.B
- 1- Write readable Lab. Report
 - 2- Use appropriate scales for graphing (ask for log papers where required)
 - 3- Refer charts and tabular data from hand books for concluding about the nature of the results.

Experiment 1

'Water content' test by oven dry method

Test method ASTM D 2216

1. Theory

The water content or moisture content of a soil is defined as the ratio between the weight of the water in the sample and the weight of solid material. It is expressed as a percentage. For any materials water content is one of the most significance index properties used in establishing a relation between soil behaviour and its properties. The water content of a material is used in expressing the phase relation ship of air, water and solids in a given soil type depends on its water content. The water content of a soil along with its liquid and plastic limits is used to express its relative consistency termed as 'liquidity index'.

The laboratory work to determine the water content consists of drying the moist soil in an oven to a constant weight of water and the weight of water and the weight of dry specimen.

2. Objective

To determine the 'water content' of soil sample in terms of dry weight.

3. Apparatus and supplies

Drying oven

Balance

Containers

Miscellaneous items such as gloves, tongs, knives, spatula and scoop etc

4. Sample preparation and test procedure

1. Determine the weight of a clean and dry specimen container with its cover. Usually number or letter written on the containers to identify them.
2. Select a representative test specimen.
3. Place the moist specimen in the container.
4. Determine the weight of the container and moist soil.
5. Remove the cover and place the container with moist soil in drying oven.
6. Dry the soil to constant weight in the drying oven at a temperature of 105°C - 115°C for 12 - 24 hours.
7. Remove the container from the oven after the material has dried to constant weight.

oil Mechanics Laboratory Manual

8. Allow the material to cool in the desiccators to room temperature or until the container can be handled comfortably with bare hands.
9. Determine the weight of the container and oven dried material.

Computation

Calculate the moisture content of the soil as

$$w = \frac{W_{cws} - W_{cs}}{W_{cs} - W_c} \times 100 = \frac{W_w}{W_s} \times 100$$

Where w - moisture content in %

Wcs- weight of container and moist soil in gms

Wcs - weight of container and oven dried soils in gms

Wc- weight of container in gms

Ws- weight of solid particles in gms

Table: Minimum weight of sample required for 'water content' test

Maximum particle size (100% passing)	Recommended minimum mass of specimen for water content test
2 mm or less	20 g
4.75 mm	20 g
9.5 mm	50 g
19 mm	250 g
37.5 mm	1000 g
75 mm	5000g

Observation sheet for 'water content' test

Description of sample:

Determination No	Obs. 1	Obs. 2	Obs. 3
Container number			
Weight of container g			
Weight of container + wet soil g			
Weight of container + dry soil g			
Weight of water (Ww) g			
Weight of dry soil (Ws) g			
Water content (w) %			
Average water content (w) %			

Remark.....

.....

Experiment 2

Determining 'specific gravity' of soil

Test method ASTM D 854-92, 1988

1. Theory:

The term specific gravity is defined as the ratio of the weight of a given volume of material to the weight an equal volume of water. In effect it tells how much the material is heavier (or lighter) than water.

$$G = \frac{W_s}{V_s \gamma_w}$$

Where G_s = specific gravity of soil

W_s = weight of solids

V_s = volume of solids

γ_w = unit weight of water (1g/cm³)

2. Object

To determine the specific gravity of soil

3. Apparatus

- | | |
|----------------------------------|---------------------|
| 1. Pycnometer (Volumetric flask) | 5. Vacuum pump |
| 2. Balance | 6. Evaporating dish |
| 3. Thermometer | 7. Spatula |
| 4. Drying oven | 8. Large beaker |



4. Sample preparation

Take 25 g of soil sample passing 2.00mm (No 10) sieve if the volumetric flask is used and 10 g when the coppered bottle is to be used. Oven dry it For 24 hrs.

5. Procedure

oil Mechanics Laboratory Manual

1. Place the sample in the pycnometer, taking care not to lose any of the soil in case the weight of the sample has been determined.
2. Add distilled water to fill the volumetric flask about three fourths full.
3. Remove entrapped air from soil water using vacuum pump.
4. Fill the pycnometer with distilled water up to the top mark, clean the outside, and dry with a clean, dry cloth.
5. Determine the weight of the pycnometer and contents (W_{pws}) and temperature in degrees Celsius (T_x).
6. Empty the pycnometer, clean it from outside, and fill it with distilled water.
7. Determine the weight of pycnometer with distilled water (W_{pw}).
8. Repeat the experiment at least three times and compute specific gravity.

6. Observations and calculations

Observations

Weight of pycnometer, $W_p(g)$

Weight of pycnometer plus water W_{pw}

Observed temperature of water, $T_i(^{\circ}C)$

Calculations

The specific gravity of soils can be computed using the equation.

$$G_s = \frac{KW_s}{W_s + W_{pw}(at T_x) - W_{pws}}$$

Where G_s = specific gravity of soil based on water at $20^{\circ}C$

K = conversion factor used to report specific gravity based on water at $20^{\circ}C$, K can be determined from table.

W_s = weight of sample of oven dried soil.

$W_{pw}(at T_x)$ = weight of pycnometer filled with water at temperature T_x

T_x = temperature of contents of pycnometer when W_{pw} was determined, $^{\circ}C$

W_{ps} = weight of pycnometer plus water and soil (at T_x), g

General Remarks

- Specific gravity of clayey soil is determined using kerosene and then expressing it in terms of water.
- Specific gravity of clay particles varies between 2.5 and 2.9 and statically average 2.7 may be taken as 2.65.

Uses:

1. To determine the size of particle by Stokes law
2. To determine the void ratio of the fully saturated soil on knowing its water content (consolidation test)
3. To determine the various unit weights of soils on knowing the property of soils.

$$\gamma_s = \frac{G + S_e}{1 + e} \times \gamma_w$$

'Specific Gravity' Determination observation sheet

oil Mechanics Laboratory Manual

Sample No. _____ Project No. _____
Location. _____
Description of sample _____
Tested by _____ Date _____

A) Calibration of Pycnometer

1. Weight of dray, clean Pycnometer, W_p _____ g
2. Weight of Pycnometer + Water, W_{pw} _____ g
3. Observed temperature of water, T_i _____ °C

B) Specific Gravity Determination

Determination No	1	2	3
Weight of Pycnometer +soil + Water, W_{pws} (g)			
Temperature, T_x (0C)			
Weight of Pycnometer + Water at T_x , $W_{pw}(at\ T_x)$ (g)			
Weight of solids, W_s (g)			
Conversion factor, K			
Specific gravity of soil $G_s = \frac{K W_s}{W_s + W_{pw}(atT_x) - W_{pws}}$			
Average			

Remark.....
.....

Table: Relative Density of water and conversion factor K for various Temperatures

Temperature 0C	Relative Density of Water	Conversion factor K
18	0.9986224	1.0004
19	0.9984347	1.0002
20	0.9982343	1.0000
21	0.9980233	0.9998
22	0.9978019	0.9996
23	0.9975702	0.9993
24	0.9973286	0.9991
25	0.9970770	0.9989
26	0.9968156	0.9986

oil Mechanics Laboratory Manual		
27	0.9965451	0.9983
28	0.9962652	0.9980
29	0.9959761	0.9977
30	0.9956780	0.9974

7. Questions

1. Define specific gravity of soil?
2. What are the typical values of specific gravities of soil?
3. What is the effect of water temperature on the determination of specific gravity?

Experment 3

Determination of 'water content' by Pycnometer method

1. Theory

This method is used when the moisture content of soils is required to be obtained quickly. Because it requires lesser time than oven dry method as the sample doesn't need to be in an oven for 8 or more hours.

2. Object

To determine the moisture content of soil.

3. Apparatus and supplies

Pycnometer
4.75 mm IS sive
Balance
Vacume pump

4. Procedure

1. Weigh the pycnometer, while weighing it should be clean and dry.
2. Take about 350 g of wet soil. Place it in the pycnometer, taking care not to loos any of the soil in case the weight of the sample has been determined. And weight correctly.
3. Add distilled water to fill the volumetric flask about three fourths full.
4. Stir well and remove entrapped air from soil water using vacume pump for about 10-15 minutes.
5. Fill the pycnometer with distilled water up to the top mark, clean the out side, and dray with a clean, dry cloth.
6. Determine the weight of he pycnomete and contents.
7. Empty the pycnometer, clean it from outside, and fill it with distilled water.
8. Determine the weight of pycnometer with distilled water.
9. Repeat the experiment at least three times and compute moisture content.

oil Mechanics Laboratory Manual

5. Calculation

$$w = \frac{(G - 1)W_5 - G(W_3 - W_4)}{G(W_3 - W_4)} \times 100$$

Where

- w = Water content
- G = Specific gravity of the soil
- W₁ = Weight of pycnometer
- W₂ = Weight of Pycnometer + wet soil
- W₃ = Weight of pycnometer + soil + water
- W₄ = Weight of pycnometer full of water
- W₅ = Weight of wet soil = W₂ - W₁

‘Moisture content’ determination (pycnometer method) observation sheet.

Sample No. _____ Project No. _____

Location. _____

Description of sample _____

Tested by _____ Date _____

Specific gravity G of the soil = _____

No	Particulars	1	2	3
	Container No			
1	Weight of pycnometer (W ₁) g			
2	Weight of Pycnometer + wet soil (W ₂) g			
3	Weight of pycnometer + soil + water (W ₃) g			
4	Weight of pycnometer full of water (W ₄) g			
5	Weight of wet soil = W ₂ - W ₁ = W ₅ g			
6	Water content (w) %			

Remark:

.....
.....

Experiment-4

'Sieveanalysis'test

TestmethodASTEMD422-90,1988

1. Theory

Statistical relationships have been established between grain size and significant soil properties. The suitability criteria for road, air field and embankment construction have been based on grain size distribution. The proper gradation of filter material is established from particle size distribution. Grain size analysis is usually used in engineering soil classifications

A good spacing of soil diameters will be obtained when the nest of sieves are arranged in such away that each sieve has an opening approximately one half that of the coarser sieve above it.

2. Object

To determine the percentage of varies size particles in a soil sample

oil Mechanics Laboratory Manual

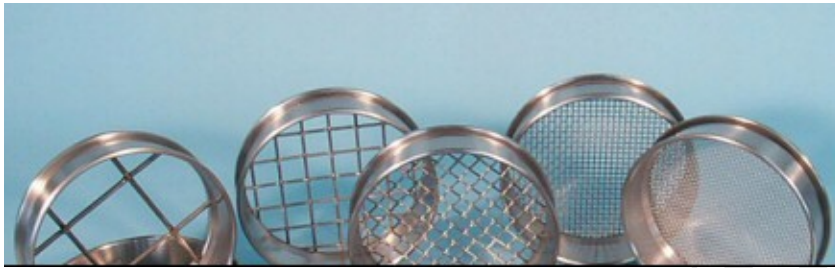
Grain size analysis of a soil is generally carried out by two methods

1. dry sieving
2. wet sieving

1. Dry Sieving

3. Apparatus and supplies

- | | |
|-------------------------------|--------------------|
| 1. a complete set of IS sieve | 4. Sieve shaker |
| 2. Drying oven | 5. Brush |
| 3. Balance | 6. Sample splitter |



4. Sample preparation

Expose the soil in the air until it is dried. Break up the dried sample by mortar with a rubber covered pestle and select a representative sample of the amount required to perform the test by the method of quartering or by use of sample splitter. The amount of soil selected based on the maximum size of aggregate.

5. Procedure

1. Oven dries the soil at a temperature of 105 – 115°C for 24 hours.
2. Determine the total mass of the sample.
3. Select the appropriate of varying size sieves. Stack the sieves in such a way that the smallest sieve will be at the bottom and the largest at the top.
4. Weight each sieve and the pan. Make sure each sieve is clean before weighing it.
5. Place the stack on the sieve shaker. Carefully pour the sample through the stack of sieve.
6. Place sieve cover on top sieve. Sieve the soil through the stack of sieves using mechanical shaker for about 10 minutes.
7. Remove the stack from the sieve shaker. Weigh the sieves and pan with soil retained on them.

6. Calculation

- i. Mass of each sieve retained on each sieve= mass of sieve and retained soil – mass of sieve
- ii. Percentage retained on each = Mass of soil retained/Total mass of test sample.
- iii. Cumulative percentage retained on each sieve = sum of percentage retained on all coarser sieves.
- iv. Percentage finer than any sieve = 100 – Cumulative retained on any sieve.
- v. Plot the distribution curve. The grain size distribution of a soil is presented as a curve on a semi-logarithmic plot, the ordinate being the percentage finer and the abscissa, particle size (mm) in log scale. Compute the 'coefficient of uniformity' and 'coefficient of curvature' using the relation.

$$C_U = D_{60}/D_{10} \quad \text{and} \quad C_Z = (D_{30})^2 / (D_{10} \times D_{60})$$

oil Mechanics Laboratory Manual

Where D_{10} , D_{30} and D_{60} are the particle size on grain size distribution curve at 10, 30, and 60 percentages finer the particles respectively.

Table: The range of 'grain size' for 'different soils'

Soil description	Grain size range (mm)
Gravel	75 - 4.75
Sand	4.75 - 0.075
Silt	0.075 - 0.002
Clay	< 0.002

Table: The 'largest particle size' and 'suggested mass' of soil to be used for testing

Nominal diameter of largest particle size, mm	9.5	19	25	37.5	50	75
Approximate minimum mass of portion, g	500	1000	2000	3000	4000	5000

Not. The sum of the mass retained should closely equal to the total mass of sample before testing. Generally a mass loss of less than 2% is considered as acceptable otherwise the test must be repeated.

2. Wet Sieving

The wet sieving is used when more than 5% of the soil sample passes through sieve No 200 (0.075mm). The procedure of wet sieve analysis is the same with dry analysis but the only difference is the sample preparation.

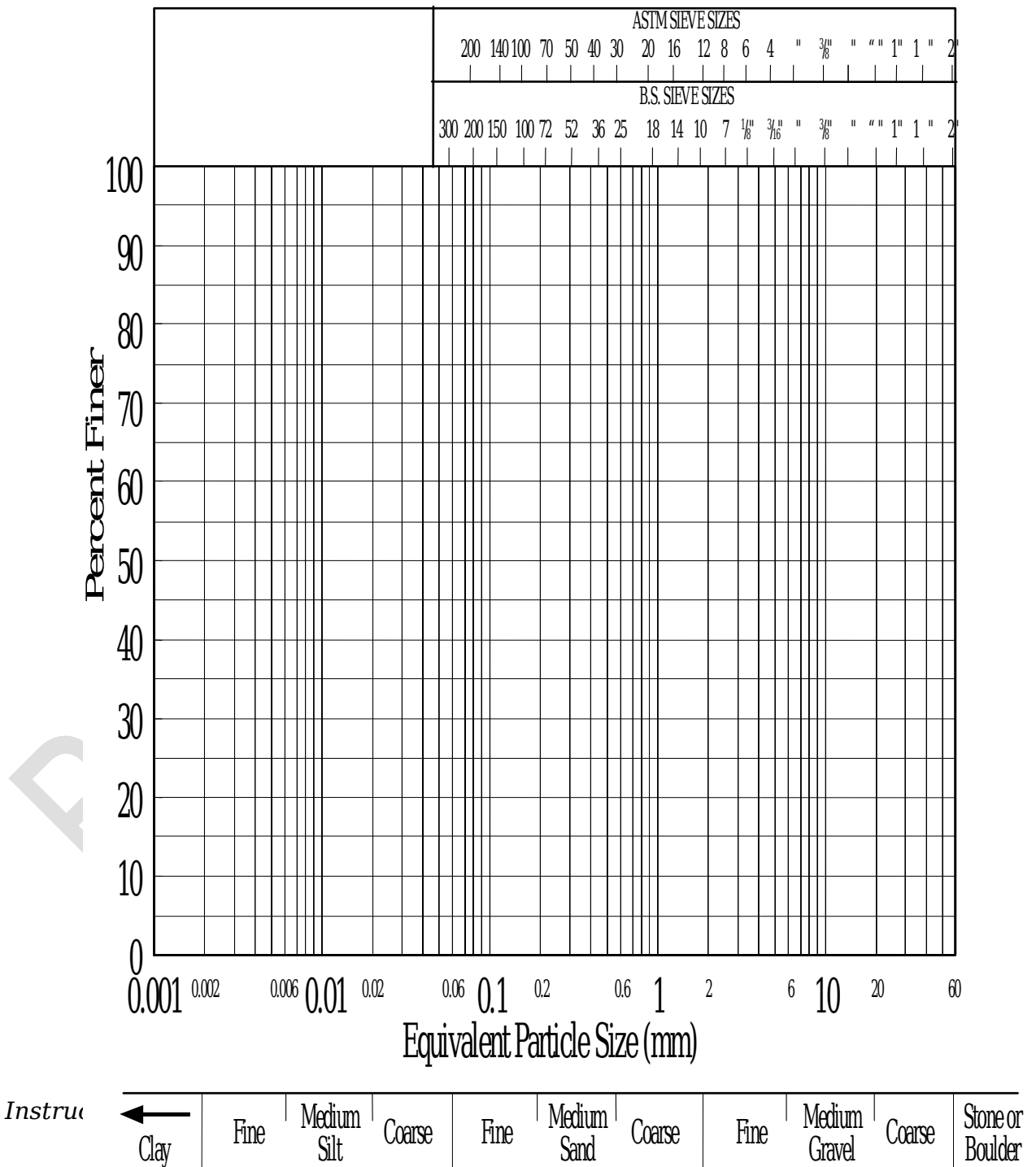
Sample preparation

Expose the soil in the air until it is dried. Break up the dried sample by mortar with a rubber covered pestle and select a representative sample of the amount required to perform the test by the method of quartering or by use of sample splitter. The amount of soil selected based on the maximum size of aggregate. Wash the quartered sample on sieve No 8 (2.36mm) and sieve No200 (0.075mm) then oven dry the soil at a temperature of 105 - 115°C for 24 hours.

7. Questions

1. What is the purpose of grain size analysis?
2. Under what conditions should you use wet sieving instead of dry sieving?
3. What is the implication of C_u and C_c ?

oil Mechanics Laboratory Manual



Experiment 5

'Hydrometer' analysis

Test method ASTM D 422-9D, 1988

1. Theory:

Soils with small grain sizes can not generally be analyzed using sieves, because of the very small size of sieve opening that would be required and the difficulty of getting such small particles to pass through. Grain-size analysis for these soils is done, therefore, by another method hydrometer analysis. The hydrometer method is based on Stokes' law.

2. Object

To determine the grain size of soil particles passing through 200mm sieve

3. Apparatus:

- | | |
|---------------------------------------|-----------------------|
| 1. Hydro meter | 4. Stirring apparatus |
| 2. Two glass cylinders (Volume 1 lit) | 5. Balance |
| 3. Deflocculating agent | 6. Distilled water |
| | 7. 2 mm IS sieve |
| | 8. Oven |
| | 9. Thermometer |
| | 10. Stop Watch |
| | 11. Weight box |



4. Preparation of test samples

oil Mechanics Laboratory Manual

After air drying the required amount of required amount passing through the No 200 sieve should be approximately 115g for sandy soils and approximately 65g for silty and clayey soils. And oven dried.

5. Procedure

1. Take 50g of the oven-dried soil passing through 200mm sieve
2. Transfer the sample carefully in to the container of the stirrer using distilled water and add 100 cc deflocculating agent (mixing 33g of Sodium hexametaphosphate and 7g of Sodium carbonate)
3. Operate the stirrer for about 10 minutes.
4. Meanwhile clean the hydrometer and keep in 1000cc sedimentation jar No1 filled with distilled water and 10 cc of deflocculating agent solution.
5. After stirring put the sample in to another sedimentation jar No2 of 1000cc capacity. Add enough distilled water to bring to the 1000cc mark. After proper and through mixing put the jar on a flat surface, Start the stop watch and gently insert the hydrometer in it .Take the hydrometer readings at half one two and four minutes.
6. Remove the hydrometer gently
7. Reinsert the hydrometer in distilled water and deflocculating agent. Note the temperature of the soil suspension.
8. Reinsert the hydrometer in the suspension and not the readings at 8, 15 and 30 minutes, 1,2,4,8 and 24 hours after shaking.

Note:

- i. Record the temperature of the suspension once during the first 15 minutes and there after at every subsequent observation.
- ii. Hydrometer readings should be taken at the top of the meniscus.
- iii. The surface of the hydrometer should not touch the wall of the jar.

6. Observations and calculations

Observations

- i. Record each actual hydrometer reading (R_h)
- ii. Take composite correction to the readings taken.
- iii. Take the hydrometer reading with composite correction applied R
- iv. Take the temperature observations

Calculations

a) Determination of equivalent particle size D :

Calculate the diameter of particles corresponding to the percentage indicated by a given hydrometer readings as follows.

$$D = \sqrt{\frac{30\gamma}{980(G_s - G_1)}} \sqrt{\frac{L}{T}}$$

Where D = Diameter of particles in mm.

η = Viscosity of water in poises (varies with the change in temperature of the suspending media).

L = Distance from the surface of the suspension to the level at which the density of the suspension is being measured in cm. For a given hydrometer and sedimentation cylinder, values vary according to the hydrometer readings. This distance is known as effective depth. The values of effective depth are given in table.

T = Elapsed time for the beginning of sedimentation to the taking of the hydrometer reading, min.

G_s = Specific gravity of solid particle.

G_1 = Specific gravity (relative density) of water value may be used as 1.00 for all practical purpose.

For convenience in calculation the above formula can be written as follows.

$$D = K \sqrt{\frac{L}{T}} \quad \text{Where } K = \sqrt{\frac{30\gamma}{980(G_s - G_1)}}$$

K = constant depending on temperature of the suspension and specific gravity of the soil particles. Values of 'K' for a range of temperature and specific gravity are given in Table.

b) Determination of percentage finer than D:

Percentage of soil remain in suspension at a time t

$$P = \left[\frac{G_s V \gamma_w}{(G_s - G_1) M_s} (R - 1) \right] \times 100 \quad \text{for 151H hydrometer}$$

oil Mechanics Laboratory Manual

$$P = \frac{R\alpha}{M_s} \times 100 \quad \text{for 152H hydrometer}$$

Where: P = Percentage of soil remaining in suspension at the level at which the hydrometer measures the density of the suspension.
 α = Correction factor to be applied to the readings of hydrometer 152H. Values shown on the scale are computed using specific gravity of 2.65. Correction factors are given in table.
R = Hydrometer reading with composite correction applied.
 M_s = Oven dry mass of the soil used for hydrometer test.
 G_s = Specific gravity of solid particle.
 G_1 = Specific gravity (relative density) of water value may be used as 1.00 for all practical purpose.
V = Volume of suspension usually it is 1000cc.

c) Determination of effective depth

Values of *effective depth* are calculated from the equation.

$$L = L_1 + \frac{1}{2} [L_2 - (V_B / A)]$$

Where L = effective depth, cm.

L_1 = distance along the stem of the hydrometer from the top of the bulb to the mark for a hydrometer reading, cm.

L_2 = overall length of hydrometer bulb, cm

V_B = volume of hydrometer bulb, cm^3 and

A = Cross-sectional area of sedimentation cylinder, cm^2

For both hydrometers, 151H & 152H; $L_2 = 14.0 \text{ cm}$ $V_B = 67.0 \text{ cm}^3$ $A = 27.8 \text{ cm}^2$

e) Corrections

i. Meniscus correction (C_m) - Since the soil suspension is opaque, reading is taken at the upper level of meniscus. The difference between the upper and lower level reading in a solution of dispersing agent and distilled water is meniscus correction. It is always positive.

ii. Temperature correction (C_t) - It is because of different in density of water at different temperature. It may be +Ve or -Ve. Correction for temperature is given in table.

iii. Deflocculating agent correction (C_d) - Due to addition of deflocculating agent the density of suspension increases. It can be observed in sedimentation Jar No 1. It is always negative.

oil Mechanics Laboratory Manual

.....
 $R = R_h + C_m \pm C_t - C_d$ **Where** R_h = Hydrometer readings, observed at the top of the meniscus.

Table: Value of 'K' for use in Equation for computing diameter of particles in hydrometer analysis.

Temp °C	Specific gravity of soil particles								
	2.45	2.50	2.55	2.60	2.65	2.70	2.75	2.80	2.85
16	0.01510	0.01505	0.01481	0.01457	0.01435	0.01414	0.01394	0.01374	0.01356
17	0.01211	0.01486	0.01462	0.01439	0.01417	0.01396	0.01376	0.01356	0.01338
18	0.01492	0.01467	0.01443	0.01421	0.01399	0.01378	0.01359	0.01339	0.01321
19	0.01474	0.01449	0.01425	0.01403	0.01382	0.01361	0.01342	0.01323	0.01305
20	0.01456	0.01431	0.01408	0.01386	0.01365	0.01344	0.01325	0.01307	0.01289
21	0.01438	0.01414	0.01391	0.01369	0.01348	0.01328	0.01309	0.01291	0.01273
22	0.01421	0.01397	0.01374	0.01353	0.01332	0.01312	0.01294	0.01276	0.01258
23	0.01404	0.01381	0.01358	0.01337	0.01317	0.01297	0.01279	0.01261	0.01243
24	0.01388	0.01365	0.01342	0.01321	0.01301	0.01282	0.01264	0.01246	0.01229
25	0.01372	0.01349	0.01327	0.01306	0.01286	0.01267	0.01249	0.01232	0.01215
26	0.01357	0.01334	0.01312	0.01291	0.01272	0.01253	0.01235	0.01218	0.01201
27	0.01342	0.01319	0.01297	0.01277	0.01258	0.01239	0.01221	0.01204	0.01188
28	0.01327	0.01304	0.01283	0.01264	0.01244	0.01225	0.01208	0.01191	0.01175
29	0.01312	0.01290	0.01269	0.01249	0.01230	0.01212	0.01195	0.01178	0.01162
30	0.01298	0.01276	0.01256	0.01236	0.01217	0.01199	0.01182	0.01165	0.01146

Aksum University
Collage Of Engineering & Technology
 Department of Civil Engineering

S

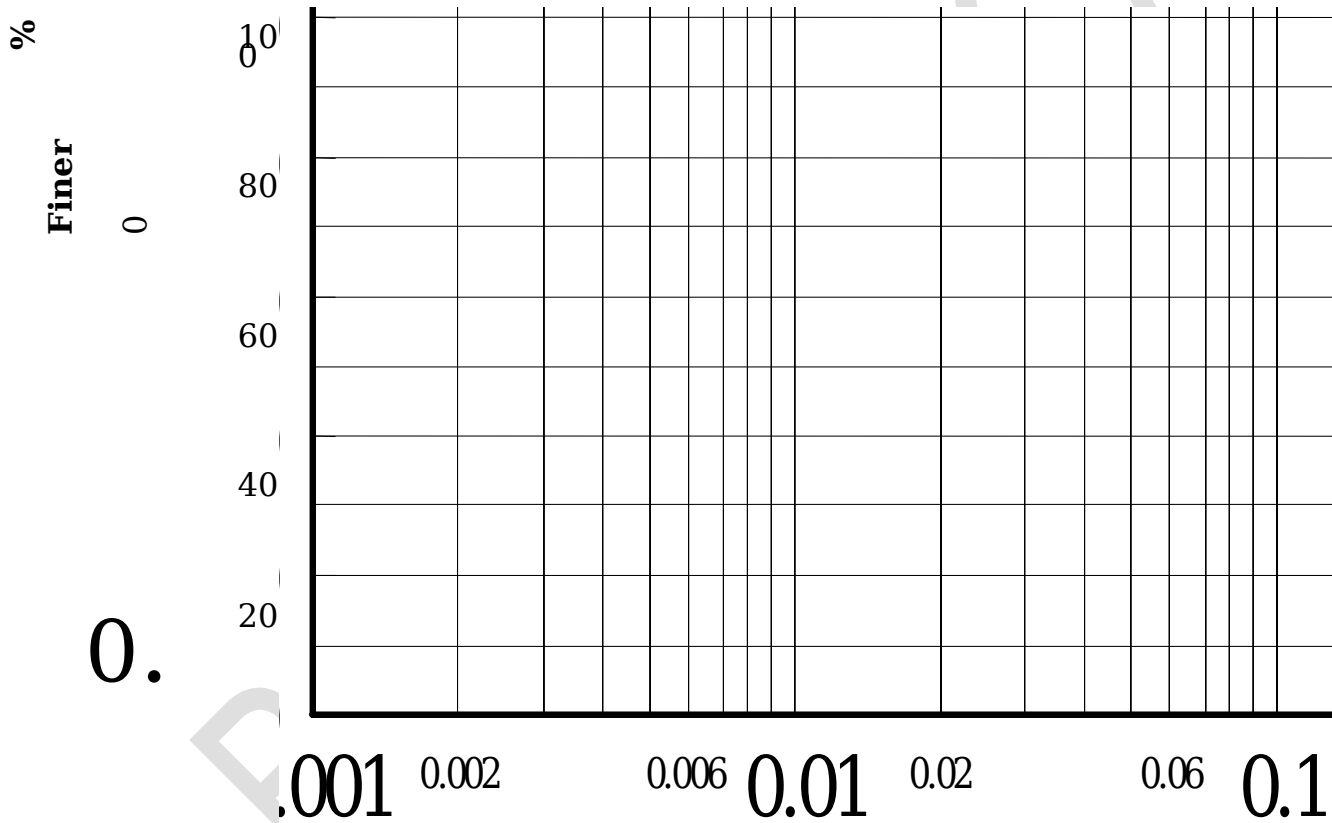
oil Mechanics Laboratory Manual

Table 4 : Values of ‘Effective Depth’ Based on Hydrometer and Sedimentation cylinder of Specific Sizes (Ref:2)

Hydrometer 151H		Hydrometer 152H			
Actual Hydrometer Reading	Effective Depth, L(cm)	Actual Hydrometer Reading	Effective Depth, L(cm)	Actual Hydrometer Reading	Effective Depth, L(cm)
1.000	16.3	0	16.3	39	9.9
1.001	16.0	1	16.1	40	9.7
1.002	15.8	2	16.0	41	9.6
1.003	15.5	3	15.8	42	9.4
1.004	15.2	4	15.6	43	9.2
1.005	15.0	5	15.5	44	9.1
1.006	14.7	6	15.3	45	8.9
1.007	14.4	7	15.2	46	8.8
1.008	14.2	8	15.0	47	8.6
1.009	13.9	9	14.8	48	8.4
1.010	13.7	10	14.7	49	8.3
1.011	13.4	11	14.5	50	8.1
1.012	13.1	12	14.3	51	7.9
1.013	12.9	13	14.2	52	7.8
1.014	12.6	14	14.0	53	7.6
1.015	12.3	15	13.8	54	7.4
1.016	12.1	16	13.7	55	7.3
1.017	11.8	17	13.5	56	7.1
1.018	11.5	18	13.3	57	7.0
1.019	11.3	19	13.2	58	6.8
1.020	11.0	20	13.0	59	6.6
1.021	10.7	21	12.9	60	6.5
1.022	10.5	22	12.7		
1.023	10.2	23	12.5		
1.024	10.0	24	12.4		
1.025	9.7	25	12.2		
1.026	9.4	26	12.0		
1.027	9.2	27	11.9		
1.028	8.9	28	11.7		
1.029	8.6	29	11.5		
1.030	8.4	30	11.4		
1.031	8.1	31	11.2		
1.032	7.8	32	11.1		
1.033	7.6	33	10.9		
1.034	7.3	34	10.7		
1.035	7.0	35	10.6		
1.036	6.8	36	10.4		
1.037	6.5	37	10.2		
1.038	6.2	38	10.1		

oil Mechanics Laboratory Manual

Remark.....
.....
.....



7. Questions

1. What are the corrections made on the hydrometer reading? And why?

oil Mechanics Laboratory Manual

2. What is the draw back of hydrometer analysis?
3. What is hygroscopic moisture and the importance of its correction?
4. State stokes' law

Experiment 6

'Liquid Limit' Determination using Cassa Grande apparatus

Test method ASTM D 4318

1. Theory

The liquid limit is the dividing line between the liquid and plastic states. It is quantified for a given soil as specific water content; and from a physical standpoint, it is the water content at which the shear strength of the soil becomes so small that the soil "flows" to close standard groove cut.

2. Object

To determine liquid limit of soil.

3. Apparatus

- | | |
|---------------------------|------------------------|
| 1. Cassa Grande apparatus | 4. NO 40(0.425mm)sieve |
| 2. Grooving tool | 5. evaporating dish |
| 3. Washing bottle | 6. Spatula |



4. Procedure

1. Take about 200gms of air dried soil passing sieve No 40(0.425mm) in porcelain evaporating dish and mix it thoroughly with a little distilled water, using a spatula, until the soil mass becomes a thick homogenous paste.
2. Adjusting the liquid limit device (Cassa Grand) with the aid of cup equal to 1cm above the base. Turn the hands and practice to obtain a speed of giving the blows at 2 blows per second.

oil Mechanics Laboratory Manual

3. Place the paste in the cup and level up to the depth of 1cm at the point which comes in to contact with the base divided the pest by grooving tool a long the diameter through the canter of the hinge while simultaneously holding it normal to the surface of the cup.
4. Turn the handle at the rate of 2 revolutions per second and allow the cup to be lifted and dropped until the two parts of the paste come in the bottom of the grooving made along the distance 1cm. record the number of blows at which this occurs.
5. Place the sample of the joined portion in moisture can determining the moisture content. Keep the cans in the humidifier until the test is completed.
6. Repeat this process three or more times adding some distilled water each time. Adjust the amount of water visually so that two of these reading are above 25 blows. (The No of blows between 15- 40).
7. Weight the moisture cans placed in the humidifier and then place them in the oven for drying. Enter all observations in the table.

Observation sheet for '**liquid limit**' test

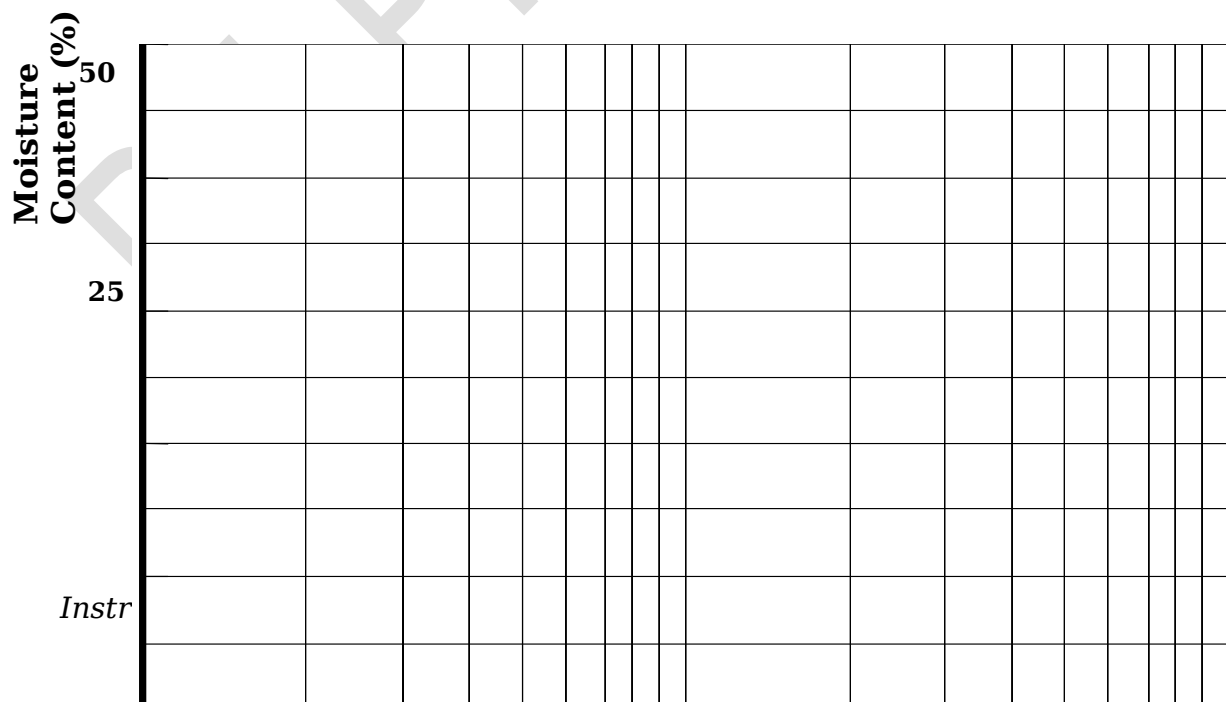
Sample No. _____ Project No. _____

Location. _____

Description of sample _____

Tested by _____ Date _____

Trial Number	1	2	3	4
Can Number				
A. Weight of Wet Soil + Tare				
B. Weight of Dry Soil + Tare				
C. Weight of Water(A-B)				
D. Weight of Tare				
E. Weight of Dry Soil(B-D)				
Water Content % (C/E x 100)				
Number of Blows				
Liquid Limit %				



oil Mechanics Laboratory Manual

0

1

10

100

Number of blows

Experiment 7

Determination of Liquid limit using cone penetration method.

1. Theory

This test is based on the measurement of penetration in to the soil of standard cone of specified mass. At the liquid limit the cone penetration is 28mm. It requires the same apparatus as is used for bituminous materials testing, but filled with special cone.

Liquid limit can be determined by two methods that is either using Cassa Grand apparatus or by penetration method.

2. Object

To determine the '*Liquid limit*' of soil using 'cone penetration method'.

3. Apparatus

- | | |
|---|------------------------|
| 1. cone of stainless steel | 6. An evaporating dish |
| 2. Knife | 7. Distilled water |
| 3. A metal cup | 8. Balance |
| 4. A penetrometer | 9. Draying oven |
| 5. A non corrodible air tight container | |

oil Mechanics Laboratory Manual



4. Sample preparation

Dry the soil in air until is dried and pulverize. Take a representative of it and sieve on sieve

No 40 (0.425mm opening).

5. Procedure

1. Take a sample weighting at least 300 gm from the material passing the 0.425mm test sieve.
2. Place the sample on the flat glass plate and mix thoroughly with distilled water until the mass becomes a thick homogeneous paste. Then this paste shall then be allowed to stand in airtight container for about 24 hrs. To allow the water to permeate throughout the soil mass.
3. Remove the sample from the container and remix for at least 10 min. If necessary further water shall be add so that the first cone penetration reading is approximately 15mm.
4. Push the remixed soil in to the cup with a palette edge of the straight edge, to give a smooth surface.
5. Lower the cone so that it just touches the surface of the soil. When the cone is in the correct position, a slight movement of the cup will just mark the surface of the soil and not the dial gauge reading to the nearest 0.1mm. The cone shall then be released for period 5 ± 1 sec.
6. After the cone has been locked in position the dial gauge shall be lowered to the new position of the cone shaft and note the reading. The reading at the beginning and end of the drop shall be recorded as the cone penetration.

oil Mechanics Laboratory Manual

7. Lift out the cone and clean it to avoid scratching.
8. Add a little more wet soil to the cup, taking care not to trap air, and repeat 4, 5 and 6
9. If the difference between the first and the second penetration reading is not more than 0.5mm record the average of the two penetrations and proceed to 11.
10. If the second penetration is more than 0.5mm and less than 1mm from the first, carry out a third test. If the over all range is not more than 1mm record the average of three penetrations and precede to 11 if the over all range is more than 1mm remove the soil from the cup, remix and repeat 4 to 6.
11. Take about 70 gm samples from the area penetrated by the cone to determine the moisture content.

6. Calculations

The moisture content of the soil from each penetration reading is calculated from the wet and dry weighing as in the moisture content test.

Each cone penetration (mm) is plotted as abscissa, against the corresponding moisture content (%) as ordinate, both to linear scales, the best straight line fitting these points is drawn.

From the graph the moisture content corresponding to a cone penetration of 20 mm is read off to the nearest 0.1%. The result is reported to the nearest whole number as a liquid limit (cone penetration test)

Observation sheet for 'liquid limit' test

Sample No. _____ Project No. _____
Location. _____
Description of sample _____
Tested by _____ Date _____

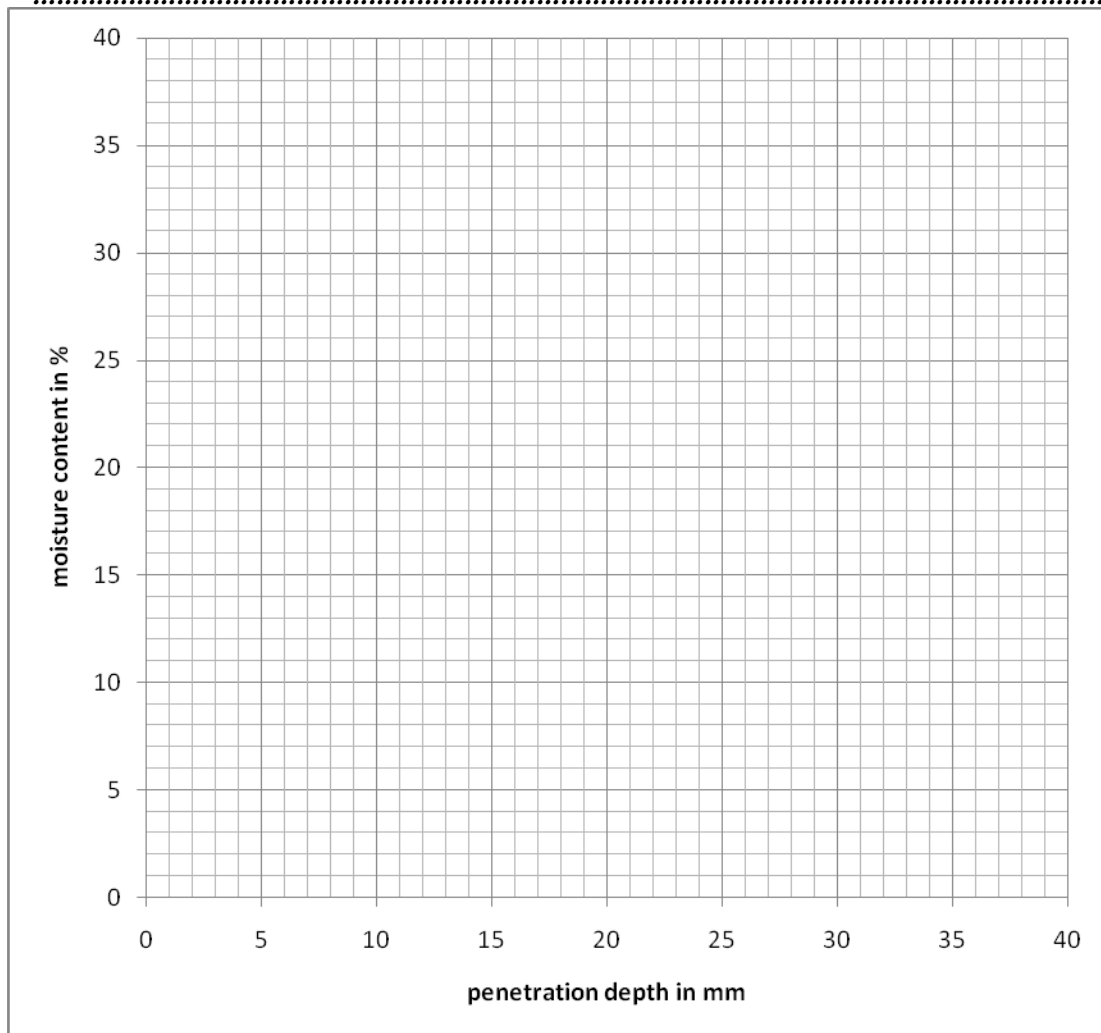
Trial Number	1	2	3	4
--------------	---	---	---	---

oil Mechanics Laboratory Manual

Can Number				
A. Weight of Wet Soil + Tare				
B. Weight of Dry Soil + Tare				
C. Weight of Water(A-B)				
D. Weight of Tare				
E. Weight of Dry Soil(B-D)				
Water Content %(C/Ex100)				
Penetration in mm				
Liquid Limit %				

Remark.....
.....
.....

oil Mechanics Laboratory Manual



Experiment 8

Determination of Plastic limit

Test method ASTM D 4318

1. Theory

The 'plastic limit' of a soil is the water content at the boundary between the plastic and semisolid state. The water content at this boundary is arbitrarily defined as the water content at which soil begins to crumble when rolled into threads of specified size (3mm).

2. Object

To determine the plastic limit of soils.

3. Apparatus

- | | |
|--------------------------|----------------------|
| 1. Balance | 5. Distilled water |
| 2. Dish | 6. Oven |
| 3. Spatula | 7. Sieve No 40 |
| 4. Moisture content cans | 8. Large glass plate |

4. Sample preparation

Dry the soil in air until is dried and pulverize. Take a representative of it and sieve on sieve

No 40 (0.425mm opening).

5. Procedure

1. Take 30 gm of sample passing sieve No 40.
2. Mix thoroughly with water. The water shall be added to produce a paste that has water content less than the liquid limit.
3. Roll the soil on large glass plate with hand until 3mm diameter of soil tread is obtained.
4. When the 3mm diameter tread is obtained, break the tread in to pieces, and squeeze together between thumbs and fingers of both hands in to a uniform ellipsoidal shape. And repeat step 3 until the tread crumbles under the required for rolling and the soil can not longer to be rolled in to treads.
5. Gather the portion of the crumbled soil and determine the water content (the plastic limit)

oil Mechanics Laboratory Manual

Note The crumbling may occur when the tread have a diameter greater than 3mm. This shall be a satisfactory end point, Provide the soil has been previously rolled in to a tread of 3mm in diameter.

6. Calculation

Calculate the water content of the crumbled soil. This water content is the plastic limit of the soil

$$\text{Moisture content \%} = \frac{\text{Weight of water (gm)}}{\text{Weight of dry soil (gm)}}$$

Observation sheet for 'Plastic limit' test

Sample No. _____ Project No. _____
Location. _____
Description of sample _____
Tested by _____ Date _____

Trial Number	1	2	3
Can Number			
F. Weight of Wet Soil + Can			
G. Weight of Dry Soil + Can			
H. Weight of Water(F-G)			
I. Weight of Can			
J. Weight of Dry Soil(G-I)			
Water Content %(H/J x 100)			
Plastic Limit %(Average)			

7. Questions

1. Compute the plasticity index as $PI = LL - PL$
2. Based on the plasticity index classify the soil as per *Unified Classification* system. Assume more than 50% of the sample is less than 0.075mm particle size.
3. Is it possible for a soil to have a liquid and plasticity index both equal? Why?

\

Experiment 9

'Proctor compaction' test

Test method ASTM D 698

1. Theory:

Optimum moisture content (OMC) is the water content at which a soil can be compacted to a maximum dry unit weight by a given compaction effort and maximum dry density is the peak value of the compaction curve.

Compaction may be defined as a process of increasing the soil unit weight by forcing the soil solids into a denser state, reducing the air voids. It is accomplished by static or dynamic loads. Many types of earth construction such as dams, embankment, highway and air port run ways require soil fill which is placed in layers and compacted. A well compacted soil is mechanically more stable, has a high compressive strength and high resistance deformation than a loose soil.

The purpose of the laboratory test is to determine the proper amount of moulding water to be added when compacting the soil in the field and the degree of compaction comparable to that obtained by the method used in the field.

Procter (1938) developed the standard method for light compaction taking into consideration the field equipment then available. The soil attained relatively low density. As field compacting equipment became heavier and more efficient it was necessary to increase

oil Mechanics Laboratory Manual

the amount of compacting energy in the laboratory test. Hence modified proctor test developed. The comparison between two tests is shown in table below.

Table: Comparison of 'Proctor' and 'Modified Proctors' compaction tests.

Type of test	Hammer mass (Kg)	Hammer drop (m)	Blows /layer	Number of layers	Compaction energy Kg/cm ³
Standard proctor	2.5	0.30	25	3	590
Modified proctor	4.5	0.45	25	5	2700

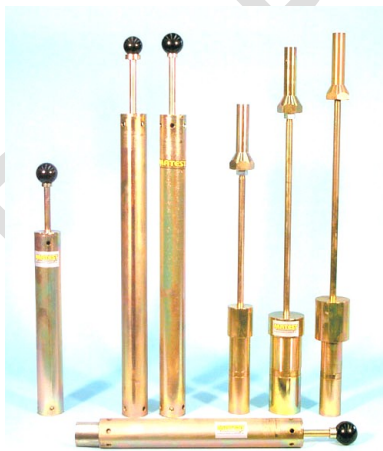
The proctor test is adequate for most applications like highway embankments earth dams, retaining back fill while modified proctor is usually favoured for heavier load application like airport runway base courses.

2. Object

To determine the relation between 'moisture content' and the 'dry density' of soils using proctor compaction and determine the 'optimum water content' and 'maximum dry density'.

3. Apparatus

1. mould with removable collar and base
2. Hammer
3. No 4 sieve
4. Balance
5. Large mixing pan
6. Drying oven
7. Moisture content cans
8. Sample extruder (optimal)
9. Mortar and rubber tipped pestle



oil Mechanics Laboratory Manual

4. Sample preparation

Expose the soil sample to the air until it is dried thoroughly. And pulverize it using mortar and rubber tipped pestle.

5. Procedure

1. Select a representative sample of about 18 Kg which passes sieve No 4 and divide in to 5-6 equal parts by weight.
2. Prepare a series of 5-6 specimens with different moisture contents. The moisture content selected shall include the optimum moisture content, thus providing specimens which, when compacted will increases in mass to maximum density and then decrease in density.
3. Place the specimens in separate covered containers and allow to stand prior to compaction to insure even distribution of moisture throughout the specimens.
4. Weigh the empty mould with base but with out collars.
5. Attach the mould and extension collar, compact the first specimen with 25 blows in three layers of approximately height. Each layer should receive 25 evenly distributed blows.
6. Remove the collar. While removing the collar locate it to break the bond between it and the soil before lifting of the mould. This prevents removing some of the compacted soil when the solar is taken off. If the collar is hard to remove do not risk twisting of the last layers of soil. Take a spatula and trim long the sides of the collar until it comes off easily.
7. Remove the base plate. Carefully strike both the top and the base of the compacted cylinder of soil with a steel edge. Fill any holes in the compacted specimens with soil if the smoothing process removes any small pebbles.

Note: *That the all layers should be approximately of equal thickness. If the mould is not filled above the collar joint from the last compacted layer, do not add soil to make the deficiency. Redo the test Also you should try to have not more than about 0.5 cm of soil above the collar joint.*

8. Weigh the weight of the mould with base and compacted soil.
9. Remove the soil from the cylinder and obtain a representative sample for water content determination.
10. Repeat steps 6-10 for remaining specimens.

6. Computation

Calculate the 'moisture content' and 'dry density' for each compacted specimen as below

oil Mechanics Laboratory Manual

Moisture content $w = (w_w/w_s) \times 100$

Where w_w = Weight of water.
 w_s = Weight of dry soil.

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

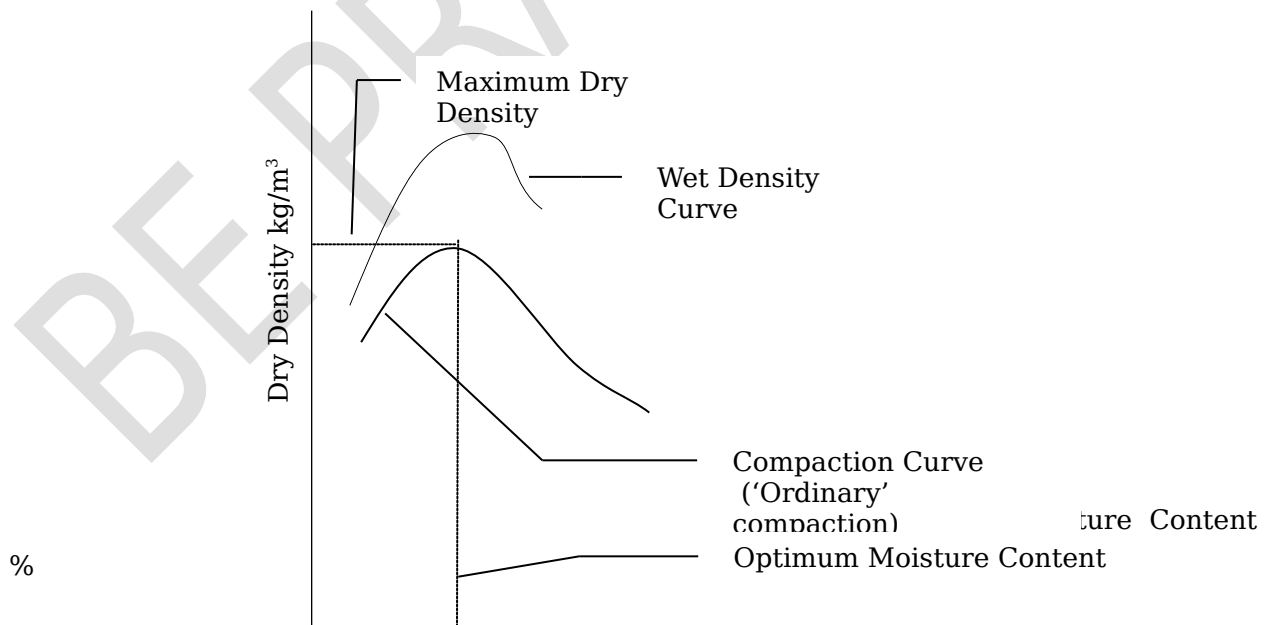
Where γ_{wet} = Wet unit weight of the soil
 γ_{dry} = Dry unit weight of the soil
 w = Water content

From the data obtained plot 'dry density' versus 'moisture content'. Obtain the peak value of dry density (maximum dry density) and the corresponding value is the 'optimum moisture content'.

Also draw a curve termed the 100% saturation curve (zero air void curve) on this plot.

$$\gamma_{dry} = \frac{G\gamma_w}{1 + Gw/S}$$

Where G = Specific gravity of the soil
 γ_{dry} = Dry unit weight of the soil
 γ_{wet} = Wet unit weight of the soil
 γ_w = Unit weight of water
 w = Water content
 S = Degree of saturation



oil Mechanics Laboratory Manual

Fig: 'Dray density' and 'moisture content' relationship for a typical soil.

Observation sheet for 'compaction Test'

Specific gravity of the soil _____

Date _____

Volume of the mould _____

Description of the sample _____

DETERMINATION No		1	2	3	4	5
A	MOULD No					
B	WEIGHT OF MOULD & WET SOIL (gm)					
C	WEIGHT OF MOULD (gm)					
D	WEIGHT OF WET SOIL (gm)	B-C				
E	VOLUME OF MOULD (cm ³)					
F	WET DENSITY (Kg/ m ³)	D/E				

DETERMINATION No.		1	2	3	4	5
G	CONTAINER No.					
H	WEIGHT OF CONTAINER & WET SOIL (gm)					
I	WEIGHT OF CONTAINER & DRY SOIL (gm)					
J	WEIGHT OF WATER (gm)	H-I				
K	WEIGHT OF CONTAINER (gm)					
L	WEIGHT OF DRY SOIL (gm)	I-K				
M	MOISTURE COONTENT %	J/L				
N	AVERAGE MOISTURE CONTENT %					
O	DRY DENSITY (Kg/ m ³)					

oil Mechanics Laboratory Manual

Remark:

Experiment 10

'Consolidation' tests

Test method ASTM D 2435

Objective

To determine the coefficient of consolidation (C_v) which indicating the rate of compressibility under a load increment and the compression index (C_v), which indicates the compressibility of the specimen.

Introduction

Consolidation is the gradual reduction in volume of a soil mass by expulsion of water resulting form an increase in compressive stress. Sand and gravels have relatively large pores and there is no large 'time lag' between the strain caused by expulsion of water and application of stress and the resulting strain. The phenomenon of time dependent compression of a saturated soil is called 'consolidation'.

The settlement of clay layer sand witched between two sand layers and at some depth below the ground level will be due to one dimensional consolidation. The computation of total settlement and time rate of settlement of structures found on clayey soil is essential for design of such structure. The consolidation equation give by Terzaghi foe one-dimensional consolidational consolidation of saturated soils is give below.

$$\frac{\partial u}{\partial t} = c_v \cdot \frac{\partial^2 u}{\partial z^2} \quad \& \quad c_v = \frac{k}{m_v \cdot \gamma_w}$$

Where C_v = coefficient of consolidation

u = Excess hydrostatic pressure at any time 't' at any depth 'z'

K =coefficient of permeability

m_v = coefficient of volume change

γ_w = unite weight of water

oil Mechanics Laboratory Manual

The theory of consolidation predicts the rate at which the excess hydrostatic pressure caused by the applied loaded in the foundation soil is transferred to soil grains, leading to delayed compression. the solution to the above equation is derived in the form of $U=f(T_v)$

Where

U = degree of consolidation

T_v = time factor which is obtained $T_v = \frac{c_v \cdot t}{H^2}$

H = length of drainage path (for S.D and D.D it is H and H/2 respectively)

T = time

The relationship is useful in estimating the rate of settlement of structures founded on saturated clay layer and presented in the form of charts.

For conduction consolidation test, saturated samples, undisturbed or prepared are required. The samples are usually 6 to 10 cm in diameter and 1.25 to 4 cm thick. The sample is placed in a fixed ring or floating ring container and provided with drainage access both at top and bottom.

The consolidation ring together with porous stone and assembly is called the oedometer. The oedometre unit is placed in a load frame. The sample is saturated and is loaded in suitable increments. After Applying *each* load increment, compression dial gauge readings are noted at selected time intervals till the consolidation under the load increment is complete. The load increment generally starts with a low value of 50 KN/m² and at the end of the 24 hrs increased to 100KN/m². On successive day the load intensities are increased to 200,400,800 and 1600 KN/m². For each load increment compression dial readings are noted at selected time intervals

The data from consolidation test is used to estimate the magnitude and the rate of both differential and total settlement of a structure. Estimate of this type are of key importance in the design of engineered structures and evaluation of their performance.

Apparatus and supplies

Consolidation unit (consolidometer, load device, porous stones, deformation indicator etc)

Specimen trimmer and accessories

Stop clock

Balance

Dish

Moisture content cans

Drying oven

.

Sample preparation and test procedure

oil Mechanics Laboratory Manual

1. The prepared undisturbed sample is brought from the field. Trim the sample to fit in metal ring
2. Lubricate the inside surface of the metal ring with a thin film of oil
3. Weigh the metal ring
4. Carefully place the sample into the metal ring
5. Trim the ends of the sample carefully with the least amount of disturbance
6. Measure the diameter and height of the specimen
7. Obtain two sample specimens for water content determination
8. Determine the weight of the soil sample and the metal ring container
9. Wet two filter papers with water and fit them carefully at both ends of the soil sample
10. Soak the porous stones in water
11. Place the outside ring and tighten the whole system with the given set of screws
12. Place the sample container above the porous stone
13. Place the second porous stone which has also been well soaked in water on the soil sample
14. Place the loading block on the porous stone
15. Mount the oedometer assembly in the consolidation load frame
16. Immerse the sample completely in water
17. Adjust the loading platform till the loading yoke just touches the loading block
18. Make sure that the deflection dial has a free run and note the initial reading
19. Allow the sample to reach equilibrium under a seating load of very small magnitude
20. At the end of 24 hours, note the reading and apply the first load increment, generally 50 kN/m². Simultaneously start the stop clock
21. Record the change in thickness by deformation indicator with time. Records are normally taken at total elapsed times of 0, 0.25, 1, 2, 2.5, 4, 6, 25, 16, 25, 49, 64, 81, 100, ... and up to 1440 minutes or until compression ceases
22. At the end of 24 hours take the final reading and increase the intensity with the next desired load increment
23. The test will be continued with load intensities of 100, 200, 400, 800 and 1600 kN/m² to obtain the relationship between the consolidation stress and void ratio and between compression and time at different load intensities. If the rebound or unloading characteristics are required, the load is decreased to 400 kPa, 200 kPa

oil Mechanics Laboratory Manual

and 10 KPa. The deformation reading is noted for each load after 24 hours.

At the end the test the sample container will be dismantled and the final weight of the container and the sample will be noted. Then the sample will be dismantled and final weight of the container and the sample will be noted. Then the sample will be dried in the oven to determine the final water content.

Computation

The time compression relationship can be presented either in a 'square root time' or 'logarithm of time' plot. The 'coefficient of consolidation' is evaluated for the given load increment through appropriate fitting methods.

Determination of 'C_v' by 'square root of time fitting' method.

Make a plot of compression dial reading against the square root of elapsed time. Extend the initial straight line portion of the curve back to intersect the zero time and obtain the corrected zero point 'd_s'. Through this point draw a straight line having an inverse slope of 1.15 times the initial straight line. The intersection of this straight line and the time-compression curve is point the 0% consolidation point. The 't₉₀' corresponding to this 'd₉₀' is obtained from the curve. The coefficient of consolidation (C_v) can be obtained from the below equation.

$$C_v = \frac{0.848 H^2}{t_{90}}$$

Where H = the length of drainage path for the load increment

t₉₀ = time at 90% compression determined from the compression time curve

Determination of 'C_v' by 'log time fitting' method

The compression dial readings are plotted in the y-axis against logarithm of time in the x-axis. The two straight-line portions of the compression curve in the later stages of consolidation are extended to intersect. The intersection point is the 100% consolidation point d₁₀₀. The corrected zero point is located by laying off above a point in the neighbourhood of 1 minute distance equal to the vertical distance between the point and one at a time four times greater. The 50% compression point 'd₅₀' is immediately between 'd_s' and 'd₁₀₀'. The corresponding 't₅₀' is obtained from the graph. The coefficient of consolidation (C_v) is then calculated from.

$$C_v = \frac{0.197 H^2}{t_{50}}$$

oil Mechanics Laboratory Manual

Where H = the length of drainage path for the load increment

t_{50} = time at 50% of compression, determined from the compression time curve

Determination of 'Cc'

For every load increment there is one final void ratio and from the whole series of loads, the relation between 'pressure' and void ratio 'can be plotted as shown below

1. Calculate the 'initial volume' V_o .

$$V_o = A_o \times H$$

Where A_o = initial area of the sample

H = initial thickness of the sample

2. Calculate the 'solid volume' V_s from the specific gravity G_s and dry weight of the sample W_s

$$V_s = \frac{W_s}{G_s Y_w}$$

3. Calculate the initial void ratio' e_o

$$e_o = \frac{V_v}{V_s} = \frac{V_o - V_s}{V_s}$$

Where V_v = volume of voids

V_s = volume of solids

V_o = initial volume

4. Calculate the 'change in void ratio' for each load increment using relation as

$$\Delta e = \frac{\Delta H(1 + e_o)}{H}$$

Where ΔH = the change in thickness when compression ceases

H = the initial thickness of the sample

Δe = the change in final void ratio

e_o = initial void ratio

5. Calculate the ratio for the first load increment e_1 as follows

$$e_1 = e_o - \Delta e$$

in the same way determine e_2, e_3, e_4 for the second, third and fourth load increments respectively then plot 'e' versus 'log p'

Compression index 'c_s' is numerically equal to the slope of the straight portion of the 'e-log p' curve

Observation sheet for 'consolidation list'

Sample height:

Sample diameter:

Sample weight:

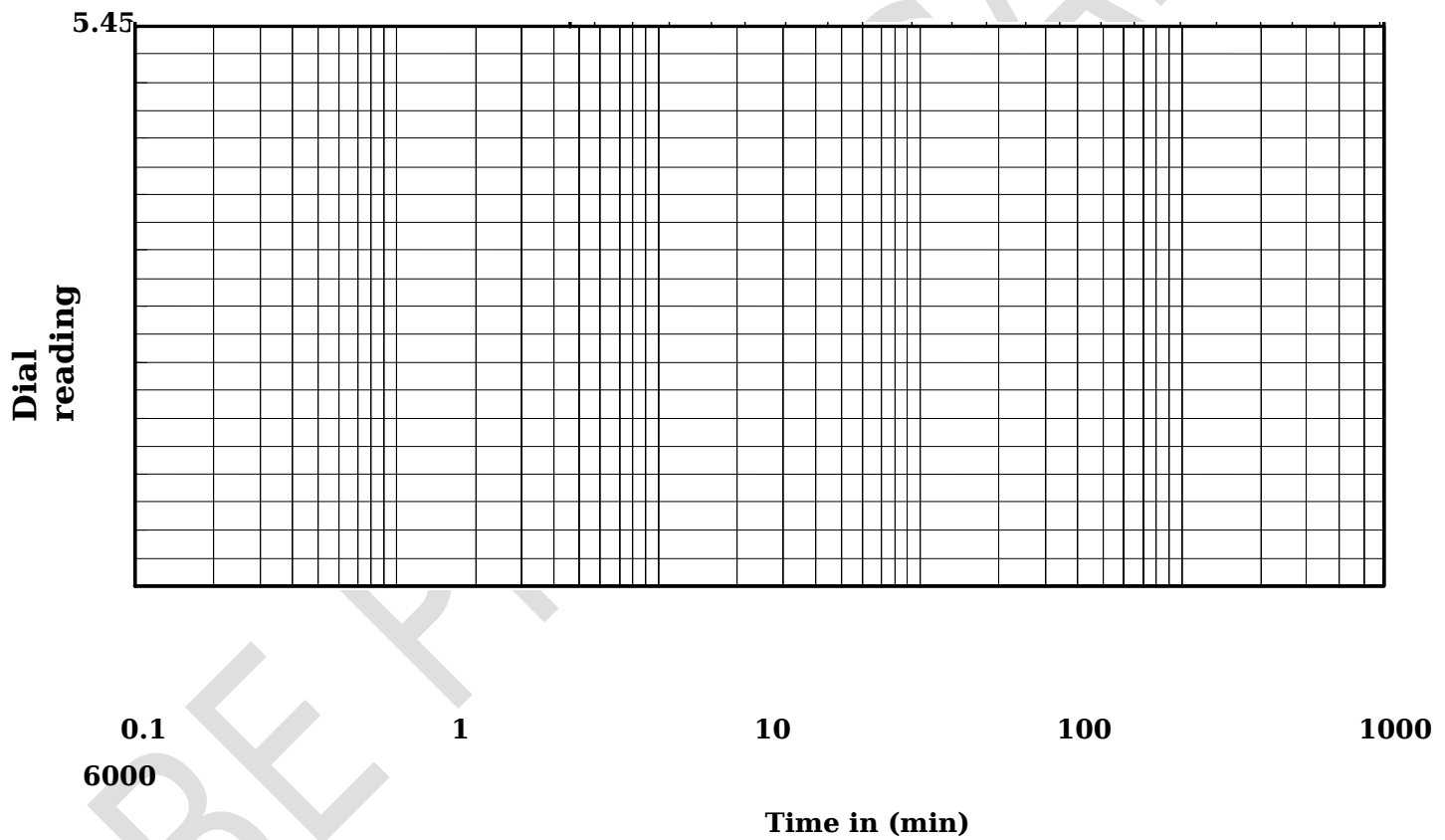
Weight of container with sample:

Weight of container:

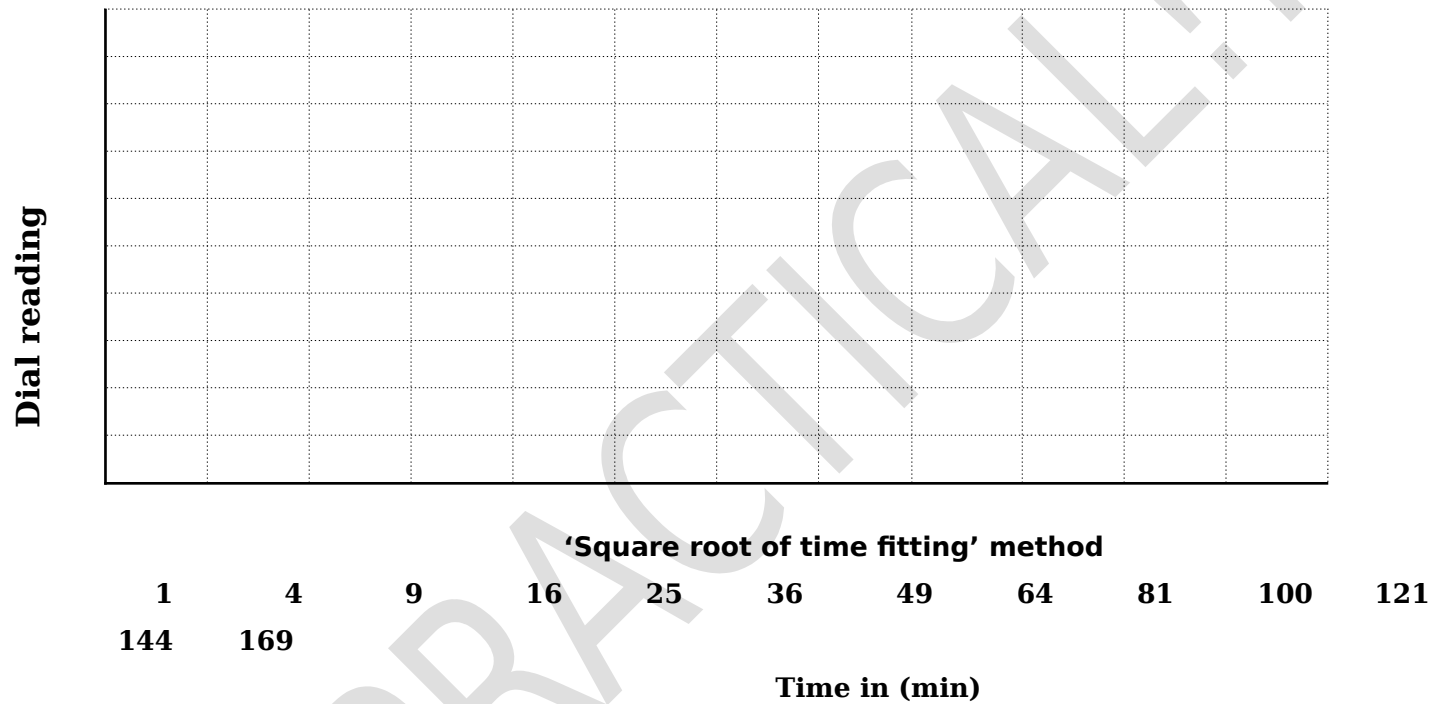
[illegible]

Remark.

'Log time fitting' method



oil Mechanics Laboratory Manual



Experiment 11

Constant head 'Permeability' test

Test method ASTM D 2434

Theory

The facility with which water flows through the soil is termed as permeability. The permeability of soil is an engineering property. It is required in

1. Estimating the quality of seeping through or beneath earth dams and embankments and through irrigation ditches.
2. Evaluating the up lift or seepage forces beneath hydraulic structures.
3. Estimating pumpage requirement for dewatering excavations.
4. Providing control of seepage velocity so that the fine soil particles are not eroded from the soil mass.
5. Determining the rate of settlement of structures due to consolidation of clay layer.

A permeameter is devise for measuring permeability of soils in the laboratory. The constant head permeameter is preferred for soils with high permeability such as sand and sandy gravel. They have large void openings and large flow quantity is required to improve computational precision. Note that in the field the hydraulic gradient will be in the order of 0.5 to 1.0 where as in the laboratory it is generally five or more.

In fine-grained soils discharge will be very small. Hence constant head permeameter is not suitable. In clays it is more feasible to not the quantity of water going in to the specimen than that going out. The falling head permeameter is based on this principle and is used to measure the permeability of fie-grained soils.

The coefficient of permeability, k depends on the unit weight and viscosity of the fluid which are dependent on the temperature and the pore size of the voids. The pore size of voids depends on the ration and size of grains. Hence the coefficient of permeability of

oil Mechanics Laboratory Manual

coarse sands is large by many magnitudes than that of silts and clays. The degree of saturation also affects the permeability.

1. Object

To determine the 'coefficient of permeability' of soils by 'constant head permeability test'.

2. Apparatus

- | | |
|--------------------------------|----------------|
| 1. Constant head permeameter | 4. Thermometer |
| 2. graduated cylinders | 5. Stop watch |
| 3. Water and water supply hose | |

3. Sample preparation

Compact the soil in the mould at specified water content to the required density. If undisturbed sample is to be tested, trim the sample to fit in to the mould.

4. Procedure

1. Measure the length and diameter of the sample.
2. Saturate the sample by connecting the source of supply to the bottom value of the permeability mould for up ward flow. Vacuum if available may be used to ensure saturation.
3. Disconnect the water supply line after saturation is complete and close the lower valve.
4. Supply water to the sample by keeping the water level constant at top.
5. Open the lower value, start the stop clock and collect water that passes through soil sample.
6. Record the volume of water collected, elapsed times and test temperature.
7. Measure the height of water causing flow.
8. Repeat the test for two more addition trials.

Computation

The magnitude of coefficient of permeability ' k_t ' can be calculated from the following eq;

$$K_t = \frac{QL}{Aht}$$

Where Q = Total discharge in cm^3
 t = Elapsed time in seconds.
 A = Area of sample in cm^2 .
 h = Constant head causing flow in cm.
 L = Length of sample in cm.

The coefficient of permeability K_{20} corresponding to standard temperature 20°C can be calculated from

oil Mechanics Laboratory Manual

$$K_{20} = K_t \left(\frac{\eta_t}{\eta_{20}} \right)$$

Where η_t and η_{20} are viscosity of water at test temperature 't' and at 20°C respectively.

Observation sheet for '**Constant head permeability**' test

Diameter of specimen (d) cm _____ Length of specimen (L) cm _____

Area of specimen (A) cm². _____ Constant head (h) cm. _____

Obs. No	Discharge collected Q m ³	Time for collected of discharge (t) sec.	Coefficient of permeability at test temperature k_t cm/sec	Viscosity ratio μ_T/μ_{20}	Coefficient of permeability at 20°C K_{20} cm/sec

Experiment 12

'Unconfined compression' test

Test method ASTM 2166

1. Theory:

The primary purpose of 'unconfined compression strength' test is to obtain quickly, approximate compressive strength of a soil possessing. The unconfined compressive strength is defined as the load per unit area at which an unconfined cylindrical specimen of soil fails. In simple compression test in these tests unconfined compression strength

oil Mechanics Laboratory Manual

.....
maximum load attained per unit area or the load per unit area at 20% axial strain, whichever is attained first during the performance of the test.

The shearing strength of fine grained soil is a function of the applied normal pressure, the pre consolidation pressure and drainage condition. Tri axial compression test gives the most reliable results. Unconfined compression test can be described as a tri axial compression test performed with zero lateral pressure. Since there is no lateral pressure, the test may be performed only on a soil with sufficient cohesion to maintain its shape under its own weight.

The relationship between 'major' and 'minor' principal stress in tri axial compression test can be stated as

$$\sigma_1 = \sigma_3 \tan\left(45 + \frac{\phi}{2}\right) + 2c \cdot \tan\left(45 + \frac{\phi}{2}\right)$$

Where σ_1 = Major principal stress
 σ_3 = Minor principal stress
 Φ = Angle of internal friction
 c = Cohesive strength

In un confined compression test $\sigma_3 = 0$, and for saturated clays in un drained test $C = 0$.
Hence,

$$\sigma_1 = 2c$$
$$c = \sigma_1/2 = q_u/2$$

Where q_u = the 'unconfined compressive strength' of soil.

So the 'shearing strength' of soil is assumed to be one half of the failure load.

The unconfined compression test is usually a strain-controlled test. The stress strain curve obtained from unconfined compression tests are similar to those obtained from tri axial compression tests. Since the test specimens are exposed to laboratory air, test should be conducted within about 10 minute. Otherwise changes in water content may alter the unconfined compressive strength.

2. Apparatus

1. Compression machine
2. Sample ejector
3. Vernier caliper
4. Stopwatch
5. Drying oven



6. Deformation indicator

6. Trimming tools
7. Moisture content cans
8. Remoulding device

3. Sample preparation

Prepare a compacted of specimen by compacting the disturbed material in a mould of circular cross section at a pre-determined moisture content and dry density or prepare undisturbed specimen for large undisturbed sample by trimming or from sample secured from thin wall sampling of soil.

4. Procedure

1. Place the specimen in testing machine so that it is cantered on bottom platen.
2. Make the initial weight of the specimen reading of the deformation zero.
3. Start to apply the load.
4. Record simultaneously the load and deformation dial gauge readings at frequent intervals to define the stress and strain relation.
5. Continue loading until the load values decrease with increasing strain or until 20% strain is reached.
6. Measure the failure angle with the horizontal after the sample has failed.
7. Remove the specimen and sketch the shape of the failed specimen.
8. Determine the moisture content using the entire sample or part of it.

Note

The height to diameter ratio of the test specimen shall be between 2 and 2.5 and specimen should have a minimum diameter of 33mm.

5. Computation

1. Calculate the vertical displacement (ΔL) for each load increment.
Vertical displacement = Vertical dial reading * gauge calibration factor
2. Calculate the axial (applied) load as follows
Axial load (P) = proving ring reading * ring calibration factor
3. Calculate the axial strain ϵ for applied load as follows

$$\epsilon = \Delta L / L_0$$

Where: ΔL = Vertical displacement.

L_0 = Initial length of the specimen.

4. Calculate the average cross sectional area A for a given applied load as follows.

$$A_c = A_0 / (1 - \epsilon)$$

Where: A_0 = Initial average cross sectional area of the specimen.

ϵ = Axial strain for a given load.

5. Calculate the load per unit area σ_d for a given applied load as follows.

$$\sigma_d = P / A_c$$

Where

P = given applied load.

A_c = Corresponding corrected cross sectional area.

6. Plot the graph of 'stress' versus 'strain'.

Finally determine the maximum value of load per unit area or load per unit area at 20% strain which ever is attained first. This is the 'unconfined compressive strength' of the specimen. Make a sketch the test specimens at failure showing the slope angle of the failure surface.

Report the unconfined compressive strength, height to diameter ratio, initial density and moisture content as well as a sketch of the test specimen at failure.

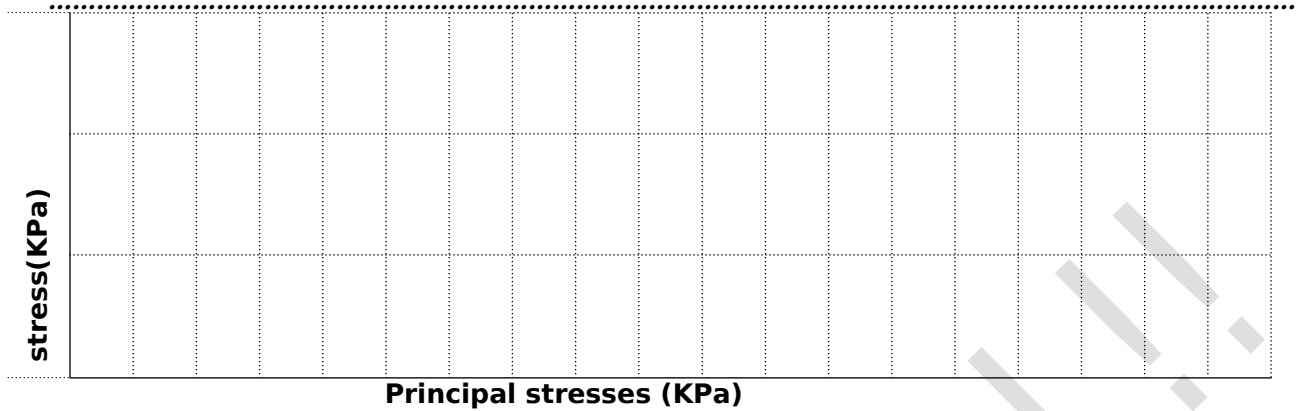
Unconfined compressive strength q_u (Kg/cm ²)	Consistency of soil
<0.25	Very soft
0.25-0.50	Soft
0.50-1.00	Medium
1.00-2.00	Stiff
2.00-4.00	Very stiff
>4.00	Hard

Density of sample ρ g/cm³

[illegible]



oil Mechanics Laboratory Manual



Experiment 13

Laboratory Vane shear Test

General Theory

A direct measurement of undrained shear strength of soft cohesive soils can be made by a vane shear test. This can be performed on a soil sample in a laboratory or in to undisturbed soil in situ at the bottom of a borehole.

A vane shear essential consists of four steel plates called vanes, welded orthogonally to a steel rod as shown in the figure. After

Objective

To determine the 'shear strength' of soils by 'laboratory vane shear' test

Apparatus

Vane Shear apparatus

Mould

Soil sampler for undisturbed soils



Laboratory Van shear test apparatus

Field Van shear test apparatus

Procedure

1. Push the vane gently in to a soil sample
2. Rotate the vane at a uniform speed by applying a turning moment through the steel torque rod. The rotation of the vane shears the soil along a cylindrical surface.

Computation

If the top end of the vane is evaded into the soil, both the top and bottom ends also partake in shearing the soil. Let τ_f be the unit shear strength of the soil, H the height of the vane and d the diameter of vane. If it is further assumed that the shear resistance of soil develops uniformly on the cylindrical surface and the top and the bottom of the sheared cylinder, the maximum total shear resistance at failure equals to

$$\left[\pi.dH\tau_f + 2 \int_0^{d/2} (2\pi.dr)\tau_f \right], \text{ Where } r \text{ is the radius of the sheared surface. The}$$

maximum moment of the total shear resistance about the axis of torque rod equals the torque T at failure.

$$T = \pi.dH\tau_f \cdot \frac{d}{2} + 2 \int_0^{d/2} (2\pi.dr)\tau_f \cdot r$$

$$\text{or } T = \pi\tau_f \left[\frac{d^2H}{2} + \frac{d^3}{6} \right]$$

If only the bottom end of the vane partakes in shearing the soil, then the above equation becomes as

$$T = \pi\tau_f \left[\frac{d^2H}{2} + \frac{d^3}{12} \right]$$

For saturated clay, τ_f is replaced by c_u or $q_u/2$

- The torque applied is obtained by multiplying the dial reading with the spring constant.

Table: strain rate range of various springs for 12.7X 12.7 mm vane

Spring number	Useable range, Kg.cm	Vane shear strength range, Kpa
1	0.5-1.5	12-34
2	1.0-3.5	23-80
3	1.75-5.0	40-114
4	2.75-8.0	63-180

Observation sheet for '**van shear**' test

Sample No. _____ Project No. _____

Location. _____

oil Mechanics Laboratory Manual

Description of sample _____

Tested by _____ Date _____

Diameter of the vane 'd' cm Height of the vane 'H' cm

Obs.No	Moisture content %	Torrque failure Kg-cm	at	Shear strength Kg/cm ²	Remark
1					
2					
3					
4					

RESULT

'Shear strength' of the soils is expressed at various moisture contents as shown below

Obs.No	Moisture content (%)	Shear strength (Kg/cm ²)
1		
2		
3		
4		

Remark.....
.....
.....

Experiment 14

FIELD DENSITY TEST BY SAND REPLACEMENT METHOD

OBJECTIVE

Determine the in situ density of natural or compacted soils using sand pouring cylinders.

NEED AND SCOPE

The in situ density of natural soil is needed for the determination of bearing capacity of soils, for the purpose of stability analysis of slopes, for the determination of pressures on underlying strata for the calculation of settlement and the design of underground structures.

It is very quality control test, where compaction is required, in the cases like embankment and pavement construction.

APPARATUS REQUIRED

1. Sand pouring cylinder of 3 liter/16.5 liter capacity mounted above a pouring cone and separated by a shutter cover plate.
2. Tools for excavating holes; suitable tools such as scraper tool to make a level surface.

oil Mechanics Laboratory Manual

3. Cylindrical calibrating container with an internal diameter of 100 mm/200 mm and an internal depth of 150 mm/250 mm fitted with a flange 50 mm/75 mm wide and about 5 mm surrounding the open end.
4. Balance to weight up to an accuracy of 1g.
5. Metal containers to collect excavated soil.
6. Metal tray with 300 mm/450 mm square and 40 mm/50 mm deep with a 100 mm/200 mm diameter hole in the centre.
7. Glass plate about 450 mm/600 mm square and 10mm thick.
8. Clean, uniformly graded natural sand passing through 2.00 mm I.S.sieve and retained on the 250micron I.S. sieve. It shall be free from organic matter and shall have been oven dried and exposed to atmospheric humidity.
9. Suitable non-corrodible airtight containers.
10. Thermostatically controlled oven with interior on non-corroding material to maintain the temperature between 105°C to 110°C.

THEORY

By conducting this test it is possible to determine the field density of the soil. The moisture content is likely to vary from time and hence the field density also. So it is required to report the test result in terms of dry density. The relationship that can be established between the dry density with known moisture content is as follows:

$$\gamma_d = \frac{\gamma_b}{(1 + w)}$$

γ_d = Dry density

γ_b = Bulk density

w = water content

PROCEDURE

Calibration of the Cylinder

1. Fill the sand pouring cylinder with clean sand so that the level of the sand in the cylinder is within about 10 mm from the top. Find out the initial weight of the cylinder plus sand (W_1) and this weight should be maintained constant throughout the test for which the calibration is used.
2. Allow the sand of volume equal to that of the calibrating container to run out of the cylinder by opening the shutter, close the shutter and place the cylinder on the glass sand

oil Mechanics Laboratory Manual

.....
takes place in the cylinder close the shutter and remove the cylinder carefully. Weigh the sand collected on the glass plate. Its weight (W_2) gives the weight of sand filling the cone portion of the sand pouring cylinder. Repeat this step at least three times and take the mean weight (W_2). Put the sand back into the sand pouring cylinder to have the same initial constant weight (W_1)

Determination of Bulk Density of Soil

3. Determine the volume (V) of the container by filling it with water to the brim. Check this volume by calculating from the measured internal dimensions of the container.
4. Place the sand pouring cylinder centrally on top of the calibrating container making sure that constant weight (W_1) is maintained. Open the shutter and permit the sand to run into the container. When no further movement of sand is seen close the shutter, remove the pouring cylinder and find its weight (W_3).

Determination of Dry Density of Soil In Place

5. Approximately 60 sqcm of area of soil to be tested should be trimmed down to a level surface, approximately of the size of the container. Keep the metal tray on the level surface and excavate a circular hole of volume equal to that of the calibrating container. Collect all the excavated soil in the tray and find out the weight of the excavated soil (W_w). Remove the tray, and place the sand pouring cylinder filled to constant weight so that the base of the cylinder covers the hole concentrically. Open the shutter and permit the sand to run into the hole. Close the shutter when no further movement of the sand is seen. Remove the cylinder and determine its weight (W_3).
6. Keep a representative sample of the excavated sample of the soil for water content determination.

Aksum University
Collage Of Engineering & Technology
Department of Civil Engineering

S

oil Mechanics Laboratory Manual

S. No.	Measurement of Soil Density	Obs-1	Obs-2	Obs-3	Remark
--------	-----------------------------	-------	-------	-------	--------

BE PRACTICAL!!

oil Mechanics Laboratory Manual

1	Weight of wet soil from hole W_w gm				
2	Weight of sand + cylinder before pouring W_1 gm				
3	Weight of sand + cylinder after pouring W_4 gm				
4	Weight of sand in hole $W_b = (W_1 - W_2 - W_4)$ gm				
5	Bulk density $\gamma_b = (W_w / W_b) \diamond \gamma_s$ gm/cc				
6	Water content determination				
7	Container number				
8	Weight of wet soil				
9	Weight of dry soil				
10	Moisture content (%)				
11	Dry density $\gamma_d = \gamma_b / (1 + w)$ gm/c				
12					

GENERAL REMARKS

1. While calibrating the bulk density of sand great care has to be taken.
2. The excavated hole must be equal to the volume of the calibrating container.

