NORTH SOUTH UNIVERSITY
Center of Excellence in Higher Education
The First Private University in Bangladesh

Department of
CIVIL AND ENVIRONMENTAL ENGINEERING

CEE240L Soil Mechanics Lab
GEOTECHNICAL ENGINEERING LABORATORY

NORTH SOUTH UNIVERSITY
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North South University
Department of Civil and Environmental Engineering

CEE 240L
GEOTECHNICAL ENGINEERING LAB

Sl.	Name of the Experiment
01	Field Identification Test
02	Moisture Content Determination
03	Specific Gravity Test
04	Grain Size Analysis Test (Sieve Analysis)
05	Particle Size Analysis Test by Hydrometer
06	Atterberg Limit Test
07	Constant Head Permeability Test
08	Compaction Test
09	Direct Shear Test
10	Unconfined Compressive Strength Test

North South University
Department of Civil and Environmental Engineering

CEE 240L GEOTECHNICAL ENGINEERING LAB WORKBOOKS FOR LABORATORY PRACTICE

EXPERIMENT NO: 01
FIELD IDENTIFICATION TEST

Name: ID:

Group:

Section:

Performance Date:

Submission Date:

EXPERIMENT NO: 01
FIELD IDENTIFICATION TEST

Standard practice for Description and Identification of Soils (Visual-Manual procedure)

Scope of the test

- The practice covers the procedures for the description of soils for engineering use.
- The identification is based on Visual- examination and manual test. It must be clearly stated in reporting identification that it is based on visual-manual procedure.

Standard Reference

ASTM D 2488 - Standard Practice for Description and Identification of Soils (Visual - Manual Procedure)

Identification of Peat

A sample composed primarily of vegetable tissue in various stages of decomposition that has a fibrous to amorphous texture, usually a dark brown to black color, and organic odor shall be designated as a highly organic soil and shall be identified as peat, PT.

Preliminary identification

Soils can be classified into two general categories: (1) coarse grained soils and (2) fine grained soils. Examples of coarse-grained soils are gravels and sands. Examples of fine-grained soils are silts and clays. Procedures for visually identifying these two general types of soils are described in the following sections.

- The soil is fine grained if it contains 50% or more fines.
- The soil is coarse grained if it contains less than 50%fines.

a. Identify the color (e.g. brown, gray, brownish gray), odor (if any) and texture (coarse or fine- grained) of soil.
b. Identify the major soil constituent (>50% by weight) using Table 1 as coarse gravel, fine gravel, coarse sand, medium sand, fine sand, or fines.
c. Estimate percentages of all other soil constituents using Table 1.1 and the following terms:

Trace - 0 to 5% by weight

Few – 5 to 10 %
Little - 15 to 25%
Some - 30 to 45%
Mostly - 50 to 100%
(Examples: trace fine gravel, little silt, some clay)

Table 1.1 Grain size distributions

Soil Constituent	Size Limits	Familiar Example
Boulder	12 in. (305 mm) or more	Larger than basketball
Cobbles	3 in (76 mm) -12 In (305 mm)	Grapefruit
Coarse Gravel	% in. (19 mm) — 3 in. (76 mm)	Orange or Lemon
Fine Gravel	4.75 mm (No.4 Sieve) — % in. (19 mm)	Grape or Pea
Coarse Sand	2 mm (No.10 Sieve) — 4.75 mm (No. 4 Sieve)	Rocksalt
Medium Sand	0.42 mm (No. 40 Sieve) — 2 mm (No. 10 Sieve)	Sugar, table salt
Fine Sane	0.075 mm (No. 200 Sieve) — 0.42 mm (No. 40 Sieve)	Powdered Sugar
Fines	Less than 0.0075 mm (No. 200 Sieve)	-

*Particles finer than fine sand cannot be discerned with the naked eye at a distance of 8 in (20 cm).

d. If the major soil constituent is sand or gravel: Identify particle distribution. Describe as well graded or poorly graded. Well-graded soil consists of particle sizes over a wide range. Poorly graded soil consists of particles which are all about the same size. Identify particle shape (angular, subangular, rounded, subrounded) using Figure 1.1 and Table1.2.

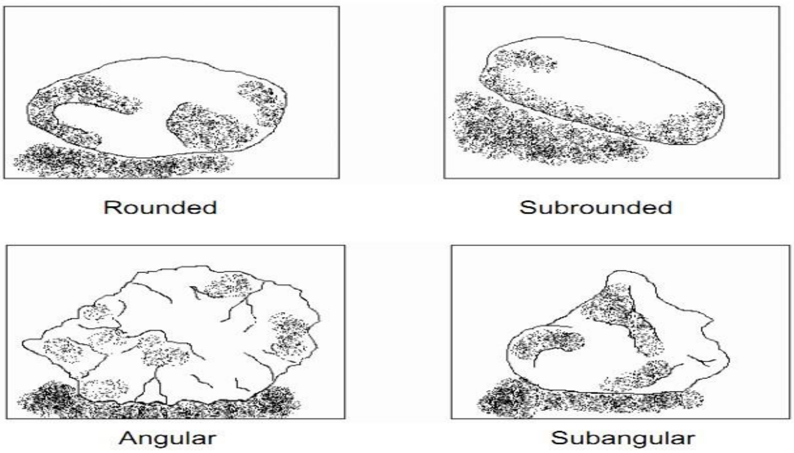

Figure 1.1 Shapes of coarse-grained soil particles

Table 1.2 Criteria for describing shape of coarse-grained soil particle

Description	Criteria
Angular	Particles have sharp edges and relatively plane sides with unpolished surfaces.
Subangular	Particles are similar to angular description, but have rounded edges.
Subrounded	Particles have nearly plane sides, but have well-rounded corners and edges.
Rounded	Particles have smoothly curved sides and no edges.

e. If the major soil constituents are fines, perform the following tests:

Procedure for Identifying Fine-grained Soils:

Select a representative sample of the material for examination. Remove particles larger than the No. 40 sieve (medium sand and larger) until a specimen equivalent to about a handful of material is available. Use this specimen for performingthe-

- Dry strength
- Dilatancy/shaking,
- Plasticity and
- Dispersion.

1. Dispersion:

- A rough estimate of the relative amounts of sand, silt and clay in a soil can be made by dispersion test.
- A small quantity of the soil is dispersed with water in a glass cylinder or beaker and then allowed to settle.
- The coarser particle fall out first and the finest particles remain in suspension the longest.
- Usually, sands settle in 30-60 sec, silts settle in 15-60 min and clays remain in suspension for several hours.

Figure 1.2: Dispersion Test

2. Dry strength:

- From the specimen, select enough material to mold into a ball about 1" (25mm). in diameter. Mold the material until it has the consistency of putty, adding water if necessary.
- From the molded material, make at least three test specimen about .5" (12.5mm) in diameter. Allow the test specimen to dry in air, or sun, or by artificial means, as the temperature does not exceed 60^0 C.
- If the test specimen contains natural dry lumps, those that are about 0.5" in diameter may be used in place of the molded balls. Note- The process of molding and drying usually produces higher strengths that are found in natural dry lumps of soil.
- Test the strength of the dry balls or lumps by crushing between the fingers and note the strength in accordance with the criteria in table1.3.

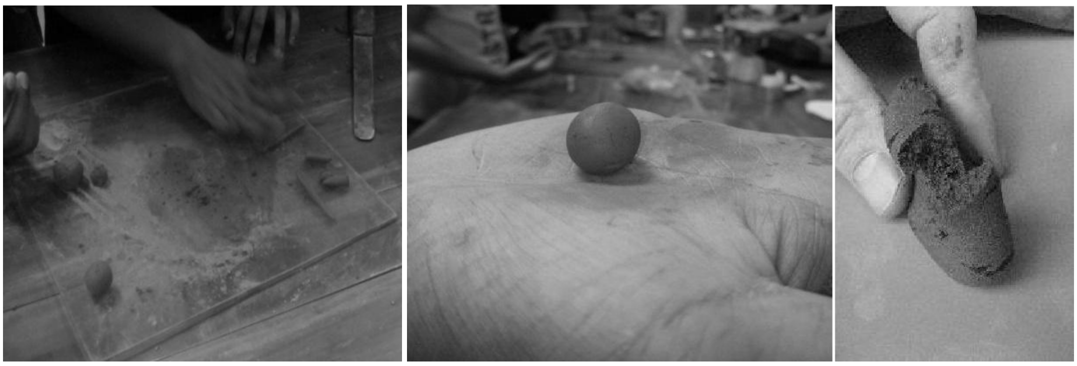

Figure 1.3: Dry Strength Test

Table-1.3 Dry Strength

Description	Criteria
None	The dry specimen crumbles into powder with mere pressure of handling
Low	The dry specimen crumbles into powder with some finger pressure
Medium	The dry specimen break into pieces or crumbles with considerable finger pressure
High	The specimen cannot be broken with finger pressure. Specimen will break into pieces between thumb and hand surface.
Very High	The specimen cannot be broken between the thumb and hard surface.

The presence of high-strength water soluble cementing materials, such as calcium carbonates, may cause exceptionally high dry strength. The presence of calcium carbonate can usually be deleted from the intensity of the reaction with dilute hydrochloric acid.

3. Dilatancy:

From the specimen select enough material to mold into a ball about 0.5" in diameter. Mold the material, adding water if necessary, until it has a soft, but not sticky, consistency. Smooth the soil ball in the palm of one hand with the blade of a knife or small spatula. Shake horizontally, striking the side of the hand vigorously against the other hand several times. Note the reaction of water appearing on the surface of the soil. Squeeze the sample by closing the hand or punching the soil between the fingers, and note the reaction in accordance with the criteria in table 1.4.

Table-1.4: Dilatancy

Description	Criteria
None	No visible change in specimen
Slow	Water appears slowly on the surface of the specimen during shaking and does not disappear or disappear slowly upon squeezing.
Rapid	Water appears quickly on the surface of the specimen during shaking and disappears quickly upon squeezing.

4. Toughness and plasticity:

- Following the completion of the dilatancy test, the test specimen is shaped into an elongated pat and rolled by hand on a smooth surface or between the palms into a thread about 1/8 in, in diameter. If the sample is too wet to roll easily, it should be spread into a thin layer and allowed to lose some water by evaporation.
- Fold the sample threads and reroll repeatedly until the thread crumbles at a diameter of about 1/8 in. The thread will crumbles at a diameter of 1/8 in, when the soil is near the plastic limit. Note the pressure required to roll the thread near the plastic limit.
- Also note the strength of the thread. After the thread crumbles, note the toughness of the materials during kneading.


Figure 1.4: Toughness and plasticity Test

Table-1.5: Toughness of plastic thread

Description	Criteria
Low	Only slight pressure is required to roll the thread near the plastic limit. The thread and the lump are weak and soft.
Medium	Medium pressure is required to roll the thread near the plastic limit. The thread and the lump have medium stiffness.
High	Considerable pressure is required to roll the thread near the plastic limit. The thread and the lump have very high stiffness.

Table-1.6: Plasticity

Description	Criteria
Nonplastic	A 1/8 in, thread cannot be rolled at any water content.
Low	The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit.
Medium	The thread is easily to roll and not much time is required to reach the plastic limit. The thread cannot be rolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit.
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit.

Combining all four field test result:

Table-1.7: Field Identification of Fine Grained Soil

Typical Name	Dry strength	Dilatancy reaction	Toughness of plastic thread	Time to settle in dispersion test
Sandy silt	None to very high	Rapid	Low	30sec to 60 min
Silt	Very low to low	Rapid	Low	15 to 60 min
Clayey silt	Low to medium	Rapid to slow	Medium	15 to several hours
Sandy clay	Low to high	Slow to none	Medium	30 sec to several hours
Silty clay	Medium to high	Slow to none	Medium	15 min to several hours
Clay	High to very high	None	High	Several hours to days
Organic silt	Low to medium	Slow	Low	15 min to several hours
Organic clay	Medium to very high	None	High	Several hours to days

Table 1.7 Identification of inorganic fine-grained soil

Soil Symbol	Dry Strength	Dilatency	Toughness
ML	None or Low	Slow to Rapid	Low or thread cannot be formed
CL	Medium to High	None to Slow	Medium
MH	Low to Medium	None to Slow	Low to Medium
CH	High to Very High	None	High

Note: ML = Silt: CL = Lean Clay (low plasticity clay) MH = Elastic Soil; CH = Fat Clay (high plasticity clay). The terms ‘lean’ and tat' may not be used in certain geographic regions (midwest).

Table 1.9 Criteria for describing soil moisture condition

Description	Criteria
Dry	Soil is dry to the touch, dusty, a clear absence of moisture
Moist	Soil is damp, slight moisture; soil may begin to retain molded form
Wet	Soil is clearly wet; water is visible when sample is squeezed
Saturated	Water is easily visible and drains freely from the sample

DATA SHEET

Experiment Name : **Field Identification of Soil**
Experiment Date :

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

1. Color :
2. Odor :
3. Texture :
4. Major soil constituent :
5. Minor soil constituents :

6. For coarse-grained soils:

Gradation

:
Particle Shape :

7. For fine-grained soils:
Dry Strength :
Dilatancy :
Plasticity :
Toughness :
Soil Symbol :

8. Moisture

Condition: Classification:

Course Teacher :
Designation :

Signature

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CEE 240L GEOTECHNICAL ENGINEERING LAB WORKBOOKS FOR LABORATORY PRACTICE

EXPERIMENT NO: 02
MOISTURE CONTENT DETERMINATION

Name:

ID:

Group:

Section:

Performance Date:

Submission Date:

EXPERIMENT NO: 02
MOISTURE CONTENT DETERMINATION

Purpose

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.

$$\mathbf{M_S = M_3 - M_1}$$

(2) Determine the mass of pore water.

$$\mathbf{M_W = M_3 - M_2}$$

(3) Determine the water content.

$$\boldsymbol{W = \frac{M_W}{M_S} \times 100\%}$$

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

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EXPERIMENT NO: 03
SPECIFIC GRAVITY TEST

Name:

ID:

Group:

Section:

Performance Date:

Submission Date:

EXPERIMENT NO: 03
SPECIFIC GRAVITY TEST

Purpose

This test is performed to determine the specific gravity of soil by using a pycnometer. Specific gravity is the ratio of unit weight of soil at a stated temperature to the unit weight of same volume of gas-free distilled water at a stated temperature.

Standard Reference

ASTM D 854-00 – Standard Test for Specific Gravity of Soil Solids by Water Pycnometer.

Equipment

Pycnometer, Balance, Vacuum pump, Funnel, Spoon etc.

Test Procedure

(1) Determine and record the weight of the empty clean and dry pycnometer.
(2) Place 50g of a dry soil sample (passed through the sieve No. 10) in the pycnometer. Determine and record the weight of the pycnometer containing the dry soil.
(3) Add distilled water to fill about half to three-fourth of the pycnometer. Soak the sample for 10 minutes.
(4) Apply a partial vacuum to the contents for 10 minutes, to remove the entrapped air.
(5) Stop the vacuum and carefully remove the vacuum line from pycnometer.
(6) Fill the pycnometer with distilled (water to the mark), clean the exterior surface of the pycnometer with a clean, dry cloth. Determine the weight of the pycnometer and contents.
(7) Empty the pycnometer and clean it. Then fill it with distilled water only (to the mark). Clean the exterior surface of the pycnometer with a clean, dry cloth. Determine the weight of the pycnometer and distilled water
(8) Empty the pycnometer and clean it.

Sample Calculation

$$G_S = \frac{(M2 - M1)}{(M4 - M1) - (M3 - M2)} G_T$$

Here,
M_1=Weight of Pycnometer
M_2=Weight of Pycnometer+Soil

M_3=Weight of Pycnometer+Soil+Water
M_4=Weight of Water + Pycnometer
G_T=Specific gravity of distilled water. (If normal tap water is used)
(You will get value of G_T from Soil Testing for Engineers-Lambe: Appendix A-Table A2)

DATA SHEET

Experiment Name : **Specific Gravity Determination of Soil**
Experiment Date :

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

Sample Description :
Data Table :

Specimen number	1	2
Pycnometer bottle number		
Weight of Pycnometer, M_1		
Weight of Pycnometer + Soil, M_2		
Weight of Pycnometer + Soil+Water, M_3		
Weight of Pycnometer + Water, M_4		
Specific gravity of distilled water, G_T		
Specific gravity of the Soil, G_S		

Sample Calculation :

$$G_S = \frac{(M2 - M1)}{(M4 - M1) - (M3 - M2)} G_T$$

Result:
Specific Gravity of the soil is :

Course Teacher :
Designation :

Signature

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CEE 240L GEOTECHNICAL ENGINEERING LAB
WORKBOOKS FOR LABORATORY PRACTICE

EXPERIMENT NO: 04
GRAIN SIZE ANALYSIS TEST
(SIEVE ANALYSIS)

Name:

ID:

Group:

Section:

Performance Date:

Submission Date:

EXPERIMENT NO: 04
GRAIN SIZE ANALYSIS TEST (SIEVE ANALYSIS)

Purpose

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.

Table 3.1 Sieve no. and openings

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

Apparatus

- #4, #8, #16, #30, #50, #100, #200sieve
- 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 10minutes.
(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.

$$C_u = \frac{D_{60}}{D_{10}} \text{ And } C_Z = \frac{D_{30}^2}{D_{60}D_{10}}$$

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	CZ	:	
%Fines	:	D60	:	mm			

Unified Classification of Soil :

Course Teacher :
Designation :

Signature

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EXPERIMENT NO: 05
PARTICLE SIZE ANALYSIS TEST BY HYDROMETER

Name: ID:

Group:

Section:

Performance Date:

Submission Date:

EXPERIMENT NO: 05
PARTICLE SIZE ANALYSIS TEST BY HYDROMETER

Purpose

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 hexametaphosphate (NaPO3)
- Thermometer

Figure 4.1 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 hexametaphosphate (40 g/L)) solution. Stir the mixture until the soil is thoroughly 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 theeading 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 24hours

Table 4.1: Values of k for Use in Equation for Computing Diameter of Particle in Hydrometer Analysis

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 4.2: Temperature Correction Factors C_T

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 4.3: Correction Factors a for Unit Weight of Solids

Unit Weight of Soil Solids, g/cm^3	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 4.4: Properties of distilled water Stokes formula for (h=absolute) 152H

Temperature C	Density (g/cm^3)	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

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

Table 4.5: Value of L (effective depth) for use in diameters of particles for ASTM soil hydrometer

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 : NaPO3 Weight
of Soil Sample, M_S : 50gm

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

Data Table :

Elapsed Time, t (min)	Actual Reading R_a	$R = R_a$ + Meniscus correction	Corrected Reading, $R_C = R_a$ - Zero correction + C_T	L = (16.29 – 0.1641R)	$\sqrt{\frac{L}{t}}$	K	Particle size, D = $K\sqrt{\frac{L}{t}}$	% of Finer, P = $\frac{R_C}{M_S}$*a*100
.25								
.5								
1								
2								
4								
8								
15								

[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

Grain size distribution curve

North South University
Department of Civil and Environmental Engineering

CEE 240L GEOTECHNICAL ENGINEERING LAB WORKBOOKS FOR LABORATORY PRACTICE

EXPERIMENT NO: 06
ATTERBERG LIMIT TEST

Name:

ID:

Group:

Section:

Performance Date:

Submission Date:

EXPERIMENT NO: 06
ATTERBERG LIMIT TEST

Purpose
This test is performed to determine the plastic and liquid limits of a fine-grained soil.

Standard Reference
ASTM D 4318 - Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.

Significance
The Swedish soil scientist Albert Atterberg originally defined seven “limits of consistency” to classify fine-grained soils, but in current engineering practice only two of the limits, the liquid and plastic limits, are commonly used. (A third limit, called the shrinkage limit, is used occasionally.) The Atterberg limits are based on the moisture content of the soil. The plastic limit is the moisture content that defines where the soil changes from a semi-solid to a plastic (flexible) state. The liquid limit is the moisture content that defines where the soil changes from a plastic to a viscous fluid state. The shrinkage limit is the moisture content that defines where the soil volume will not reduce further if the moisture content is reduced. Awide variety of soil engineering properties have been correlated to the liquid and plastic limits, and these Atterberg limits are also used to classify a fine-grained soil according to the Unified Soil Classification system or AASHTO system.

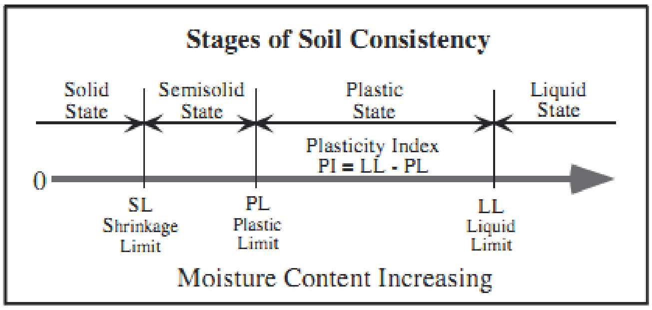


Figure 7.1: Atterberg Limits

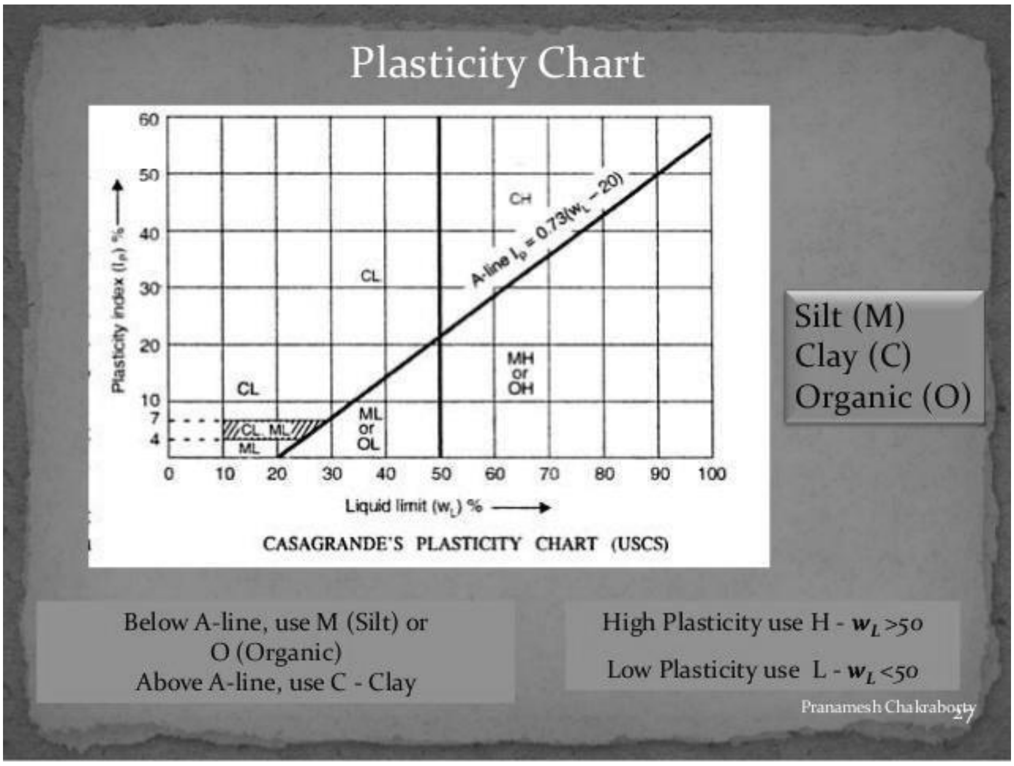


Figure 7.2: Modified Plasticity chart

Equipment

- Liquid limit device
- Porcelain (evaporating)dish
- Flat grooving tool with gage,
- Moisture cans
- Balance
- Glass plate
- Spatula
- Wash bottle filled with distilled water
- Drying oven set at105^{o}C

Figure 7.3: Atterberg Limit Test Apparatus

Test Procedure

Liquid Limit

(1) Take roughly 3/4 of the soil and place it into the porcelain dish. Assume that the soil was previously passed through a No. 40 sieve, air-dried, and then pulverized. Thoroughly mix the soil with a small amount of distilled water until it appears as a smooth uniform paste. Cover the dish with cellophane to prevent moisture from escaping.

(2) Weigh four of the empty moisture cans with their lids, and record the respective weights and can numbers on the datasheet.

(3) Adjust the liquid limit apparatus by checking the height of drop of the cup. The point on the cup that comes in contact with the base should rise to a height of 10 mm. The block on the end of the grooving tool is10 mm high and should be used as a gage. Practice using the cup and determine the correct rate to rotate the crank so that the cup drops approximately two times per second.

(4) Place a portion of the previously mixed soil into the cup of the liquid limit apparatus at the point where the cup rests on the base. Squeeze the soil down to eliminate air pockets and spread it into the cup to a depth of about 10 mm at its deepest point. The soil pat should form an approximately horizontal surface.

(5) Use the grooving tool carefully cut a clean straight groove down the center of the cup. The tool should remain perpendicular to the surface of the cup as groove is being made. Use extreme care to prevent sliding the soil relative to the surface of the cup.

(6) Make sure that the base of the apparatus below the cup and the underside of the cup is clean of soil. Turn the crank of the apparatus at a rate of approximately two drops per second and count the number of drops, N, it takes to make the two halves of the soil pat come into contact at the bottom of the groove along a distance of 13 mm (1/2 in.). If the number of drops exceeds 50, then go directly to step eight and do not record the number of drops, otherwise, record the number of drops on the data sheet.

(7) Take a sample, using the spatula, from edge to edge of the soil pat. The sample should include the soil on both sides of where the groove came into contact. Place the soil into a moisture can cover it. Immediately weigh the moisture can containing the soil, record it's mass, remove the lid, and place the can into the oven. Leave the moisture can in the oven for at least 16 hours. Place the soil remaining in the cup into the porcelain dish. Clean and dry the cup on the apparatus and the grooving tool.

(8) Remix the entire soil specimen in the porcelain dish. Add a small amount of distilled water to increase the water content so that the number of drops required closing the groove decrease.

(9) Repeat steps six, seven, and eight for at least two additional trials producing successively lower numbers of drops to close the groove. One of the trials shall be for a closure requiring 25 to 35 drops, one for closure between 20 and 30 drops, and one trial for a closure requiring 15 to 25 drops. Determine the water content from each trial by using the same method used in the first laboratory. Remember to use the same balance for all weighing.

Plastic Limit

(1) Weigh the remaining empty moisture cans with their lids, and record the respective weights and can numbers on the datasheet.

(2) Take the remaining 1/4 of the original soil sample and add distilled water until the soil is at a consistency where it can be rolled without sticking to the hands.

(3) Form the soil into an ellipsoidal mass. Roll the mass between the palm or the fingers and the glass plate. Use sufficient pressure to roll the mass into a thread of uniform diameter by using about 90 strokes per minute. (A stroke is one complete motion of the hand forward and back to the starting position.) The thread shall be deformed so that its diameter reaches 3.2 mm (1/8 in.), taking no more than two minutes.

(4) When the diameter of the thread reaches the correct diameter, break the thread into several pieces. Knead and reform the pieces into ellipsoidal masses and re-roll them. Continue this alternate rolling, gathering together, kneading and re-rolling until the thread crumbles under the pressure required for rolling and can no longer be rolled into a 3.2 mm diameter thread.

(5) Gather the portions of the crumbled thread together and place the soil into moisture can, and then cover it. If the can does not contain at least 6 grams of soil, add soil to the can from the next trial. Immediately weigh the moisture can containing the soil, record it's mass, remove the lid, and place the can into the oven. Leave the moisture can in the oven for at least 16hours.

(6) Repeat steps three, four, and five at least two more times. Determine the water content from each trial by using the same method used in the first laboratory. Remember to use the same balance for all weighing.

Analysis

Liquid Limit

(1) Calculate the water content of each of the liquid limit moisture cans after they have been in the oven for at least 16hours.
(2) Plot the number of drops, N, (on the log scale) versus the water content (w). Draw the best-fit straight line through the plotted points and determine the liquid limit (LL) as the water content at 25 drops.

Plastic Limit

(1) Calculate the water content of each of the plastic limit moisture cans after they have been in the oven for at least 16hours.
(2) Compute the average of the water contents to determine the plastic limit, PL. Check to see if the difference between the water contents is greater than the acceptable range of two results (2.6%).
(3) Calculate the plasticity index, PI=LL-PL. Report the liquid limit, plastic limit, and plasticity index to the nearest whole number, omitting the percent designation.

DATA SHEET

Experiment Name : **Atterberg Limit test**
Experiment Date :

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

Visual Classification :

Liquid Limit Determination :

Sample No.	**1**	**2**	**3**	**4**
Can no.				
Can weight				
Can + wet soil				
Can + dry soil				
Weight of water				
Water content w%				
No. of drop				

Liquid Limit for 25 blows from graph:

Plastic Limit Determination:

Sample No.	**1**	**2**	**3**	**4**
Can no.				
Can weight				
Can + wet soil				
Can + dry soil				
Weight of water				
Water content w%				

Plastic Limit (PL) = Average w %:

Final Results:
Liquid Limit :
Plastic Limit :
Plasticity Index:

Course Teacher :
Designation :

Signature

North South University
Department of Civil and Environmental Engineering

CEE 240L GEOTECHNICAL ENGINEERING LAB WORKBOOKS FOR LABORATORY PRACTICE

EXPERIMENT NO: 07
CONSTANT HEAD PERMEABILITY TEST

Name:

ID:

Group:

Section:

Performance Date:

Submission Date:

EXPERIMENT NO: 07
CONSTANT HEAD PERMEABILITY TEST

Purpose

The purpose of this test is to determine the permeability (hydraulic conductivity) of a sandy soil by the constant head test method. There are two general types of permeability test methods that are routinely performed in the laboratory:

(1) The constant head test method, and

(2) The falling head test method.

The constant head test method is used for permeable soils (k>10-4cm/s) and the falling head test is mainly used for less permeable soils (k<10-4cm/s).

Standard Reference

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

Significance

Permeability (or hydraulic conductivity) refers to the ease with which water can flow through a soil. This property is necessary for the calculation of seepage through earth dams or under sheet pile walls, the calculation of the seepage rate from waste storage facilities (landfills, ponds, etc.), and the calculation of the rate of settlement of clayey soil deposits.

Permeability depends on a number of factors-

- The size of the soil grains
- The properties of the pore fluid
- The void ratio of the soil
- The shape and arrangement of pores
- The degree of saturation

Equipment

- Permeameter
- Tamper
- Balance
- Scoop
- Cylinders
- Watch (or Stopwatch),
- Thermometer
- Filter paper.

Figure 8.1 Permeability Apparatus

Test Procedure

(1) Measure the initial mass of the pan along with the dry soil (M1).

(2) Remove the cap and upper chamber of the permeameter by unscrewing the knurled cap nuts and lifting them off the tie rods. Measure the inside diameter of upper and lower chambers. Calculate the average inside diameter of the permeameter (D).

(3) Place one porous stone on the inner support ring in the base of the chamber then place a filter paper on top of the porous stone

(4) Mix the soil with a sufficient quantity of distilled water to prevent the segregation of particle sizes during placement into the permeameter. Enough water should be added so that the mixture may flow freely

(5) Using a scoop, pour the prepared soil into the lower chamber using a circular motion to fill it to a depth of 1.5 cm. A uniform layer should be formed.

(6) Use the tamping device to compact the layer of soil. Use approximately ten rams of the tamper per layer and provide uniform coverage of the soil surface. Repeat the compaction procedure until the soil is within 2 cm. of the top of the lower chamber section

(7) Replace the upper chamber section, and don't forget the rubber gasket that goes between the chamber sections. Be careful not to disturb the soil that has already been compacted. Continue the placementoperationuntilthelevelofthesoilisabout2cm.belowtherimoftheupperchamber.
Level the top surface of the soil and place a filter paper and then the upper porous stone on it

(8) Place the compression spring on the porous stone and replace the chamber cap and its sealing gasket. Secure the cap firmly with the cap nuts.

(9) Measure the sample length at four locations around the circumference of the permeameter and compute the average length. Record it as the sample length.

(10) Keep the pan with remaining soil in the drying oven.

(11) Adjust the level of the funnel to allow the constant water level in it to remain a few inches above the top of the soil.

(12) Connect the flexible tube from the tail of the funnel to the bottom outlet of the permeameter and keep the valves on the top of the permeameter open.

(13) Place tubing from the top outlet to the sink to collect any water that may come out.

(14) Open the bottom valve and allow the water to flow into the permeameter.

(15) As soon as the water begins to flow out of the top control (desiring) valve, close the control valve, letting water flow out of the outlet for some time.

(16) Close the bottom outlet valve and disconnect the tubing at the bottom Connect the funnel tubing to the top side port.

(17) Open the bottom outlet valve and raise the funnel to a convenient height to get a reasonable steady flow of water.

(18) Allow adequate time for the flow pattern to stabilize.

(19) Measure the time it takes to fill a volume of 750 - 1000 mL using the graduated cylinder, and then measure the temperature of the water. Repeat this process three times and compute the average time, average volume, and average temperature. Record the values as t, Q, and T, respectively.

(20) Measure the vertical distance between the funnel head level and the chamber outflow level, and record the distance ash.

(21) Repeat step 17 and 18 with different vertical distances.

(22) Remove the pan from the drying oven and measure the final mass of the pan along with the dry soil (M2).

Calculation

1. Calculate the permeability, using the following equation:

$$K_T = QL/Ath$$

Where:
K_T = coefficient of permeability at temperature T, cm/sec.
L = length of specimen in centimeters t
= time for discharge in seconds
Q = volume of discharge in cm^3 (assume 1 mL = 1 cm^3)
A = cross-sectional area of permeameter (= $\frac{\pi D^2}{4}$, D= inside diameter of the permeameter)
h = hydraulic head difference across length L, in cm of water; or it is equal to the vertical distance between the constant funnel head level and the chamber overflow level.

2. The viscosity of the water changes with temperature. As temperature increases viscosity decreases and the permeability increases. The coefficient of permeability is standardized at 20°C, and the permeability at any temperature T is related to K20 by the following

$$K_{20} = K_T \frac{\eta_T}{\eta_{20}}$$

Where:
η_T and η_{20} are the viscosities at the temperature T of the test and at 20°C, respectively. From Table below obtain the viscosities and compute K20.

Temperature C	Density (g/cm^3)	Viscosity (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

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

3. Compute the dry density (ρ_d) of soil

$$\rho_d = \frac{M}{V} = \frac{M1 - M2}{LA}$$

DATA SHEET

Experiment Name : **Content Head Permeability Test**
Experiment Date :

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

Visual Classification :
Initial Dry Mass of Soil +Pan (M1) : g
Length of Soil Specimen, L : cm
Diameter of the Soil Specimen (Permeameter), D : cm
Final Dry Mass of Soil +Pan (M2) : g
Dry Mass of Soil Specimen (M) : g
Volume of Soil Specimen (V) : cm^3
Dry Density of Soil (ρd) : g/cm^3

Trial No.	Constant Head, h (cm)	Elapsed Time, t (sec)	Outflow Volume, Q (cm^3)	Water Temp., T (^0C)	K_T	K_{20}
1						
2						
3						
4						

Average K_{20} : cm/sec

Result:
Permeability of the soil is:

Course Teacher :
Designation :

Signature

North South University
Department of Civil and Environmental Engineering

CEE 240L GEOTECHNICAL ENGINEERING LAB WORKBOOKS FOR LABORATORY PRACTICE

EXPERIMENT NO: 08
COMPACTION TEST

Name: ID:

Group:

Section:

Performance Date:

Submission Date:

EXPERIMENT NO: 08
COMPACTION TEST

Purpose

This laboratory test is performed to determine the relationship between the moisture content and the dry density of a soil for a specified compactive effort. The compactive effort is the amount of mechanical energy that is applied to the soil mass. Several different methods are used to compact soil in the field, and some examples include tamping, kneading, vibration, and static load compaction. This laboratory will employ the tamping or impact compaction method using the type of equipment and methodology developed by R. R. Proctor in 1933, therefore, the test is also known as the Proctor test.

Two types of compaction tests are routinely performed: (1) The Standard Proctor Test, and (2) The Modified Proctor Test. Each of these tests can be performed in three different methods as outlined in the attached Table 1. In the Standard Proctor Test, the soil is compacted by a 5.5 lb hammer falling a distance of one foot into a soil filled mold. The mold is filled with three equal layers of soil, and each layer is subjected to 25 drops of the hammer. The Modified Proctor Test is identical to the Standard Proctor Test except it employs, a 10 lb hammer falling a distance of 18 inches, and uses five equal layers of soil instead of three. There are two types of compaction molds used for testing. The smaller type is 4 inches in diameter and has a volume of about 1/30 ft^3 (944 cm^3), and the larger type is 6 inches in diameter and has a volume of about 1/13.333 ft^3 (2123 cm^3). If the larger mold is used each soil layer must receive 56 blows instead of 25 (See Table).

Table 10.1 Alternative Proctor Test Methods

	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	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/layer	25	25	56	25	25	56

Note: Volume of 4" diameter mold = 944 cm^3, Volume of 6" diameter mold = 2123 cm^3 (verify these values prior to testing)

Figure 10.1 Standard and Modified proctor compaction mold

Standard Reference

ASTM D 698 - Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbs/ft^3 (600 KN-m/m^3))

ASTM D 1557 - Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbs/ft^3 (2,700 KN-m/m^3))

Significance

Mechanical compaction is one of the most common and cost effective means of stabilizing soils. An extremely important task of geotechnical engineers is the performance and analysis of field control tests to assure that compacted fills are meeting the prescribed design specifications. Design specifications usually state the required density (as a percentage of the "maximum" density measured in a standard laboratory test), and the water content. In general, most engineering properties, such as the strength, stiffness, resistance to shrinkage, and imperviousness of the soil, will improve by increasing the soil density.

The optimum water content is the water content that results in the greatest density for a specified compactive effort. Compacting at water contents higher than (wet of) the optimum water content results in a relatively dispersed soil structure (parallel particle orientations) that is weaker, more ductile, less pervious, softer, more susceptible to shrinking, and less susceptible to swelling than soil compacted dry of optimum to the same density. The soil compacted lower than (dry of) the optimum water content typically results in a flocculated soil structure (random particle orientations) that has the opposite characteristics of the soil compacted wet of the optimum water content to the same density.

Equipment

Molds, Manual rammer, Extruder, Balance, Drying oven, Mixing pan, Trowel, #4 sieve, Moisture cans, Graduated cylinder, Straight Edge.

Test Procedure

(1) Depending on the type of mold you are using obtain a sufficient quantity of air-dried soil in large mixing pan. For the 4-inch mold take approximately 10 lbs, and for the 6-inch mold take roughly 15 lbs. Pulverize the soil and run it through the # 4 sieve.

(2) Determine the weight of the soil sample as well as the weight of the compaction mold with its base (without the collar) by using the balance and record the weights.

(3) Compute the amount of initial water to add by the following method:

(a) Assume water content for the first test to be 8percent.

(b) Compute water to add from the following equation:

$$\text{water to add (in ml)} = \frac{(\text{soil mass in grams})8}{100}$$

Where, "water to add" and the "soil mass" are in grams. Remember that a gram of water is equal to approximately one milliliter of water.

(4) Measure out the water, add it to the soil, and then mix it thoroughly into the soil using the trowel until the soil gets a uniform color.

(5) Assemble the compaction mold to the base, place some soil in the mold and compact the soil in the number of equal layers specified by the type of compaction method employed. The number of drops of the rammer per layer is also dependent upon the type of mold used (See Table). The drops should be applied at a uniform rate not exceeding around 1.5 seconds per drop, and the rammer should provide uniform coverage of the specimen surface. Try to avoid rebound of the rammer from the top of the guide sleeve.

(6) The soil should completely fill the cylinder and the last compacted layer must extend slightly above the collar joint. If the soil is below the collar joint at the completion of the drops, the test point must be repeated. (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.)

(7) Carefully remove the collar and trim off the compacted soil so that it is completely even with the top of the mold using the trowel. Replace small bits of soil that may fall out during the trimming process.

(8) Weigh the compacted soil while it's in the mold and to the base, and record the mass. Determine the wet mass of the soil by subtracting the weight of the mold and base.

(9) 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.

(10) Place the soil specimen in the large tray and break up the soil until it appears visually as if 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 lesser compacted soil masses.

Analysis

(1) Calculate the moisture content of each compacted soil specimen by using the average of the two water contents.

(2) Compute the wet density in grams per cm3 of the compacted soil sample by dividing the wet mass by the volume of the mold used.

(3) Compute the dry density using the wet density and the water content determined in step 1. Use 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 cm^3 = (M/V).

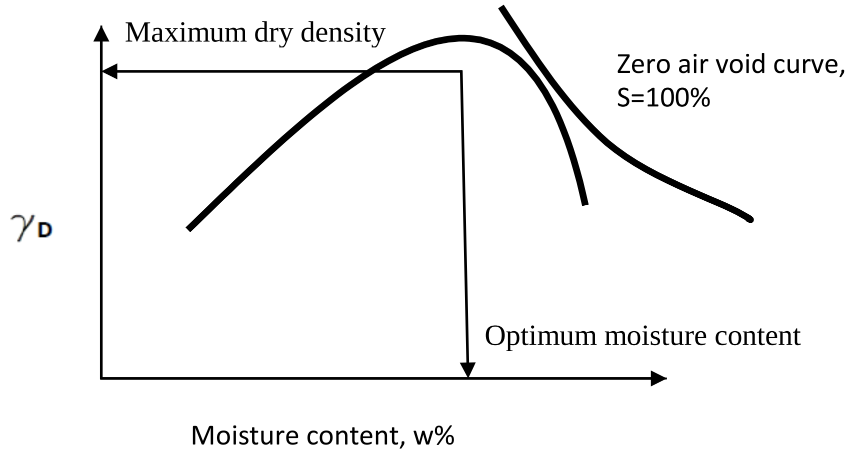
(4) Plot the dry density values on the y-axis and the moisture contents on the x-axis. Draw a smooth curve connecting the plotted points.

(5) 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:

$$\rho_d = \frac{\rho_w}{\left(\frac{w}{100} + \frac{1}{G_S}\right)}$$

Where: ρ_d = dry density of soil grams per cm^3, Gs = specific gravity of the soil being tested, ρ_w = density of water in grams per cm^3 (approximately1 g/cm^3) w_{sat} = moisture content in percent for complete saturation.

(6) Identify and report the optimum moisture content and the maximum dry density.



DATA SHEET

Experiment Name : **Proctor Compaction Test**
Experiment Date :

Student's Name :
Student's ID :
Year/Semester :
Section/Group :
Visual Classification :
Test Method :
Diameter of mold :
Height of mold :
Volume of mold, V :
Mass of mold, M :

Water Content Determination

Sample no.	1	2	3	4	5
Moisture can no.					
Mass of empty clean can					
Mass of can + wet soil					
Mass of can + dry soil					
Mass of soil solid					
Mass of pore water					
Water content w%					

Density Determination

Compacted soil sample no.	1	2	3	4	5
Water content w%					
Mass of compacted soil and mold (gm)					
Mass of wet soil (gm)					
Wet density, $\rho = (M/V)$					
Dry density, $\rho D= [\rho/(1+w)]$					
Dry density (S=100%)					

Result:

Optimum Moisture Content: % Maximum Dry
Density: g/cm3

Course Teacher :
Designation :

Signature

North South University
Department of Civil and Environmental Engineering

CEE 240L GEOTECHNICAL ENGINEERING LAB WORKBOOKS FOR LABORATORY PRACTICE

EXPERIMENT NO: 09
DIRECT SHEAR TEST

Name:

ID:

Group:

Section:

Performance Date:

Submission Date:

EXPERIMENT NO: 09
DIRECT SHEAR TEST

Purpose
This test is performed to determine the consolidated-drained shear strength of a sandy to silty soil. The shear strength is one of the most important engineering properties of a soil, because it is required whenever a structure is dependent on the soil's shearing resistance. The shear strength is needed for engineering situations such as determining the stability of slopes or cuts, finding the bearing capacity for foundations, and calculating the pressure exerted by a soil on a retaining wall.

Standard Reference
ASTM D 3080 - Standard Test Method for Direct Shear Test of Soils Under Consolidated Drained Conditions

Significance
The direct shear test is one of the oldest strength tests for soils. In this laboratory, a direct shear device will be used to determine the shear strength of a cohesionless soil (i.e. angle of internal friction (ϕ). From the plot of the shear stress versus the horizontal displacement, the maximum shear stress is obtained for a specific vertical confining stress. After the experiment is run several times for various vertical- confining stresses, a plot of the maxi mum shear stresses versus the vertical (normal) confining stresses for each of the tests is produced. From the plot, a straight-line approximation of the Mohr-Coulomb failure envelope curve can be drawn, f may be determined, and, for cohesionless soils (c = 0), the shear strength can be computed from the following equation:

$$\tau = \delta \tan\phi$$

Equipment
Direct shear device, Load and deformation dial gauges, Balance.

Figure 11.1 Direct Shear Test device of the laboratory

Test Procedure

(1) Weigh the initial mass of soil in the pan.

(2) Measure the diameter and height of the shear box. Compute 15% of the diameter in millimeters.

(3) Carefully assemble the shear box and place it in the direct shear device. Then place a porous stone and a filter paper in the shear box.

(4) Place the sand into the shear box and level off the top. Place a filter paper, a porous stone, and a top plate (with ball) on top of the sand.

(5) Remove the large alignment screws from the shear box! Open the gap between the shear box halves to approximately 0.025 in. using the gap screws, and then back out the gap screws.

(6) Weigh the pan of soil again and compute the mass of soil used.

(7) Complete the assembly of the direct shear device and initialize the three gauges (Horizontal displacement gage, vertical displacement gage and shear load gage) to zero.

(8) Set the vertical load (or pressure) to a predetermined value, and then close bleeder valve and apply the load to the soil specimen by raising the toggles witch.

(9) Start the motor with selected speed so that the rate of shearing is at as elected constant rate, and take the horizontal displacement gauge, vertical displacement gage and shear load gage readings. Record the readings on the data sheet. (Note: Record the vertical displacement gage readings, if needed).

(10) Continue taking readings until the horizontal shear load peaks and then falls, or the horizontal displacement reaches 15% of the diameter.

Analysis

(1) Calculate the density of the soil sample from the mass of soil and volume of the shear box.

(2) Convert the dial readings to the appropriate length and load units and enter the values on the data sheet in the correct locations. Compute the sample area A, and the vertical (Normal) stress S_n.

S_n= (F/A)

Where: F = normal vertical force, and S_n = normal vertical stress

(3) Calculate shear stress (τ)using

τ=(F/A)

Where F= shear force measured with shear load gage

(4) Plot the shear stress (τ) versus shear displacement.

(5) Calculate the maximum shear stress for each test.

(6) Plot the value of the maximum shear stress versus the corresponding vertical stress for each test, and determine the angle of internal friction (ϕ) from the slope of the approximated Mohr-Coulomb failure envelope.

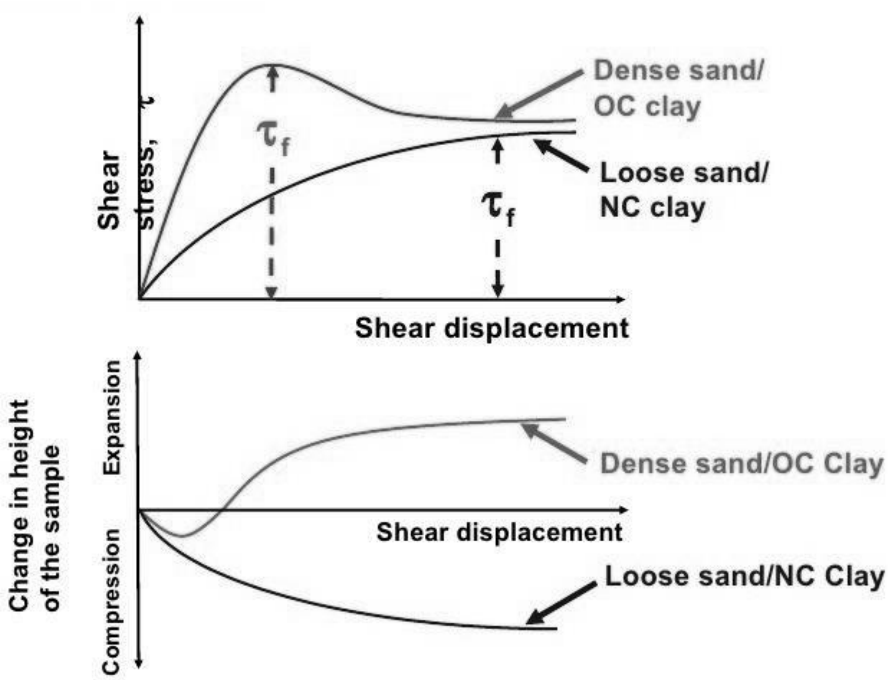


Figure 11.2 Stress-strain relationships of sand (Direct Shear Test)

DATA SHEET

Experiment Name : **Direct Shear Test**
Experiment Date :

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

Visual Classification :

Shear Box inside Diameter :
Area (A) :
Shear Box Height :
Soil Volume :

Normal stress vs maximum shear stress curve:

Normal Stress δ	Maximum shear stress τ

Result
Angle of internal friction:

Course Teacher :
Designation :

Signature

DIRECT SHEAR TEST DATA SHEET-2

Horizontal Displacement Reading (A)	Horizontal Shear Force Reading (B)	Horizontal Displacement =(A*0.025) mm	Horizontal Shear Force =(B*0.005) kN	Shear Stress

North South University
Department of Civil and Environmental Engineering

CEE 240L GEOTECHNICAL ENGINEERING LAB WORKBOOKS FOR LABORATORY PRACTICE

EXPERIMENT NO: 10
UNCONFINED COMPRESSIVE STRENGTH TEST

Name:

ID:

Group:

Section:

Performance Date:

Submission Date:

EXPERIMENT NO: 10
UNCONFINED COMPRESSIVE STRENGTH TEST

Purpose

The primary purpose of this test is to determine the unconfined compressive strength, which is then used to calculate the unconsolidated undrained shear strength of the clay under unconfined conditions. According to the ASTM standard, the unconfined compressive strength (q_u) is defined as the compressive stress at which an unconfined cylindrical specimen of soil will fail in a simple compression test. In addition, in this test method, the unconfined compressive strength is taken as the maximum load attained per unit area, or the load per unit area at 15% axial strain, whichever occurs first during the performance of a test.

Standard Reference

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

Significance

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

$$S_u = c = \frac{q_u}{2}$$

Then, as time passes, the pore water in the soil slowly dissipates, and the intergranular stress increases, so that the drained shear strength (s), given by s = c + s'tanϕ, must be used. Where s'=intergranular pressure acting perpendicular to the shear plane; and s' = (s - u), s = total pressure, and u = pore water pressure; c' and j' are drained shear strength parameters.

Equipment

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

Test Procedure

(1) Extrude the soil sample from Shelby tube sampler. Cut a soil specimen so that the ratio (L/d) is approximately between 2 and 2.5.Where L and d are the length and diameter of soil specimen, respectively.

(2) Measure the exact diameter of the top of the specimen at three locations 120° apart, and then make the same measurements on the bottom of the specimen. Average the measurements and record the average as the diameter on the datasheet.

(3) Measure the exact length of the specimen at three locations 120° apart, and then average the measurements and record the average as the length on the datasheet.

(4) Weigh the sample and record the mass on the datasheet.

(5) Calculate the deformation (DL) corresponding to 15% strain (e).

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

Where L0 = Original specimen length (as measured in step 3).

(6) Carefully place the specimen in the compression device and center it on the bottom plate. Adjust the device so that the upper plate just makes contact with the specimen and set the load and deformation dials to zero.

(7) Apply the load so that the device produces an axial strain at a rate of 0.5% to 2.0% per minute, and then record the load and deformation dial readings on the data sheet at every 20 to 50 divisions on deformation the dial.

(8) Keep applying the load until (1) the load (load dial) decreases on the specimen significantly, (2) the load holds constant for at least four deformation dial readings, or (3) the deformation is significantly past the 15% strain that was determined in step5.

(9) Draw a sketch to depict the sample failure.

(10) Remove the sample from the compression device and obtain a sample for water content determination. Determine the water content as in Experiment1.

Analysis

(1) Convert the dial readings to the appropriate load and length units, and enter these values on the data sheet in the deformation and total load columns. (Confirm that the conversion is done correctly, particularly proving dial gage readings conversion into load)

(2) Compute the sample cross-sectional area

$$A_0 = \frac{\pi}{4} \times (d)^2$$

(3) Compute the strain,

$$e = \frac{?L}{L_0}$$

(4) Compute the corrected area,

$$A' = \frac{A_0}{1-e}$$

(5) Using A‘‘, compute the specimen stress,

$$s_c = \frac{P}{A'}$$

(Be careful with unit conversions and use constant units).

(6) Compute the water content, w%

(7) Plot the stress versus strain. Show q_u as the peak stress (or at 15% strain) of the test. Be sure that the strain is plotted on the abscissa.

(8) Draw Mohr’s circle using q_u from the last step and show the undrained shear strength, s_u = c (or cohesion) =q_u/2.

DATA SHEET

Experiment Name : **Unconfined Compressive Strength Test**
Experiment Date :

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

Visual Classification :

Sample data:
Initial Diameter (d) :
Initial Length (L_0) :
Initial Area (A_0) :

Result:
Unconfined compressive strength (q_u) :
Cohesion(c) :

Course Teacher :
Designation :

Signature

UNCONFINED COMPRESSION TEST DATA SHEET-2

Deformation Reading (A)	Load Reading (B)	Deformation, $\Delta L = A*0.025$ (mm)	Strain, $\varepsilon = \Delta L/L$	% Strain	Corrected Area, A' (m^2)	Load, $L = B*0.01$ (kN)	Stress (KPa)