Geotechnical Engineering-I Sessional

CE 0732-3204

Department of Civil Engineering

University of Global Village (UGV), Barishal

Preface

Geotechnical Engineering is the specialty of Civil Engineering which deals with the property and behavior of soil and rock in engineering purposes. To obtain different properties of soil, laboratory tests are performed on collected disturbed and undisturbed soil samples, while field tests are performed on sub-soil at in-situ condition following mainly standard ASTM methods. In Bangladesh mainly wash boring method is adopted to make holes which are known as Bore Holes (BH) and from these holes, disturbed samples are collected from different layers by mainly split spoon sampler as well as undisturbed samples are collected by thin-walled tube/Shelby tube during soil exploration/investigation programme at the site. This Lab manual mainly deals with the common and standard laboratory tests on different types of soil. Field identification tests of soil and laboratory tests like- grain size analysis by sieve and hydrometer tests, specific gravity test, moisture content determination test, organic content determination test, Atterberg limits test, compaction test, relative density test and direct shear test may be performed on collected disturbed soil samples, whereas permeability test, unconfined compression test, consolidation test will be performed on collected undisturbed soil samples according to ASTM (American Standards for Testing Materials) methods.

The authors are highly indebted to their colleagues for their constant support and guidance during the course of preparing this manual. In addition, concepts were taken from principles of geotechnical engineering book by BM Das and AUST manual, while the pictures were collected from the internet.

Rubieyat Bin Ali

Assistant Professor & Chairman

Department of Civil Engineering

University of Global Village (UGV),
Barishal

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General instructions on safety and Do's and Don'ts

- Before starting laboratory work follow all written and verbal instructions carefully. If you do not understand a direction or part of a procedure, ASK YOUR CONCERN TEACHER BEFORE PROCEEDING WITH THE ACTIVITY.
- Before use equipment must be read carefully Labels and instructions. Set up and use the equipment as directed by your teacher.
- Any failure / break-down of equipment must be reported to the teacher.
- Observe good housekeeping practices. Replace the materials in proper place after work to keep the lab area tidy.
- Maintain silence and clean environment in the lab
- Protect yourself from getting electric shock.

GENERAL NOTES ON WRITING LABORATORY RECORD

All civil engineering projects require some soil exploration work at the very early stages, where soil tests are carried out in the laboratory and in situ. There are several commercial soil testing laboratories, and they have their own reporting styles. The report may be read by engineers who may not have the opportunity to see the soils being tested. Therefore, it is necessary to provide complete information in a simple and concise manner.

Notes on Plotting:

The following items should be looked into when presenting experimental data in graphical form:

1. **Scale:**

   Choose convenient scales; avoid odd, fractional, or decimal numbers per division. Even if preprinted graph paper is used, it is generally a good idea to put small tic marks at major divisions and indicate numerical values of these divisions. The scales should be chosen to adequately show the range of data i.e., the curves, data, notes, legend etc. should fill the graph.

2. **Axes:**

   Provide arrowheads at the ends. All axes need to be labelled (preferably in words) along with the units. Symbols are acceptable provided they are widely recognised or they are defined in the text. A modern approach is to enclose the graphs in a rectangular box, showing grid lines as necessary. The grid lines should be thinner than the curves or the axes.

3. **Experimental & theoretical curves:**

   If the curve is based on experimental data, show the data points clearly. If more than one set of data is included (e.g., std. proctor & modified Proctor compaction test data), differentiate between them by using different symbols and define them in a legend and/or clearly label the curves.

   It is a good idea to use different types of curves (e.g., -----, ..., ———) to distinguish the graphs.

   Smooth curves should be drawn with french curve through experimental data points - rarely should individual points be connected by straight lines. When showing variation of field water contents and blow counts with depth, in a bore log, connect the points by straight line segments.

Do not show the data points on theoretical curves, such as those plotted from calculations based on a mathematical formulae (e.g., zero air void curve).

4. **<u>Title & figure number</u>:**

   All plots, figures and tables need to be numbered and titled so that they can be referred to in the report.

5. **<u>Data from other sources</u>:**

   When you include data from other literature, clearly show them in the figure and give proper references.

The common software such as Excel, Origin, etc. have all the facilities you would need for a professional look. A good quality plot can be made within 30 minutes, with the axes, scales, etc. fixed up nicely. It is worth learning one of them.

<div align="center">

Experiment No. 1
Field Identification of Soil Sample

</div>

Introduction

Soils are usually classified into coarse and fine-grained soil depending on their particle size. Some simple tests are used to identification of these major soil components. These tests are known as identification tests. The sample should be identified first on the basis by visual inspection and certain simple tests can be performed in the field. Gravel and sand are known as coarse-grained soils, silt and clay as fine-grained soils. The distinction is based on whether the individual particles can be differentiated in visual observation. According to ASTM, classification of different soils on the basis of particle size are:

Gravel	**> 4.75 mm**
Coarse Sand	**2.00 – 4.75 mm**
Medium Sand	**0.425 – 2.00 mm**
Fine Sand	**0.075 – 0.425 mm**
Fines (silt and clay)	**< 0.075 mm**

Gravel

Coarse-grained soil. Also cohesion less. Does not possess any plasticity. Permeability is very high.

Sand

Coarse-grained soil. Also cohesion less. Does not possess any plasticity. Is also sub-divided as coarse, medium and fine. Permeability varies, generally is high for medium and coarse sand.

Silt

Property depends on its constituents. Composed, generally of bulky type (semi-equidimensional) and fine-grained particles. The least plastic varieties consists primarily of very fine rounded particles. The most plastic varieties contain an appreciable quantity of flake shaped (plate shaped or sheet like) particles called plastic silt.

Clay

Caly particles are dominantly composed of crystalline minerals having flaky shape. It is characterized by the typical colloidal properties of plasticity, cohesion, and the ability to adsorb ions. These properties are exhibited over a wide range of water content. The distinction between silt and clay cannot be based on particle size because the significant physical properties of the two materials are related only indirectly to the size of the particles. Furthermore, since both are microscopic, physical other than particle size must be used as criteria for identification.

If organic matter is present in soil, it also influences the physical properties of soil. Most organic soils are in weaker composition and more compressible. They posses dark gray to black color and odor of decaying vegetation.

Field identification test consists of the following four tests:

1. Dry Strength Test

It provides a basis for describing the strength as very low, low, medium, high, or very high. A clay fragment can be broken with great effort, whereas a silt fragment crushes easily. The higher the clay content, the higher would be the dry strength.

2. Dilatancy or Shaking Test

It describes the permeability as rapid, slow, or none. The higher the silt content, the lower would be the permeability characteristics.

3. Plasticity Test (also named as Toughness of Plastic Thread Test)

In this test highly plastic clay can be rolled into a long thread, with a diameter of approximately 1/8" just before the crumbly state is reached. Silt, on the other hand, can seldom be rolled into a thread. The record of plasticity test also indicates the toughness of the thread as it nears the crumbling stage. This condition is described as weak and friable, medium or tough. The higher the clay content, the higher would be the toughness of the plastic thread at its crumbling stage.

4. Dispersion Test

It provides a rough estimate of the relative amounts of sand, silt and clay material in a soil mass. The coarser particle fall first and the finest ones remain in suspension for long time.

Typical suspension times for sand, silt and clay for dispersion test are given below:

Particle Type	Typical Suspension Time
Gravel	Almost instantaneously
Sand	Less than a minute
Silt	Less than an hour
Clay	Several hours to days

OBJECTIVE

The main objective of this experiment is to identify coarse and fine-grained soils and by identifying the constituents of the soil, a rough idea of the soil properties cane be made.

MATERIAL

- Soil Samples
- Water

EQUIPMENT

- A Glass Cylinder

EXPERIMENTAL PROCEDURE

1. Dry Strength Test

A small briquet of the soil is molded and allowed to dry in the air. It is then broken by pressing between the thumb and the fore-finger.

2. Dilatancy or Shaking Test

A small amount of soil is mixed with water to a very soft consistency (firmness) in the palm of the hand. The back of the hand is lightly tapped. The sample is also squeezed within the palm.

3. Plasticity Test (also named as Toughness of Plastic Thread Test)

A sample of moist soil is manipulated between the palms of the hand and fingers and rolled into a long thread.

4. Dispersion Test

A small quantity of the soil is dispersed with water in a glass cylinder and then allowed to settle.

Discussion
From this experiment we obtained identification of soil which is the first step in any geotechnical engineering project. It also identifies and describes the subsoil condition. For example as soon as a ground is identified as gravel, engineer can immediately form some ideas on the nature of problems that might be encountered in a tunneling project. In contrast, a soft clay ground is expected to lead to other types of design and construction considerations. Therefore, it is useful to have a systematic procedure for identification of soils even in the planning stages of a project. The results obtained from this experiment help to progress further work of a project. These experiments are simple and get idea or result quickly. The property of a coarse grained material mass depends also on the uniformity of the sizes of the grains. Well-graded sand is more stable for a foundation base as compared to a uniform or poorly graded material. From these tests we get the idea of the uniformity of soil.

Experiment No. 2

SPECIFIC GRAVITY TEST

INTRODUCTION

The speci|c gravity (G)of a material is the ratio of the mass of a unit volume of soil solids at a speci|c temperature to the mass of an equal volume of gas-free distilled water at the same temperature.

The speci|c gravity of soil is usually reported at 20°C.

$$G_s(\text{at } T^oC) = \frac{\text{Wt. of a given volume of the material at T } ^oC}{\text{Wt. of the same volume of water at } T^oC}$$

- The specific gravity of soil solid is used in calculating the phase relationships of soils, such as the void ratio and the degree of saturation.
- The specific gravity of soil solids is used to calculate the density of the soil solids.

OBJECTIVE

The objective of this experiment is:

- To determine the specific gravity of soil solid at 20°C using a pycnometer.

EQUIPMENT

- Volumetric ask (500 ml) with a stopper that has a pipe hole.
- Thermometer graduated with a division of 0.1°C.
- Balance sensitive to 0.01 g.
- Distilled water.
- Entrapped air removal apparatus

- Hot plate or Bunsen burner that is capable of maintaining a temperature high enough to boil
- water
- Vacuum system, vacuum pump, or water aspirator
- Evaporating dishes
- Spatula

METHOD

1. Clean and dry the volumetric ask.

2. Carefully fill the ask with de-aired, distilled water up to the 500 ml mark (The bottom of the meniscus should be at the 500 ml mark).

3. Measure the mass of the flask and the water W_1
4. Insert the thermometer into the flask with the water to determine the water's temperature
5. Put approximately 100 grams of air-dried soil into an evaporating dish

6. For cohesive soil, add de-aired and distilled water to the soil and mix it until it forms a smooth

7. Add distilled water to the volumetric flask containing the soil or soil paste until it is about two third full.
8. Add de-aired, distilled water to the volumetric flask until the bottom of the meniscus touches the 500 ml mark. Dry the outside of the flask and the inside of the neck above the meniscus.
9. Determine the combined mass of the bottle plus soil plus water (W_2)

Sample No.	1	2	3
Mass of flask + water filled to mark, W_1 (g)	683	659.7	675
Mass of flask + soil + water filled to mark, W_2 (g)	745.1	722	737
Mass of dry soil, W_s (g)	100	100	100
Water temperature, T_1(°C)	23	24	23.5
Temperature correction factor, A (from table)			
Specific gravity, G_s			

A person holding a plastic squeeze bottle. He is filling a glass flask with water. The flask has some soil at the bottom.

10. Pour the soil and water into an evaporating dish. Use a plastic squeeze bottle to wash the inside of the flask, making sure that no soil is left inside.
11. Put the evaporating dish into an oven to dry it to a constant weight.
12. Determine the mass of the dry soil in the evaporating dish (W_5).

SAMPLE DATA SHEET

SAMPLE CALCULATION

For Sample no. 1,

Mass of }ask + water |lled to mark, W (g)=683 gm

Mass of }ask + soil + water |lled to mark, W (g)= 745.1 gm

Mass of dry soil, W (g)=100 gm

Water Temperatu $G_s = \dfrac{W_s}{W_1 + W_s - W_2} \times A = 2.64$

Temperature Correction Factor, A (from Table)=0.9993

Speci|c Gravity,

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Sample No.	1	2	3
Mass of flask + water filled to mark,W_1 (g)			
Mass of flask + soil + water filled to mark,W_2 (g)			
Mass of dry soil, W_s (g)			
Water Temperature, $T_1(°C)$			
Temperature Correction Factor, A (from Table)			
Specific Gravity, G_s			

Experiment No. 3

COMPACTION TEST

INTRODUCTION

This laboratory test is performed to determine the relationship between the moisture content and the dry density of soil for a speci|ed compaction energy. Compaction energy is the amount of mechanical energy that is applied to the soil mass. Several methods can be used to compact soil in the field, including tamping, kneading, vibration, and static load compaction. This laboratory will employ the tamping or impact compaction method, known as the Proctor test, using the type of equipment outlined in Table 6.1. In the standard Proctor test, the soil is compacted by a 5.5 lb. hammer falling from a distance of one foot onto a mold that isfilled with three equal layers of soil. Each layer is subjected to 25 drops of the hammer. The modi| ed Proctor test is similar to the standard Proctor test,but the mold is |lled with |ve equal layers of soil instead of three and it employs a 10 lb. hammer that falls from a distance of 18 inches. Two types of compaction molds are used for the testing. The smaller type is 4 inches in diameter and has a volume of about 1/30 ft (944 cm), and the larger type is 6 inches in diameter and has a volume of about 1/13.333 ft (2123 cm). If the larger mold is used each soil layer must receive 56 blows instead of 25 (See Table 6.1).

Alternative Proctor Test Method:

	Standard Proctor ASTM 698			Modified Proctor ASTM 1557		
	Method A	Method B	Method C	Method A	Method B	Method C
Material	≤ 20% Retained on No. 4 Sieve	>20% Retained on No. 4 ≤ 20% Retained on 3/8″ Sieve	>20% Retained on No. 3/8″ <30% Retained on 3/4″ Sieve	≤ 20% Retained on No. 4 Sieve	> 20% Retained on No. 4 ≤ 20% Retained on 3/8″ Sieve	> 20% Retained on No. 3/8″ <30% Retained on 3/4″ Sieve
For test sample, use soil passing through	Sieve No. 4	3/8″ Sieve	3/4″ Sieve	Sieve No. 4	3/8″ Sieve	3/4″ Sieve
Mold	4″ Dia	4″ Dia	6″ Dia	4″ Dia	4″ Dia	6″ Dia
No. of Layers	3	3	3	5	5	5
No. of Blows/Layers	25	25	56	25	25	56

PRACTICAL APPLICATION

- Foundation soils are often compacted to improve their engineering properties.
- Laboratory compaction tests provide the basis for determining the percent of compaction and water content needed to achieve the required engineering properties, and for controlling construction to assure that the required compaction and water contents are achieved

OBJECTIVE

The objective of this experiment is:
- To evaluate the maximum dry unit weight, γ and optimum moisture content, w_{opt} of compaction.

EQUIPMENT

- Molds, manual rammer
-
- Extruder, Balance
-

- Drying oven
-
- Mixing pan
-

- Trowel
-
- #4 Sieve
-
- Moisture cans

-
- Graduated cylinder
-
- Straight edge

METHOD

1. Put air-dried soil into a large mixing pan (10 lbs. of soil for a 4-inch mold, and 15 lbs. for a 6-inch mold). Pulverize the soil and run it through a \# 4 sieve.
2. Use the balance to determine the weight of the soil samples and compaction molds and bases (without the collar), and record the weights.
3. Compute the amount of water to add, using the following methods:

$$\text{Water to add (in ml)} = \frac{(\text{Soil mass in gram}) \times 8}{100}$$

4. Assume the water content for the first test to be 8 percent.
5. Compute the amount of water to be added by using the following equation:
   NOTE: The equation for determining the amount of water to add gives the measurement in milliliters, but the soil mass is given in grams. This is not a problem since one gram of water is equal to approximately one milliliter.
6. Measure the water and add it to the soil. Using a trowel, mix it thoroughly into the soil, until the soil becomes a uniform color.
7. Attach the compaction mold to the base, place some soil in the mold and compact the soil into the number of equal layers specified by the type of compaction method employed. The number of drops of the rammer per layer depends on the type of mold used, as shown in Table 6.1. Apply the drops evenly onto the surface of the specimen at a uniform rate of no more than 1.5 seconds per drop. Try to prevent the rammer from rebounding from the top of the guide sleeve.
8. Completely fill the cylinder with the soil, ensuring that the last compacted layer extends slightly above the collar joint. Repeat the test point if the soil is below the collar joint after the completion of the drops. (Note: For the last layer, watch carefully, and add more soil after about 10 drops if it appears that the soil will be compacted below the collar joint.)
9. Carefully remove the collar and use the trowel to trim off the compacted soil so that it is completely even with the top of the mold. Replace small bits of soil that fall out during the trimming process.

10. Weigh the compacted soil while it is in the mold and connected to the base, and record the weight. Determine the wet mass of the soil by subtracting the weight of the mold and base.

11. Remove the soil from the mold, using a mechanical extruder, and take soil moisture content samples from the top and bottom of the specimen. Fill the moisture cans with soil and determine the water content.
12. Place the soil specimen in the large tray and break up the soil until it appears that it will pass through the #4 sieve. Add 2 percent more water, based on the original sample mass, and re-mix as in step 4. Repeat steps 5 through 9 until, based on wet mass, a peak value is reached, followed by two slightly less compacted soil masses.

DATA ANALYSIS

- Calculate the moisture content of each compacted soil specimen by using the average of the two water contents.
- Compute the wet density in grams per cm^3 of the compacted soil sample by dividing the wet mass by the volume of the mold that was used.
- Compute the dry density using the wet density and the water content determined in step 1, employing the following formula:

$$\rho_d = \frac{\rho}{1+w}$$

where, w = moisture content in percent divided by 100, and ρ = wet density in grams per cm³.

- Plot the dry density values on the y-axis and the moisture contents on the x-axis. Draw a smooth curve connecting the plotted points.
- On the same graph draw a curve of complete saturation or "zero air voids curve". The values of dry density and corresponding moisture contents for plotting the curve can be computed from the following equation: where,

$$w_{sat} = \left(\frac{\rho_w}{\rho_d} - \frac{1}{G_s}\right) \times 100$$

$$or \quad \rho_d = \frac{\rho_w}{\left(\frac{w}{100} - \frac{1}{G_s}\right)}$$

ρd = dry density of soil grams per cm3

Gs = specific gravity of the soil being tested (assume 2.70 if not given)

ρw = density of water in grams per cm³ (approximately 1 g/cm³)

wsat = moisture content in percent for complete saturation

RESULTS AND DISCUSSIONS

SAMPLE DATA SHEET

Soil type: Low plastic clay (CL)

Specific gravity of soil, Gs = 2.8

Water Content Determination

Compacted Soil-Sample No.	1		2		3		4		5	
Water content-Sample No.	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B
Mass of empty can	6.9	8.5	8.2	8.5	9.7	8.9	7.9	7.6	8.3	8.2
Mass of can + moist soil	12.3	12.9	13.1	13.2	13.4	13.2	14.1	14.6	15.2	14.9
Mass of can + dry soil	11.9	12.6	12.6	12.7	12.9	12.6	13.1	13.5	13.9	13.6
Water content (%)	8.0	7.3	11.4	11.9	15.6	16.2	19.2	18.6	23.2	24.1
Average water content (%)	7.7		11.6		15.9		18.9		23.6	

Density Determination

Volume of the mold = 944 cm3
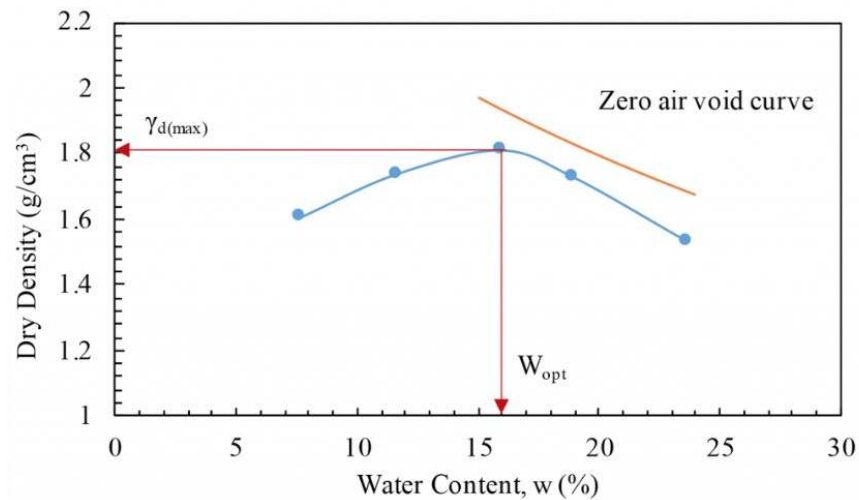
Compacted Soil-Sample No.	1	2	3	4	5
Actual average water content (from previous table)	7.7	11.6	15.9	18.9	23.6
Mass of mold (gm)	1929	1929	1929	1929	1929
Mass of compacted soil and mold (gm)	3560	3760	3910	3869	3716
Wet mass of soil in mold (gm)	1631	1831	1981	1940	1787
Wet density (g/cm3)	1.73	1.94	2.10	2.06	1.89
Dry density (g/cm3)	1.60	1.74	1.81	1.73	1.53

From Figure 6.9 Maximum dry unit weight, γd(max) = 1.81 g/cm3

Optimum moisture content, wopt = 15.9 %

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Soil type: Low plastic clay (CL)

Specific Gravity of soil, Gs = 2.8

Water Content Determination

Compacted Soil-Sample No.	1		2		3		4		5	
Water content-Sample No.										
Mass of empty can										
Mass of can + moist soil										
Mass of can + dry soil										
Water content (%)										
Average water content (%)										

Density Determination

Volume of the mold = 944 cm^3

Compacted Soil-Sample No.	1	2	3	4	5
Actual average water content (from previous table)					
Mass of mold (gm)					
Mass of compacted soil and mold (gm)					
Wet mass of soil in mold (gm)					
Wet density (g/cm3)					
Dry density (g/cm3)					

Experiment No. 4
GRAIN SIZE ANALYSIS
(SIEVE ANALYSIS)

Introduction

Sieve analysis is performed to determine the gradation (or grain size distribution) of different particle sizes of coarse grained soil (sand) or coarser portion of a soil containing both coarse (sand & silt) and fine (silt & clay) particles. A sieve analysis consists of shaking the soil through a stack of wire screens with openings of known sizes; the definition of particle diameter for a sieve test is therefore the side dimension of a square hole. It should be noted that sieve analysis does not give any idea about the shape of the particles.

Sieves are made of woven wires with square openings. Table 4 gives a list of U.S. standard sieve numbers with the corresponding size of openings. For all practical purposes #200 sieve is the sieve with the smallest opening that should be used for the test. The sieves that are commonly used in the test have diameter of 8 inch (203mm).

Table 3.1 Sieve no. and openings (Principles of Geotechnical Engineering, B.M. Das)

Sieve no.	Opening	Sieve no.	Opening
4	4.75	35	0.50
5	4.00	40	0.425
6	3.35	45	0.355
7	2.80	50	0.30
8	2.36	60	0.25
10	2.00	70	0.212
12	1.70	80	0.180
14	1.40	100	0.150
16	1.18	120	0.125
18	1.00	140	0.106
20	0.85	200	0.075
25	0.71	270	0.053
30	0.60	400	0.038

Actually for the purpose of gradation of soils there may be one of the following three tests:

1. Sieve analysis – Applicable when the soil contains mainly sand and larger particles.
2. Hydrometer analysis – Applicable when the soil is fine grained or silt and clay particles.
3. Combined analysis i.e. both sieve and hydrometer analysis – Applicable when the soil contains sizable portion of both fine and coarse fraction.

From sieve analysis, information about grain size distribution is obtained. Besides the gradation curve, other parameters namely uniformity coefficient C_u, coefficient of curvature, C_c are determined and all these information are used for classification.

It is pointed here that FM (Fineness Modulus) is determined from sieve analysis done on fine and coarse aggregates (as you have done in concrete laboratory). However, FM has almost no meaning and use in geotechnical interpretation and understanding of soil behaviour as a foundation material.
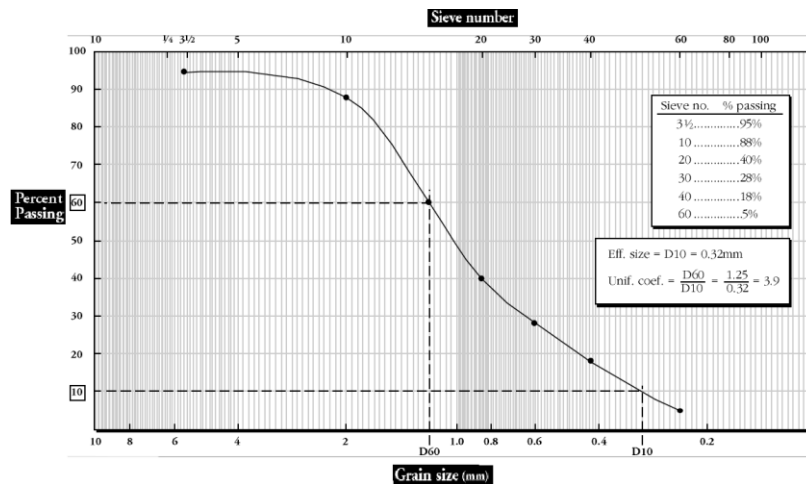
Figure 3.1: Gradation Curve (www.aboutcivil.org/Sieve-analysis-and-soil-classification.html)

Scope of the test

This test is performed to determine the percentage of different grain sizes contained within a soil. The mechanical or sieve analysis is performed to determine the distribution of the coarser, larger-sized particles, and the hydrometer method is used to determine the distribution of the finer particles.

Significance

The distribution of different grain sizes affects the engineering properties of soil. Grain size analysis provides the grain size distribution and it is required in classifying the soil.

Standard Reference

ASTM D422-63 Standard Test Method for particle Size Analysis of Soils

Apparatus

- ASTM Sieve #4, #8, #16, #30, #50, #100, #200
- Pan
- Lead
- Brush
- Container
- Spoon
- Bowel
- Balance
- Sieve shaker

Test Procedure

(1) Write down the weight of each sieve as well as the bottom pan to be used in the analysis.

(2) Record the weight of the given dry soil sample.

(3) Make sure that all the sieves are clean, and assemble them in the ascending order of sieve numbers (#4 sieve at top and #200 sieve at bottom). Place the pan below #200 sieve. Carefully pour the soil sample into the top sieve and place the cap over it.

(4) Place the sieve stack in the mechanical shaker and shake for 10 minutes.

(5) Remove the stack from the shaker and carefully weigh and record the weight of each sieve with its retained soil. In addition, remember to weigh and record the weight of the bottom pan with its retained fine soil.

Data Analysis

(1) Obtain the mass of soil retained on each sieve by subtracting the weight of the empty sieve from the mass of the sieve + retained soil, and record this mass as the weight retained on the data sheet. The sum of these retained masses should be approximately equals the initial mass of the soil sample. A loss of more than two percent is unsatisfactory.

(2) Calculate the percent retained on each sieve by dividing the weight retained on each sieve by the original sample mass.

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

(4) Make a semi logarithmic plot of grain size vs. percent finer.

(5) Compute Uniformity coefficient, C_u and Coefficient of gradation, C_z for the soil.

$$C_u = \frac{D_{60}}{D_{10}} \quad \text{and} \quad C_z = \frac{D_{30}^2}{D_{60} D_{10}}$$

(a)

(b)

(c)   (d)   (e)

Figure 3.1: (a) Clean all seives before test. (6b) Weight all seives (c) Serially set all seives according to their opening size. (d) After pouring the soil place it to seive shaker and shake 10 min. (e) Weight all seive with contained soil

Data Sheet

Experiment Name : **Grain Size Analysis Test by Sieve Analysis**
Experiment Date :

Student's Name :
Student's ID :
Year/ Semester :
Section/ Group :

Visual Classification :

Data Table :

Sieve No.	Sieve opening (mm)	Wt. of container (gm)	Wt. of container + soil (gm)	Wt. of soil retained (gm)	Percent of soil retained	Cumulative percent retained	Percent finer
4	4.76						
8	2.380						
16	1.190						
30	0.590						
50	0.287						
100	0.149						
200	0.074						
Pan							
Total weight=							

From Grain Size Distribution Curve:
   % Gravel : D10 : mm Cu :
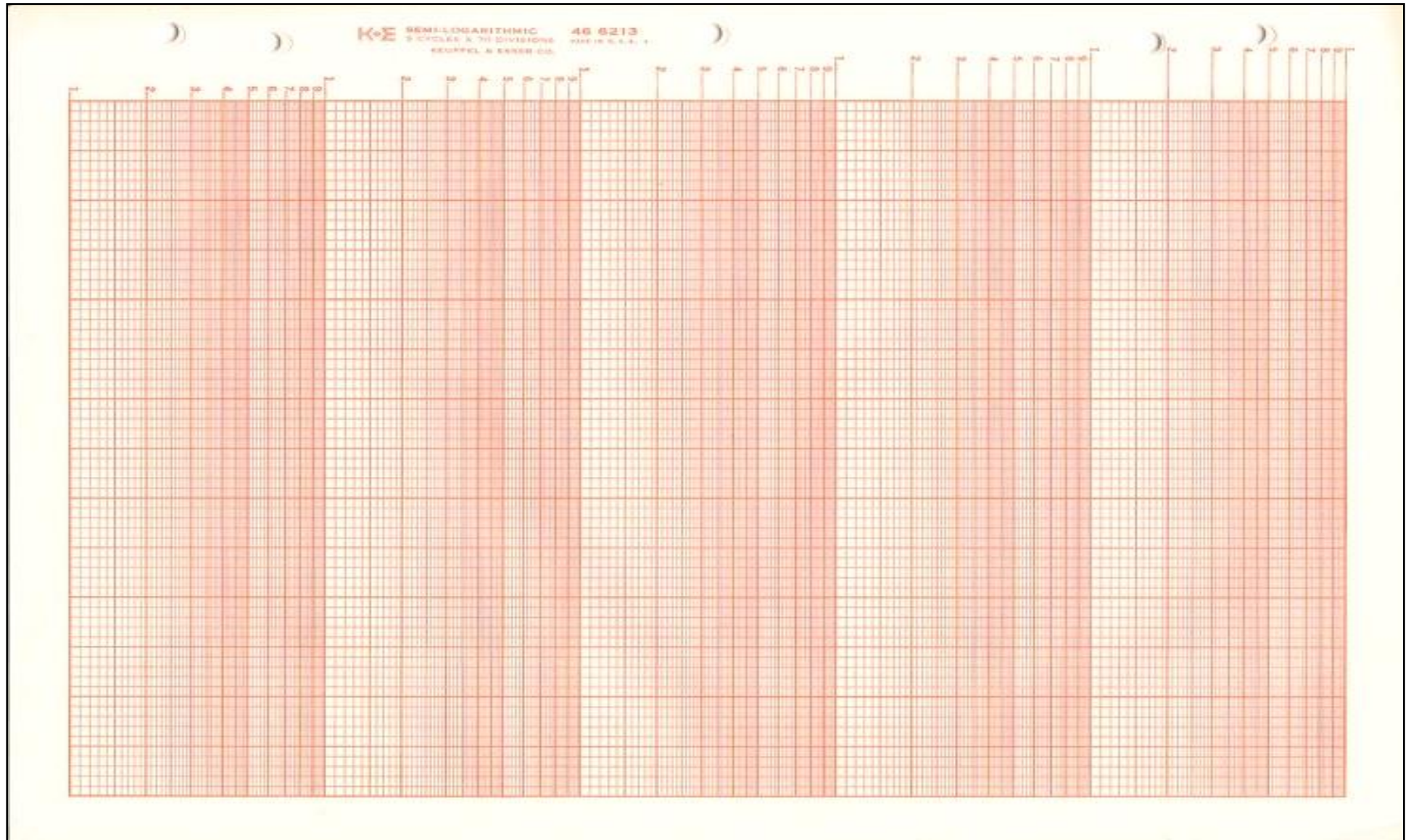   % Sand : D30 : mm C_Z :
   % Fines : D60 : mm

Unified Classification of Soil :

Course Teacher :
Designation :

Signature

Grain size distribution curve

Experiment No. 5
PARTICLE SIZE ANALYSIS BY HYDROMETER

Introduction

Grain size distribution of soil which contain significant amount of finer particles (silt and clay) cannot be done by sieve analysis. Hydrometer analysis is required to determine the grain size distribution of the finer portion. For many natural soils we require both sieve analysis and hydrometer analysis to obtain the complete gradation of the coarse and fine fraction. In the sieve analysis test you have used #200 sieve (opening 0.074 mm) as the finest sieve. Now you will perform hydrometer analysis on a fine grained soil that passes #200 sieve.[1]

According to ASTM D422, when combined analysis is required, the sample is to be divided into two parts. Sieve analysis is to be done on the coarser portion and hydrometer analysis is to be done into finer portion. Division of the sample into two portion is to be done by either of #4 (4.75mm), #10 (2.00 mm), #40 (0.425mm) or #200 (0.074 mm) sieve depending on the sp.gr. of particles. However, for our natural soils separation on #200 sieve will be sufficient.

Determination particle diameter

Determination of particle diameter using hydrometer is based on Stoke's Law which states that the the terminal velocity (v) of a freely falling sphere through a medium is proportional to the square of the diameter (D) of the particle i.e. $v \propto D^2$. From this we obtain

$$v = \frac{\gamma_s - \gamma_w}{18\eta} D^2$$

where v = velocity (cm/s)

γ_s = Unit wt. of soil particles (gm/cc)

γ_w = Unit wt. of water (gm/cc)

η = Viscosity of water ($\frac{gm.s}{cm^2}$)

D = Diameter of particle (cm)

Therefore, if the velocity of fall v is known, then diameter of the particle can be calculated as

$$D = \sqrt{\frac{18\eta}{\gamma_s - \gamma_w}} . \sqrt{v}$$

To understand the details of hydrometer analysis it is necessary to have an idea about the apparatus "hydrometer". There are two types of ASTM soil hydrometers. One is designated ASTM 151H and the other is designated ASTM 152H. The readings obtained from these two hydrometers have different meanings. Both can be used for hydrometer analysis. But, calculation procedures for these two are different. Here we have described the procedure for ASTM 152H hydrometer that you will use.

The hydrometer, made of glass, has a stem and a bulb. When it is inserted into a liquid, it floats or submerges in an upright position with its bulb on the downside. The stem of the hydrometer has graduation. ASTM 152H hydrometers are calibrated such that when inserted in a soil water suspension the reading on the hydrometer stem indicates grams of soil that are in 1000cc suspension of the density at the center of the bulb. Thus, when the hydrometer reading is zero, it indicates pure water and when the reading is 30 it means that there are 30 gms of soil in 1000cc soil suspension. Usually there are readings from 0 to 60 on a hydrometer stem. It can be easily conceived that as the density of suspension increases, more of the stem will come out of the suspension, and so the hydrometer reading will be increased. If we prepare a soil suspension in a jar and take hydrometer readings at different time intervals from the instant when the suspension is

not disturbed by stirring or any other means, then successive hydrometer readings will decrease because particles of soil will start to fall and finally settle at the bottom of the jar resulting in reduced density of the suspension. Now, suppose at any time interval t, the distance from the c.g. (center of gravity) of the bulb to the surface of suspension is L. Because the location of c.g. of the hydrometer bulb is related to the sp.gr. of the suspension around it, L may be considered to be the distance of fall of a particle in time t. Therefore, velocity of the particle will be v=L/t.

Therefore,

$$D = \sqrt{\frac{18\eta}{\gamma_s - \gamma_w}} \cdot \sqrt{\frac{L}{t}}$$

If we want to put t in minute, L in cm, ὴ in poise (1 gm-sec per square cm =g poise =980.7 poise) and want to obtain D in mm then the above equation should be modified as

$$D\,(mm) = \sqrt{\frac{18\eta}{980.7 * (\gamma_s - \gamma_w)}} \cdot \sqrt{\frac{L}{t * 60}} * 10$$

which upon simplification becomes

$$D\,(mm) = \sqrt{\frac{30\eta(poise)}{980.7 * [\gamma_s(\frac{gm}{cm^3}) - \gamma_w(\frac{gm}{cm^3})]}} \cdot \sqrt{\frac{L(cm)}{t(min)}}$$

$$or\ D\,(mm) = \sqrt{\frac{30\eta(poise)}{980.7 * (G_s - 1)\gamma_w(\frac{gm}{cm^3})}} \cdot \sqrt{\frac{L(cm)}{t(min)}}$$

The above equation is sometimes written as

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

$$where\ \ K = \int (T, G_s, \eta)$$

For example for T=20^{0}C, $\gamma_w = 0.9971$, $G_s = 2.65$,

However, when we insert the hydrometer in a soil-water suspension we do not measure L directly. Instead, if we measure the distance L1 and L2 from the c.g. of the bulb corresponding to two hydrometer readings R1 and R2 then we can calculate L easily for any hydrometer reading R from the equation (see fig.1)

$$L = \frac{L_b}{2} + L_1 - \frac{L_1 - L_2}{R_2 - R_1} . (R_L - R_1) \qquad\qquad (1)$$

Here we need to notice that as we insert the hydrometer in the jar containing the soil-water hydrometer bulb by half of this i.e. 2V. Ab$_j$ from the level where it would be if this rise have not occurred (see Fig 4.1d); V_b =Volume of the hydrometer bulb and A_j = Cross-sectional Area of the hydrometer jar. Thus equation 1 need to be modified as

$$L = \frac{L_b}{2} + L - \frac{L_1 - L_2}{R_2 - R_1}(R_L - R_1) - \frac{V_b}{2A_j} \qquad\qquad (2)$$
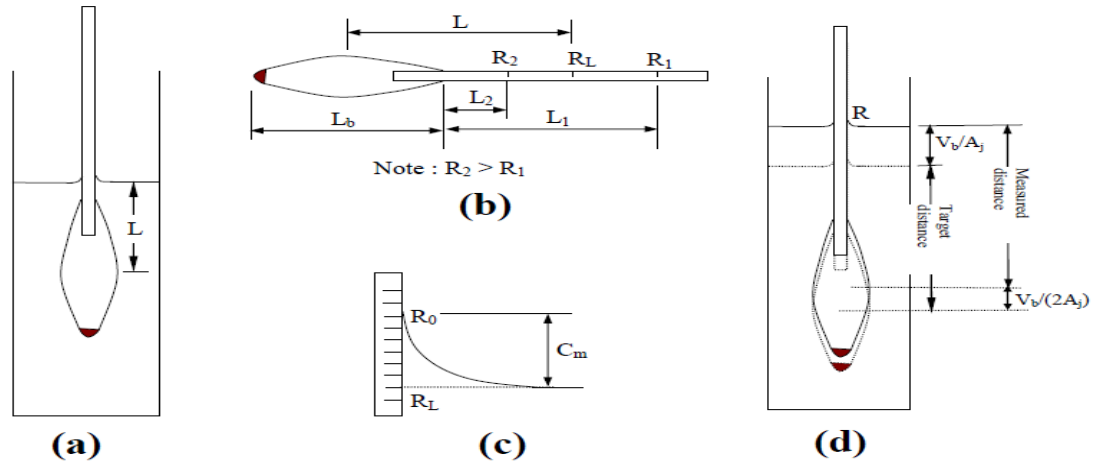
Figure 4.1 Schematic diagrams showing hydrometer readings and corrections.

Furthermore, in the soil-water suspension we can read the upper meniscus, whereas we need the reading at the lower meniscus. So, if R0 be the observed reading, then to put into equation 2, RL should be calculated as (see Fig. 4.1c)

$$R_L = R_0 \pm C_m \qquad (3)$$

For ASTM 152H hydrometers for $R_1=0$ the distance $L_1=10.5$ cm and for $R_2=50$, the distance $L_2 =2.3$ cm, $L_b=14$ cm, $V_b=67$ cm^3. Cross-sectional area of hydrometer jar is 27.8 cm^2. For these values, Equation 2 becomes

$$L = 16.29 + 0.164 * R_L , \text{(L in cm)} \qquad (2a)$$

Equation 2a is sometimes presented in tabular form as in Table 1 wherefrom values of L can be obtained for any hydrometer reading.

Table 4.1: Values of Effective depth RL for hydrometer for which ($L_1=10.5$ cm, $L_2=2.3$ cm, $R_1=0$, $R_2=50$, $L_b=14.0$ cm, $V_b= 67$ cm^3, $A_j=27.8$ cm^3)

Hydrometer reading, R_L	L	Hydrometer reading, R_L	L	Hydrometer reading, R_L	L	Hydrometer reading, R_L	L
0	16.3	15	13.8	30	11.4	45	8.9
1	16.1	16	13.7	31	11.2	46	8.8
2	16.0	17	13.5	32	11.0	47	8.6
3	15.8	18	13.3	33	10.9	48	8.4
4	15.6	19	13.2	34	10.7	49	8.3
5	15.5	20	13.0	35	10.6	50	8.1
6	15.3	21	12.9	36	10.4	51	7.9
7	15.1	22	12.7	37	10.2	52	7.8
8	15.0	23	12.5	38	10.1	53	7.6
9	14.8	24	12.4	39	9.9	54	7.4
10	14.7	25	12.2	40	9.7	55	7.3
11	14.5	26	12.0	41	9.6	56	7.1
12	14.3	27	11.9	42	9.4	57	6.9
13	14.2	28	11.7	43	9.2	58	6.8
14	14.0	29	11.5	44	9.1	59	6.6

Determination of percent finer

It has been mentioned earlier that ASTM 152H hydrometers are calibrated such that for soil of sp.gr of 2.65, the hydrometer reading after an elapsed time t, indicates the grams of soil in suspension at that instant. This means that if R_c be the hydrometer reading, then (corresponding to the diameter determined using this reading)

Percent finer, $N = \frac{R_c}{W} * 100$ 4

where W_s = Weight (in gms) of soil used to prepare the suspension and R is obtained from R_0 after applying some corrections.

Because the sp.gr. of a soil may vary from 2.65 a correction factor is introduced in equation 4. Thus,

Percent finer, $N = a * \frac{R_c}{W} * 100$ 5

Where 'a' is the correction factor introduced to accommodate the variation of specific gravity from 2.65. The correction factor a can be computed as

$$a = \frac{G_s * 1.65}{(G_s - 1) * 2.65}$$

Values of 'a' for different specific gravity of soil particles may also be obtained from Table 4.

The reading R_c to be used in equation 5 should be obtained from the observed hydrometer reading R_o after applying the following corrections

(a) Correction for meniscus (C_m). This correction is always additive.
(b) Zero correction (C_z). This correction is introduced because a deflocculating agent is used in the preparation of the soil water suspension, which increases the hydrometer reading. This correction is always subtractive.
(c) Temperature correction (C_T). ASTM 152H hydrometers are calibrated at 20^0C. So if the test temperature is different from soil water suspension a correction is needed. The values for temperature correction are given in Table 5.

$R_c = R_o + C_m - C_z \pm C_T$ 7

Now consider that hydrometer analysis is performed on a soil for which percent of material finer for #200 sieve is P. Then with respect to the original soil

$$N' = N * \frac{P}{100}$$

Scope of the test
This test is performed to determine the percentage of different particle sizes contained within a soil. The hydrometer method is used to determine the distribution of the finer particles.

Apparatus
- Sedimentation Cylinder
- Hydrometer
- Hydrometer Jar bath
- Dispersive agent, Sodium hexa metaphosphate ($NaPO_3$)
- Thermometer

Figure 4.2 Hydrometer Test Apparatus

Test Procedure

(1) Take the fine soil from the bottom pan of the sieve set, place it into a beaker, and add 125 mL of the dispersing agent (sodium hexa metaphosphate (40 g/L)) solution. Stir the mixture until the soil isthoroughly wet. Let the soil soak for at least ten minutes.

(2) While the soil is soaking, add 125mL of dispersing agent into the control cylinder and fill it with distilled water to the mark. Take the reading at the top of the meniscus formed by the hydrometer stem and the control solution. A reading less than zero is recorded as a negative (-) correction and a reading between zero and sixty is recorded as a positive (+) correction. This reading is called the **zero correction**. The **meniscus correction** is the difference between the top of the meniscus and the level of the solution in the control jar (Usually about +1). Shake the control cylinder in such a way that the contents are mixed thoroughly. Insert the hydrometer and thermometer into the control cylinder and note the zero correction and temperature respectively.

(3) Transfer the soil slurry into a mixer by adding more distilled water, if necessary, until mixing cup is at least half full. Then mix the solution for a period of two minutes.

(4) Immediately transfer the soil slurry into the empty sedimentation cylinder. Add distilled water up to the mark.

(5) Cover the open end of the cylinder with a stopper and secure it with the palm of your hand. Then turn the cylinder upside down and back upright for a period of one minute. (The cylinder should be inverted approximately 30 times during the minute.)

(6) Set the cylinder down and record the time. Remove the stopper from the cylinder. After an elapsed time of one minute and forty seconds, very slowly and carefully insert the hydrometer for the first reading. (Note: It should take about ten seconds to insert or remove the hydrometer to minimize any disturbance, and the release of the hydrometer should be made as close to the reading depth as possible to avoid excessive bobbing).

(7) The reading is taken by observing the top of the meniscus formed by the suspension and the hydrometer stem. The hydrometer is removed slowly and placed back into the control cylinder. Very gently spin it in control cylinder to remove any particles that may have adhered.

(8) Take hydrometer readings after elapsed time of 2 and 5, 8, 15, 30, 60 minutes and 24 hours

(a)   (b)

(c)

(d)

(e)   (f)

Figure 4.2: (a) Take the zero correction and meniscus correction (b) Weight the dispersion agent and make a water-agent solution. (c) Take powdered soil and mix with water-agent solution in a pan. (d) Pour the mixture at cylinder carefully (e) Shake very carefully (f) Place the hydrometer at the cylinder and take reading carefully

Table 4.2: Values of k for Use in Equation for Computing Diameter of Particle in Hydrometer Analysis
(Engineering Properties of Soils Based on Laboratory Testing Prof. Krishna Reddy, UIC)

Temperature °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	0.0394	0.01374	0.01356
17	0.01511	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	0.01255	0.01208	0.01191	0.01175
29	0.01312	0.01290	0.01269	0.01269	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	0.01149

Table 4.3: Temperature Correction Factors C_T
(Engineering Properties of Soils Based on Laboratory
Testing Prof. Krishna Reddy, UIC)

Temperature °C	factor C_T
15	1.10
16	-0.90
17	-0.70
18	-0.50
19	-0.30
20	0.00
21	+0.20
22	+0.40
23	+0.70
24	+1.00
25	+1.30
26	+1.65
27	+2.00
28	+2.50
29	+3.05
30	+3.80

Table 4.4: Correction Factors a for Unit Weight of Solids
(Engineering Properties of Soils Based on
Laboratory Testing Prof. Krishna Reddy, UIC)

Unit Weight of Soil Solids, g/cm³	Correction factor a
2.85	0.96
2.80	0.97
2.75	0.98
2.70	0.99
2.65	1.00
2.60	1.01
2.55	1.02
2.50	1.04

Table 4.5: Properties of distilled water

Temp., °C	Unit weight of water, g/cm³	Viscosity of water, poise*
4	1.00000	0.01567
16	0.99897	0.01111
17	0.99880	0.01083
18	0.99862	0.01056
19	0.99844	0.01030
20	0.99823	0.01005
21	0.99802	0.00981
22	0.99780	0.00958
23	0.99757	0.00936
24	0.99733	0.00914
25	0.99708	0.00894
26	0.99682	0.00874
27	0.99655	0.00855
28	0.99627	0.00836
29	0.99598	0.00818
30	0.99568	0.00801

$$*Poise = \frac{dyne \cdot s}{cm^2} = \frac{g}{cm \cdot s}$$

Table 4.6: Value of L (effective depth) for use in Stokes diameters of particles for ASTM soil hydrometer 152H

Original hydrometer reading (corrected for meniscus only)	Effective depth L, cm	Original hydrometer reading (corrected for meniscus only)	Effective depth L, cm	Original hydrometer reading (corrected for meniscus only)	Effective depth L, cm
0	16.3	21	12.9	42	9.4
1	16.1	22	12.7	43	9.2
2	16.0	23	12.5	44	9.1
3	15.8	24	12.4	45	8.9
4	15.6	25	12.2	46	8.8
5	15.5	26	12.0	47	8.6
6	15.3	27	11.9	48	8.4
7	15.2	28	11.7	49	8.3
8	15.0	29	11.5	50	8.1
9	14.8	30	11.4	51	7.9
10	14.7	31	11.2	52	7.8
11	14.5	32	11.1	53	7.6
12	14.3	33	10.9	54	7.4
13	14.2	34	10.7	55	7.3
14	14.0	35	10.5	56	7.1
15	13.8	36	10.4	57	7.0
16	13.7	37	10.2	58	6.8
17	13.5	38	10.1	59	6.6
18	13.3	39	9.9	60	6.5
19	13.2	40	9.7		
20	13.0	41	9.6		

Data Sheet

Experiment Name   : **Particle Size Analysis by Hydrometer**
Experiment Date   :

Student's Name   :
Student's ID   :
Year/ Semester   :
Section/ Group   :

Visual Classification   :

Hydrometer Model   :
Specific Gravity of Soil   :
Dispersing Agent   : $NaPO_3$
Weight of Soil Sample, M_S : 50gm

Zero Correction   :
Meniscus Correction   :
Room Temperature   :
Temperature Correction, C_T :

Data Table   :

| Date	Clock time	Elapsed time, min	Temp °C	Observed Hydrometer reading R_a	Hyd. Corr. Only for meniscus R_L	Effective depth L cm	Unit wt. of water γ_w	Viscosity of water η poise	Grain diameter D mm	Temperature correction C_t	Corrected Hyd. Reading. R_c	% Finer (% of portion finer than #200 sieve only) N	% Finer (combined) N_c
1	2	3	4	5	6	7	8	9	10	11	12	13	14

[Correction factor, $a = \frac{1.65 G_S}{2.65(G_S-1)}$]   [From Stokes's law, $D = \sqrt{\frac{30n}{(G_S-1)p_w}}\sqrt{\frac{L}{t}} = K\sqrt{\frac{L}{t}}$, here, n= Viscosity]

Course Teacher   :
Designation   :

Signature

Particle size distribution curve
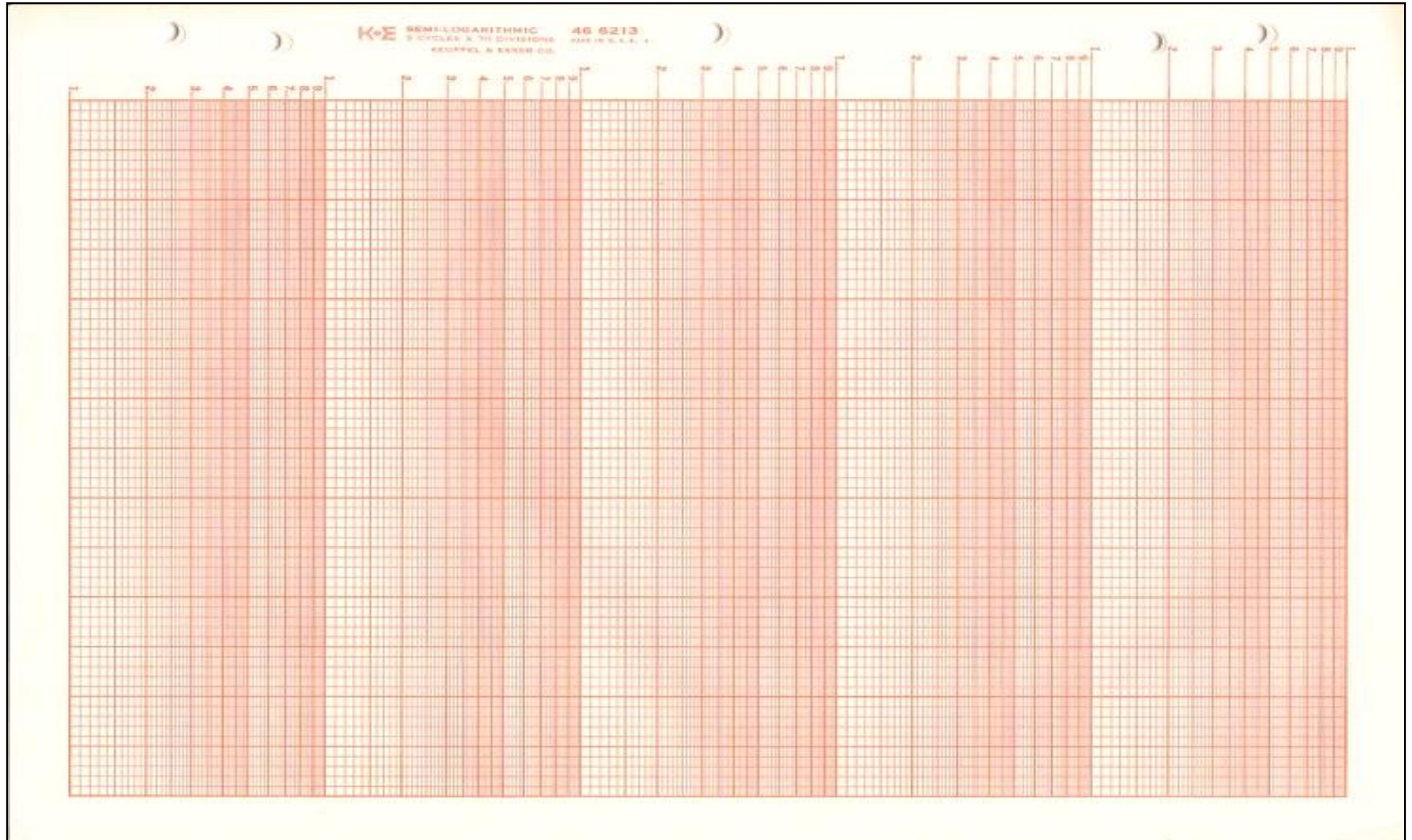
Combined Analysis of Expt. 3 and Expt. 4

For mixture of coarse-grained soil and fine-grained soil the following combined analysis was done:

(1) Oven dry the collected disturbed sample and then break up all lumps with the grinding machine or mechanically by hammer and fingers.

(2) Run a sieve analysis as above. Then wash the soil retained on the No. 200 sieve.

(3) Weigh out to 0.01g about 50g of the dry soil retained in the pan from the sieve analysis.

(4) Run a hydrometer test on the dry soil following above procedure.

(5) Compute the particle size and percent finer for the two parts of the combined analysis as shown in sieve analysis and hydrometer analysis. The weight of dry soil, W_s to be used in computing the sieve analysis should be the total sample.

(6) The corrected percentage, N' is found as follows:

$$N' = N. \frac{W_1}{W_s} = N. \text{ \% finer than No. 200 sieve}$$

where N = percentage finer that was computed in Expt. No. 4.

W_1 = weight of dry soil passing No. 200 sieve.

W_s = total weight of dry soil used for sieve analysis computation.

Experiment No. 6

MOISTURE CONTENT DETERMINATION

Scope of the test

This test is performed to determine the water (moisture) content of soils. The water content is the ratio, expressed as a percentage, of the mass of "pore" or "free" water in a given mass of soil to the mass of the dry soil solids.

Standard Reference

ASTM D 2216 - Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures.

Significance

For many soils, the water content may be an extremely important index used for establishing the relationship between the way a soil behaves and its properties. The consistency of a fine-grained soil largely depends on its water content. The water content is also used in expressing the phase relationships of air, water, and solids in a given volume of soil.

Equipment

- Drying oven
- Balance
- Moisture can
- Gloves
- Spatula.

Test Procedure

(1) Record the moisture can and lid number. Determine and record the mass of empty, clean, and dry moisture can with its lid (M_1)

(2) Place the moist soil in the moisture can and secure the lid. Determine and record the mass of the moisture can (now containing the moist soil) with the lid (M_2).

(3) Remove the lid and place the moisture can (containing the moist soil) in the drying oven that is set at 105 °C. Leave it in the oven overnight.

(4) Remove the moisture can. Carefully but securely, replace the lid on the moisture can using gloves, and allow it to cool to room temperature. Determine and record the mass of the moisture can and lid (containing the dry soil) (M_3).

(5) Empty the moisture can and clean the can and lid.

Data Analysis

(1) Determine the mass of soil solids.
$$M_S = M_3 - M_1$$

(2) Determine the mass of pore water.
$$M_W = M_3 - M_2$$

(3) Determine the water content.
$$W = \frac{M_W}{M_S} \; x \; 100\%$$

DATA SHEET

Experiment Name   : **Moisture Content determination of Soil**
Experiment Date   :

Student's Name   :
Student's ID   :
Year/ Semester   :
Section/ Group   :

Sample Description   :

Specimen number	1	2
Moisture and lid number		
M_1 = Mass of empty, clean can + lid (gm)		
M_2 = Mass of can, lid and moist soil (gm)		
M_3 = Mass of can, lid and dry soil (gm)		
M_S = Mass of soil solids (gm)		
M_W = Mass of pore water (gm)		
w = Water content %		

Sample Calculation:

Result:
Moisture content of the soil is:

Course Teacher   :
Designation   :

Signature

Experiment No. 7

ORGANIC CONTENT DETERMINATION TEST

Scope of the test

This test is performed to determine the organic content of soils. The organic content is the ratio, expressed as a percentage, of the mass of organic matter in a given soil mass to the mass of the dry soil solids.

Standard Reference

ASTM D 2974 – Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Organic Soils.

Significance

Organic matter influences many of the physical, chemical and biological properties of soils. Some of the properties influenced by organic matter include soil structure, soil compressibility and shear strength. In addition, it also affects the water holding capacity, nutrient contributions, biological activity, and water and air infiltration rates.

Equipment

> ➢ Muffle furnace,
> ➢ Balance,
> ➢ Porcelain dish,
> ➢ Spatula,
> ➢ Tongs

Test Procedure

(1) Determine and record the mass of an empty, clean, and dry porcelain dish (MP).

(2) Place a part of or the entire oven-dried test specimen from the moisture content experiment (Expt.1) in the porcelain dish and determine and record the mass of the dish and soil specimen (MPDS).

(3) Place the dish in a muffle furnace. Gradually increase the temperature in the furnace to 440°C. Leave the specimen in the furnace overnight.

(4) Remove carefully the porcelain dish using the tongs (the dish is very hot), and allow it to cool to room temperature. Determine and record the mass of the dish containing the ash (burned soil) (MPA).

(5) Empty the dish and clean it.

Data Analysis

(1) Determine the mass of the dry soil.

$M_D = M_{PDS} - M_P$

(2) Determine the mass of the ashed (burned) soil.

$M_A = M_{PA} - M_P$

(3) Determine the mass of organic matter

$M_O = M_D - M_A$

(4) Determine the organic matter (content).

$$OM = \frac{M_O}{M_D} x100$$

Data Sheet

Experiment Name   : **Organic Content determination of Soil**
Experiment Date   :

Student's Name   :
Student's ID   :
Year/ Semester   :
Section/ Group   :

Sample Description   :

Date Tested:
Tested By:
Project Name:
Sample Number:
Sample Description:

Specimen number	1	2
Porcelain dish number		
M_P = Mass of empty, clean porcelain dish (grams)		
M_{PDS} = Mass of dish and dry soil (grams)		
M_{PA} = Mass of the dish and ash (Burned soil) (grams)		
M_D = Mass of the dry soil (grams)		
M_A = Mass of the ash (Burned soil) (grams)		
M_O = Mass of organic matter (grams)		
OM = Organic matter, %		

Course Teacher   :
Designation   :

Signature

EXPERIMENT - 8

DETERMINATION OF CONSISTENCY LIMITS OF SOIL

1(a) LIQUID LIMIT TEST

Objective:

To determine the liquid limit of given soil sample by mechanical method.

Standards:

1. Indian Standards : IS: 2720 (Part-5)

2. ASTM: D-4318

3. AASHTO: T-89

Need and scope:

Liquid limit is significant to know the stress history and general properties of the soil met with construction. From the results of liquid limit the compression index may be estimated. The compression index value will help us in settlement analysis. If the natural moisture content of soil is closer to liquid limit, the soil can be considered as soft.

Definition (As per Casagrande):

The liquid limit is the moisture content at which the groove, formed by a standard tool into the sample of soil taken in the standard cup, closes for 12 mm on being given 25 blows in a standard manner. At this limit the soil possess low shear strength.

Apparatus:

1. Balance

2. Liquid limit device (Casagrande's)

3. Grooving tool

4. Mixing dishes
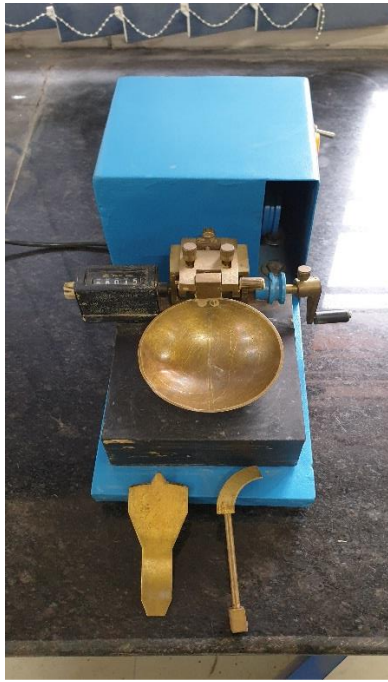
5. Spatula

6. Electrical Oven

Figure 1: Casagrande's liquid limit device

Procedure:

1. About 120 g of air-dried soil from thoroughly mixed portion of material passing 425-micron I.S sieve is to be obtained.

2. Distilled water is mixed to the soil thus obtained in a mixing dish to form uniform paste. The paste shall have a consistency that would require 30 to 35 drops of cup to cause required closer of standard groove for sufficient length.

3. A portion of the paste is placed in the cup of liquid limit device where cup rest on the base and spread into portion with few strokes of spatula.

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

5. The soil in the cup shall be divided by the firm strokes of the grooving tool along the diameter through the center line of the follower so that clean sharp groove of proper dimension is formed.

6. Lift and drop the cup by turning crank at the rate of two revolutions per second until the two halves of soil cake come in contact with each other for a length of about 12 mm by flow only (should not slip).

7. The number of blows required to cause the groove close for about 12 mm shall be recorded.

8. A representative portion of soil is taken from the cup for water content determination.

9. Repeat the test with different moisture contents at least three more times for blows between 10 and 40.

Observations:

Details of the sample: ....

Natural moisture content: ....   Room temperature: ....

Observation Table:

Determination Number	1	2	3		4
Container number					
Mass of container , M_1 (g)					
Mass of container + wet soil, M_2 (g)					
Mass of container + dry soil, M_3 (g)					
Mass of water, $M_2 - M_3$ (g)					
Mass of dry soil, M_3-M_1 (g)					
Moisture content (%) = $\dfrac{M_2 - M_3}{M_3 - M_1} \times 100$					
No. of blows					

Calculation:

Draw a graph showing the relationship between water content (on y-axis) and number of blows (on x-axis) on semi-log graph. The curve obtained is called flow curve. The moisture content corresponding to 25 drops (blows) as read from the graph represents liquid limit. It is usually expressed to the nearest whole number.

Interpretation and recording:

Result:

Flow index, $I_f = \dfrac{(W_2 - W_1)}{(log\frac{N_1}{N_2})}$ = slope of the flow curve = _____.

Questionnaire:

1. If natural water content of the soil is greater than the liquid limit and consistency index is negative, what is the consistency/ state of the soil?

2. What is the difference in consistency of soil and consistency of cement?

1(b) PLASTIC LIMIT TEST

Objective:

Determination of the plastic limit of soil

Standards:

1. Indian Standards : IS: 2720 (Part-5)

2. ASTM: D-4318

3. AASHTO: T-90

Need and scope:

Soil is used for making bricks, tiles, soil cement blocks in addition to its use as foundation for structures.

Apparatus:

1. Porcelain dish.

2. Glass plate for rolling the specimen.

3. Air tight containers to determine the moisture content.

4. Balance of capacity 200 g and sensitive to 0.01g

5. Oven thermostatically controlled with interior of non-corroding material to maintain the temperature around 105^0 and 110^0C.

Figure 1: Equipment for Plastic Limit

Procedure:

1. Take about 20 g of thoroughly mixed portion of the material passing through 425 micron I.S. sieve obtained in accordance with I.S. 2720 (Part 1).

2. Mix it thoroughly with distilled water in the evaporating dish till the soil mass becomes plastic enough to be easily molded with fingers.

3. Allow it to season for sufficient time (for 24 hrs.) to allow water to permeate throughout the soil mass.

4. Take about 8 g of this plastic soil mass and roll it between fingers and glass plate with just sufficient pressure to roll the mass into a thread of uniform diameter throughout its length. The rate of rolling shall be between 80 and 90 strokes per minute.

5. Continue rolling till you get a thread of 3 mm diameter.

6. Kneed the soil together to a uniform mass and re-roll.

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

8. Collect the pieces of the crumbled thread in air tight container for moisture content determination.

9. Repeat the test atleast 3 times and take the average of the results calculated to the nearest whole number.

Observation:

Compare the diameter of thread at intervals with the rod. When the diameter reduces to 3 mm, note the surface of the thread for cracks.
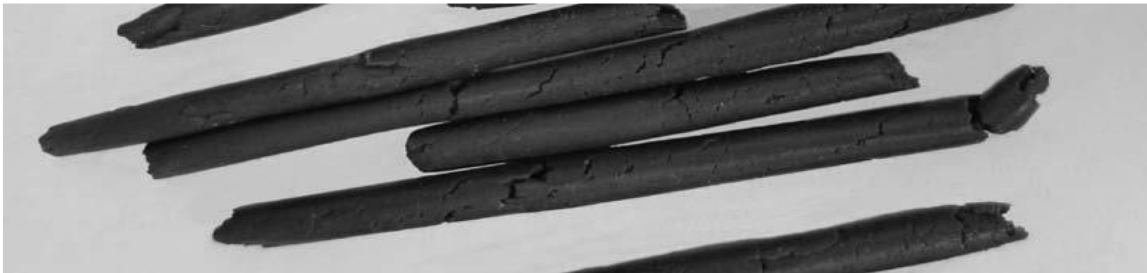

Figure 3: 3 mm thread of soil with cracks

Observation Table:

Determination Number	1	2	3
Container No.			
Mass of container + lid,W_1 (g)			
Mass of container + lid + wet sample,W_2 (g)			
Mass of container + lid + dry sample,W_3 (g)			
Mass of dry sample (soil solids) = $W_3 - W_1$ (g)			
Mass of water in the soil = $W_2 - W_3$ (g)			
Water content, w (%) = $\dfrac{W_2 - W_3}{W_3 - W_1} \times 100$			

Results:

Flow index, $I_f = \dfrac{(W_2 - W_1)}{(log\frac{N1}{N2})}$ = slope of the flow curve = _____.

Plasticity Index, $I_p = w_l - w_p$ = _____.

Toughness Index, $I_T = \dfrac{I_p}{I_f}$ = _____.

Liquidity Index, $I_L = \dfrac{w_o - w_p}{I_p}$ = _____.

Consistency Index, $I_c = \dfrac{w_l - w_o}{I_p}$ = _____.

Where, w_o = Natural Moisture content of soil

Result Summary						
Liquid limit (w_l)	Plastic limit (w_P)	Flow Index (I_f)	Plasticity Index (I_p)	Toughness Index (I_T)	Liquidity Index (I_L)	Consistency Index (I_c)

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ASTM D 2166 - Standard Test Method for Unconfined Compressive Strength of Cohesive Soil

ASTM D 2216 - Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures.

ASTM D 2434 - Standard Test Method for Permeability of Granular Soils (Constant Head) (Note: The Falling Head Test Method is not standardized)

ASTM D 2435 - Standard Test Method for One-Dimensional Consolidation Properties of Soils.

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Thank you