Properties and Behavior of Soil - Online Lab Manual

PROPERTIES AND BEHAVIOR OF SOIL - ONLINE LAB MANUAL

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The following browsers are best to use for Pressbooks:

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- Chrome
- Safari
- Edge

ABOUT THE PRINT VERSION

This publication was designed to work best online and features a number of hyperlinks in the text. We have retained the blue font for hyperlinks in the print version to make it easier to find the URL in the "Links by Chapter" section at the back of the book.

CONTACT US

Information about open education at UTA is available online. If you are an instructor who is using this OER for a course, please let us know by filling out our OER Adoption Form. Contact us at oer@uta.edu for other inquires related to UTA Libraries publishing services.

ABOUT THIS PROJECT

OVERVIEW

This OER is funded by the Department of Civil Engineering to facilitate the students of the junior-level lab in soil mechanics course CE 3143. The students undergo through difficulties in finding proper theoretical background of the experiments of soil mechanics. They were supposed to purchase textbooks and print handouts which cost them time and money. Although free resources are available on the internet, those are not comprehensive and well organized. Most of them are inappropriate in respect to our lab facility. This online manual helps students to understand both the theory and the experiment demonstration simultaneously. Comprehensive lab manual related to UTA facility, exceptional visual and audio description made this OER self explanatory.

CREATION PROCESS

Dr. MD Sahadat Hossain, professor of Civil Engineering Department created a team in Fall 2020 for this OER. During the COVID-19 pandemic, he felt the necessity of an online lab manual that will help distance learning. MD Azijul Islam, Faria Fahim Badhon and Tanvir Imtiaz, who taught the course CE 3143 in several semesters were assigned to write the materials, record and edit the videos. After extensive review by professional editors the OER was published in Pressbook with embedded videos in Spring 2021.

ABOUT THE AUTHOR

Dr. Sahadat Hossain, Ph.D., P.E. is a Professor of Civil Engineering Department and Director of Solid Waste Institute for Sustainability (SWIS) at the University of Texas at Arlington. Dr. Hossain has more than 25 (twenty-five) years of professional and research experience in geotechnical and geo-environmental engineering. Dr. Hossain's research experience includes slope stability analysis, innovative slope stabilization techniques, assessment of geo-hazard potential, and recycled aggregate materials for base and sub-base applications, pavement crack mitigation, and sustainable waste management.

Mr. Md Azijul Islam is a Ph.D. candidate at the University of Texas at Arlington. Mr. Azijul has more than 5 (five) years of professional, teaching and research experience in geotechnical and geo-environmental engineering. His research interests include ground improvement, foundation engineering, pavement materials, slope stability analysis and landslide prevention, and disaster management.

Faria Fahim Badhon is a Ph.D. candidate in the Civil Engineering Department at the University of Texas at Arlington. She has more than 5 (five) years of professional experience in geotechnical and geo-environmental engineering. She has extensive research experience on bioengineering of slope stabilization techniques. As a Ph.D. student, Ms. Faria is now working on improving the bearing capacity of weak foundation soil using recycled plastic pins.

Tanvir Imtiaz is a Ph.D. candidate at the University of Texas at Arlington. He has been working as teaching and research assistant in the Civil Engineering Department of The University of Texas at Arlington since 2018. His research interest is in recycled pavement materials, microstructure analysis of recycled materials and reusing recycled plastic in pavement construction.

ACKNOWLEDGMENTS

AUTHOR'S NOTE

Dr. Sahadat Hossain is a Professor of Civil Engineering Department and Director of Solid Waste Institute for Sustainability (SWIS) at the University of Texas at Arlington. Dr. Hossain has more than 25 (twenty-five) years of professional and research experience in geotechnical and geo-environmental engineering. Dr. Hossain's research experience includes slope stability analysis, innovative slope stabilization techniques, assessment of geo-hazard potential, and recycled aggregate materials for base and sub-base applications, pavement crack mitigation, and sustainable waste management. One of his most recent successfully implemented projects is slope stabilization with Recycled Plastic Pins (RPP), which is a major signature project in Texas. He also worked on more than 150 (One Hundred and Fifty) geotechnical design and construction projects in Bangladesh, Singapore, Hong Kong, Malaysia, Thailand and USA as a Civil/Geotechnical engineer. His working experiences include foundation analysis and design for building and bridge, excavation support system and retaining structures, cut and cover tunneling, slope stability analysis, design and construction of drilled shaft, contiguous bored pile wall, secant pile wall and diaphragm wall. Dr. Hossain has coauthored two books titled "*Sustainable Slope Stabilization using Recycled Plastic Pins*" and "*Site Investigations by Resistivity Imaging*" published by CRC press. Dr. Hossain received his bachelor's degree from Indian Institute of Technology (IIT), Bombay, India in 1994 and master's degree in Geotechnical Engineering from Asian Institute of Technology (AIT), Bangkok, Thailand in 1997. He received his PhD degree in Geo-Environmental Engineering from North Carolina State University (NCSU) at Raleigh, USA in 2002.

Mr. Md Azijul Islam is a Ph.D. candidate at the University of Texas at Arlington. He completed his B.Sc. and M.Sc. in Civil Engineering from Bangladesh University of Engineering and Technology (BUET). He worked as a lecturer and later as an assistant professor at the Department of Civil Engineering, BUET from 2015 to 2018. Mr. Azijul has more than 5 (five) years of professional, teaching and research experience in geotechnical and geo-environmental engineering. His research interests include ground improvement, foundation engineering, pavement materials, slope stability analysis and landslide prevention, and disaster management. Mr. Azijul has published in journals and conference proceedings. He has been serving as a reviewer in reputed international journals. He was awarded "Outstanding Civil Engineering Ph.D. Student" in recognition of academic excellence in Civil Engineering in 2018-19 and 2019-20 session. He wants to pursue his career in research and teaching profession.

Faria Fahim Badhon is a Ph.D. candidate in the Civil Engineering Department at the University of Texas at Arlington. Faria has completed her Bachelor of Science in Civil Engineering and Master of Science in Civil & Geotechnical Engineering from Bangladesh University of Engineering & Technology (BUET) in 2015 and 2018, respectively. She has more than 5 (five) years of professional experience in geotechnical and geo-environmental engineering. She has extensive research experience on bioengineering of slope stabilization techniques during her M.Sc. thesis. Ms. Faria worked as a lecturer in Presidency University from 2015 to 2016. She worked as an assistant engineer in Bangladesh Water Development Board from 2016 till joining to UTA. As a Ph.D. student, Ms. Faria is now working on improving the bearing capacity of weak foundation soil using recycled plastic pins. She was awarded "Outstanding Civil Engineering Ph.D. Student" in recognition of academic excellence in Civil Engineering in 2019-20 session.

Tanvir Imtiaz is a Ph.D. candidate at the University of Texas at Arlington. Tanvir received his Bachelor of Science degree from Bangladesh University of Engineering & Technology (BUET), Dhaka, Bangladesh in 2017. He has been working as teaching and research assistant in the Civil Engineering Department of The University of Texas at Arlington since 2018. His research interest is in recycled pavement materials, microstructure analysis of recycled materials and reusing recycled plastic in pavement construction. Mr. Tanvir has published in different international journals and conferences. He was awarded "Outstanding Civil Engineering Ph.D. Student" in recognition of academic excellence in Civil Engineering in 2018-19 session. He also received 1st price in National Outreach and Engagement Photo Contest Organized by Geo-Institute of ASCE.

The Department of Civil Engineering is fully committed to accommodate all students with online instructions with different modalities during COVID 19 and beyond. This Laboratory Manual is the state-of-the-art online instructional manual for "Properties and Behavior of Soil" published by MAV Open Press.

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CHAPTER 1.

DETERMINATION OF MOISTURE CONTENT

INTRODUCTION

The moisture content of soil also referred to as water content, is an indicator of the amount of water present in soil. Moisture content is the ratio of the mass of water contained in the pore spaces of soil to the solid mass of particles in that material, expressed as a percentage. A standard temperature of 110 ± 5°C is used to determine the mass of the sample.

PRACTICAL APPLICATION

- Almost all soil tests determine the natural moisture content of the soil, and it is essential knowledge for all studies of soil mechanics. The natural moisture content provides an idea of the state of the soil in the field.
- Moisture content is one of the most important index properties used for the correlation of soil behavior and its index properties.
- The moisture content of the soil is used to express the phase relationships of water, air, and solids in a given volume or weight of the material.
- For cohesive soil, the consistency of a given soil, along with its liquid and plastic limits is used to express its relative consistency.

OBJECTIVE

The objective of this experiment is

- To determine the moisture content of the given soil sample

STANDARD REFERENCE

- ASTM D2216: Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass.

EQUIPMENT

- Non-corrodible container,
- Vented, thermostatically controlled drying oven that maintains temperatures between 105°C to 115°C.
- Balance of sufficient sensitivity (sensitive to 0.01 g),
- Container handling apparatus.

METHOD

1. Clean, dry and weigh $W_1$the container (Figure 1.1). The balance needs to be tarred before it is used to measure the weight.

Figure 1.1: Taring the balance

2. Weigh W_2 a sample of the specimen in the container.

Figure 1.2: Labeled container

3. Keep the container in the oven for 24 hours. Dry the specimen to a constant weight, maintaining the temperature between 105°C to 115°C. (The time will vary with the type of soil, but 16 to 24 hours is usually sufficient.)

Figure 1.3: Soil sample in the container

4. Record the final constant weight W_3 of the container with the dried soil sample. Peat and other organic soils should be dried at a lower temperature (approximately 60°C) for a longer period of time

Figure 1.4: Keeping of the soil samples in an oven

VIDEO MATERIALS

LECTURE VIDEO

A PowerPoint presentation is created to understand the background and method of this experiment.

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://uta.pressbooks.pub/soilmechanics/?p=5#oembed-1

DEMONSTRATION VIDEO

A short video is executed to demonstrate the experiment procedure and sample calculation.

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://uta.pressbooks.pub/soilmechanics/?p=5#oembed-2

RESULTS AND DISCUSSIONS

SAMPLE DATASHEET

Sample No.	1	2	3
Can No:	#1	#2	#3
Weight of can, W_1	23.51	16.32	19.88
Weight of can + wet soil, W_2	165.21	149.77	158.23
Weight of can + dry soil, W_3	145.65	134.32	137.55

SAMPLE CALCULATION

Can No: 1
Weight of can = 23.51 gm
Weight of can + wet soil = 165.21 gm
Weight of can + dry soil = 145.65 gm
Weight of water in the soil sample, M_w= (165.21 – 145.65) = 19.56 gm
Weight of the dry soil. M_s= (145.65 – 23.51) =122.14 gm
Moisture content of the given soil sample = $M_w/M_s \times 100\%$
= 19.56/122.14×100%
= 16.01%

BLANK DATASHEET

Sample No.			
Can No:			
Weight of can, W_1			
Weight of can + wet soil, W_2			
Weight of can + dry soil, W_3			
Water/Moisture content, W (%)			

REPORT

Use the template provided to prepare your lab report for this experiment. Your report should include the following:

- Objective of the test
- Applications of the test
- Apparatus used
- Test procedures (optional)
- Analysis of test results – Complete the table provided and show one sample calculation
- Summary and conclusions – Comment on the moisture content of the given soil sample

CHAPTER 2.

SPECIFIC GRAVITY TEST

INTRODUCTION

The specific gravity (G_s)of a material is the ratio of the mass of a unit volume of soil solids at a specific temperature to the mass of an equal volume of gas-free distilled water at the same temperature. The specific gravity of soil is usually reported at 20°C.

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

PRACTICAL APPLICATION

- 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 flask (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
- Drying oven

METHOD

1. Clean and dry the volumetric flask.
2. Carefully fill the flask with de-aired, distilled water up to the 500 ml mark (The bottom of the meniscus should be at the 500 ml mark).

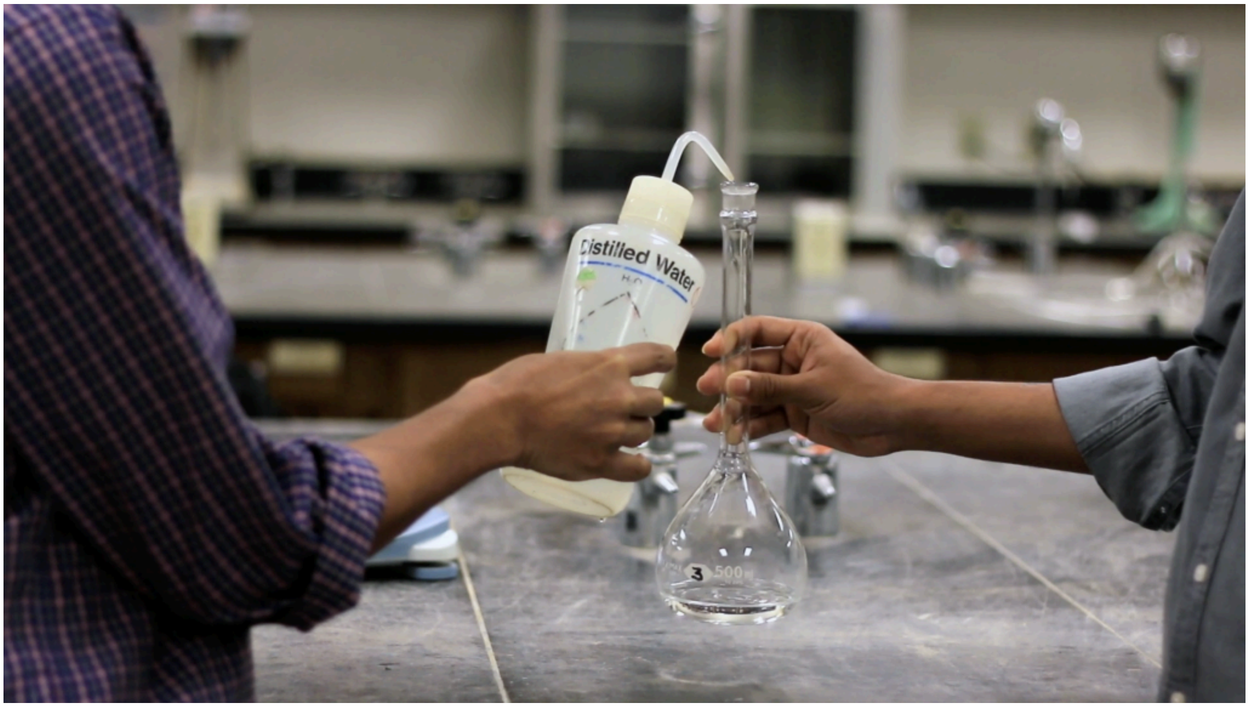

Figure 2.1: Fill the flask with distilled water

3. Measure the mass of the flask and the water W_1.

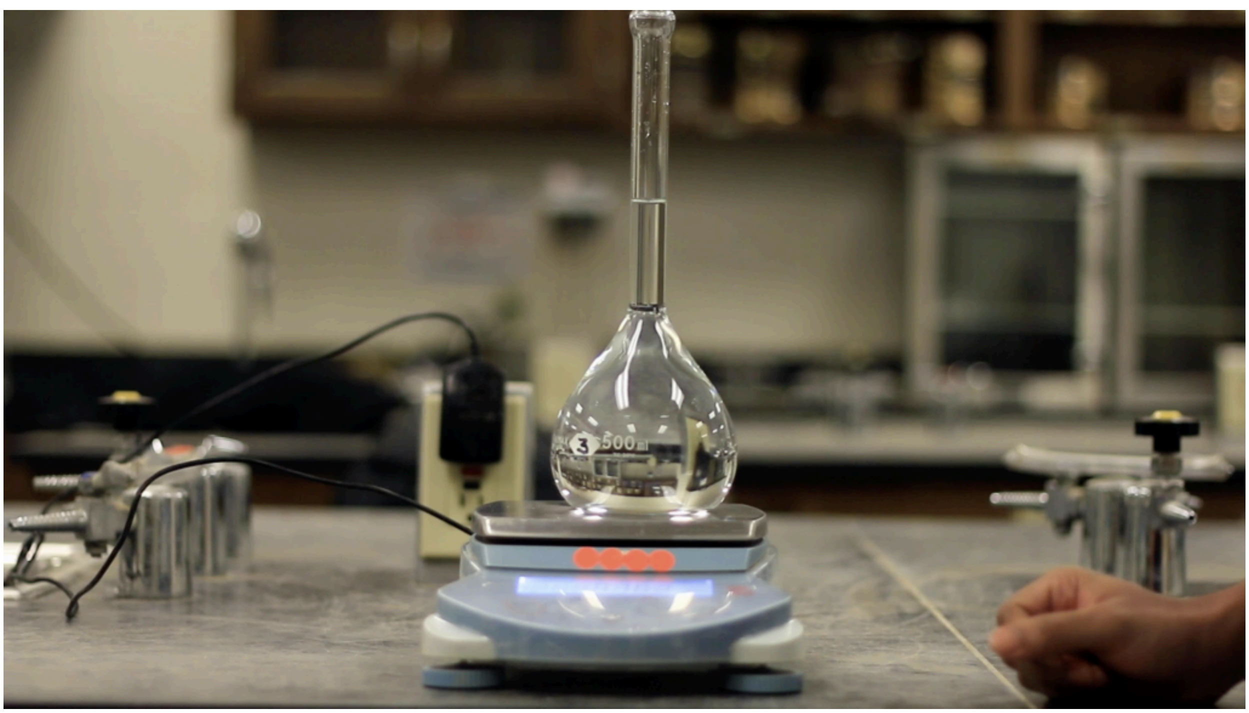

Figure 2.2: Measuring the weight of pycnometer filled with water

4. Insert the thermometer into the flask with the water to determine the water's temperature ($T = T_1$°C.)

Figure 2.3: Temperature of the water during the test

5. Put approximately 100 grams of air-dried soil into an evaporating dish.

Figure 2.4: Weighing the soil samples

6. For cohesive soil, add de-aired and distilled water to the soil and mix it until it forms a smooth paste. Soak it for one-half to one hour in the evaporating dish. (This step is not necessary for granular, i.e., non-cohesive soils.)

7. Transfer the soil (if granular) or the soil paste (if cohesive) into the volumetric flask.

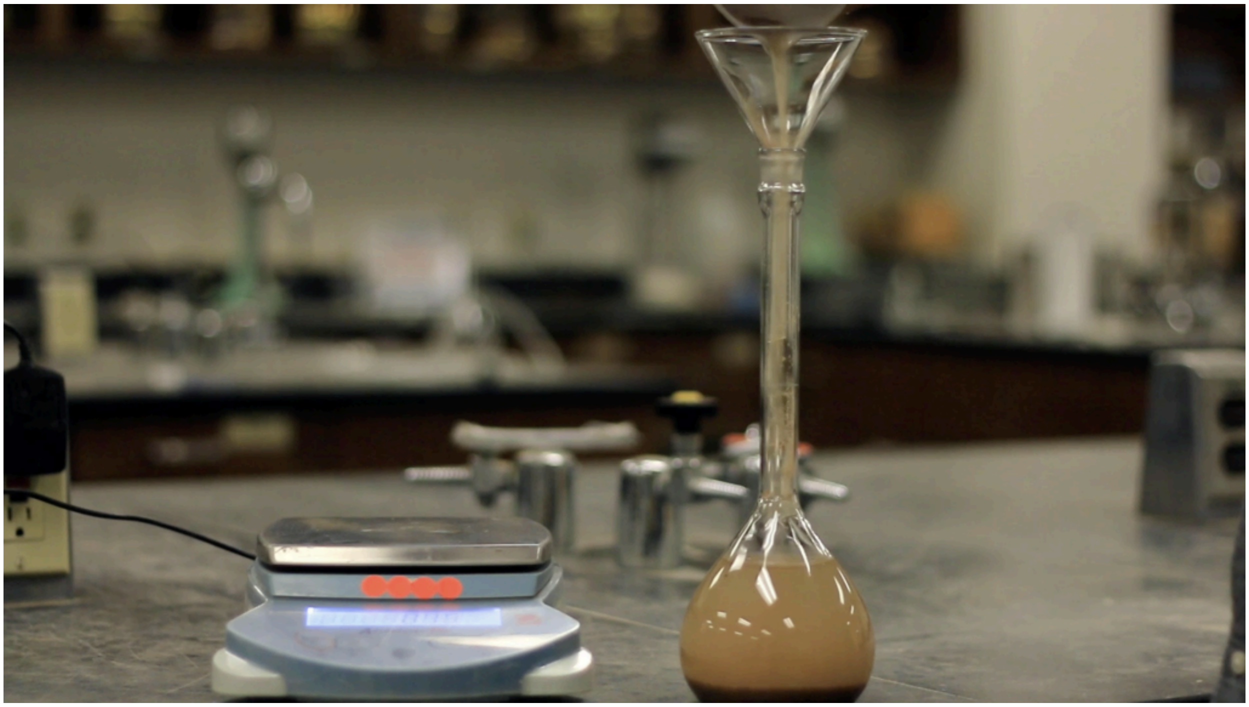

Figure 2.5: Placing the sample in a pycnometer

8. Add distilled water to the volumetric flask containing the soil or soil paste until it is about two-thirds full.

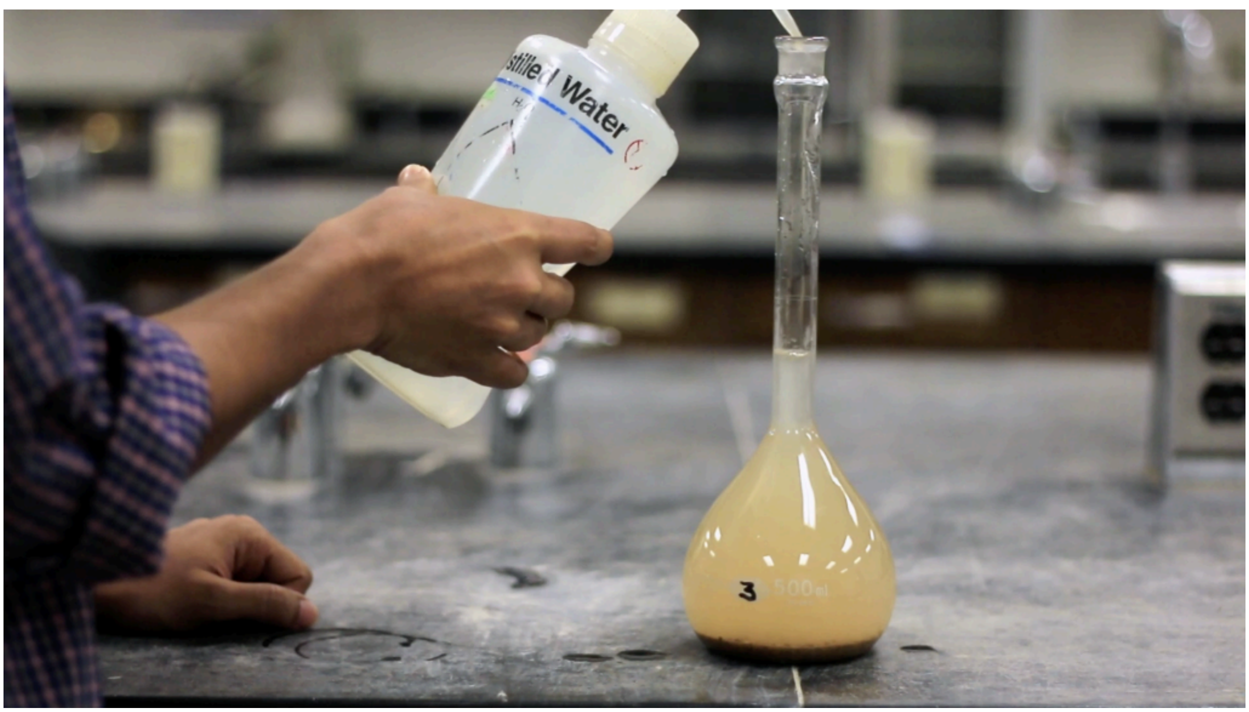

Figure 2.6: Filling the rest of the pycnometer with water

9. Remove the air from the soil-water mixture by applying a vacuum pump or an aspirator until all of the entrapped air has been removed. Notice that this is an extremely important step, as most errors in the results of the test are due to entrapped air that has not been removed.

10. 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.
11. Determine the combined mass of the bottle plus soil plus water (W_2).

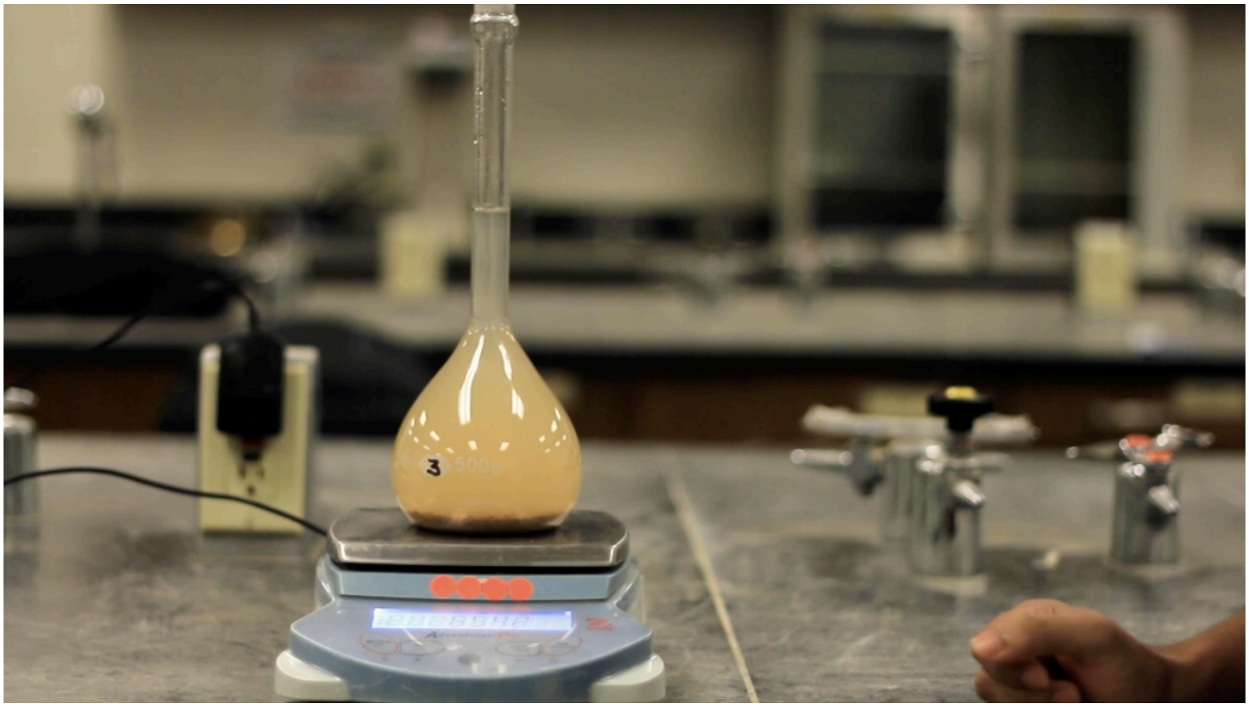

Figure 2.6: Taking the final weight of pycnometer filled with water and soil sample (after theapplication of vacuum)

12. 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.
13. Put the evaporating dish into an oven to dry it to a constant weight.
14. Determine the mass of the dry soil in the evaporating dish (W_s).

VIDEO MATERIALS

LECTURE VIDEO

A PowerPoint presentation is created to understand the background and method of this experiment.

> One or more interactive elements has been excluded from this version of the text. You can view them online here: https://uta.pressbooks.pub/soilmechanics/?p=55#oembed-1

DEMONSTRATION VIDEO

A short video is executed to demonstrate the experiment procedure and sample calculation.

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RESULTS AND DISCUSSIONS

SAMPLE DATA SHEET

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(^{o}C)	23	24	23.5
Temperature correction factor, A (from table)			
Specific gravity, G_s			

SAMPLE CALCULATION

For Sample no. 1,

Mass of flask + water filled to mark, W_1(g)=683 gm
Mass of flask + soil + water filled to mark, W_2(g)= 745.1 gm
Mass of dry soil, W_s(g)=100 gm
Water Temperature, T_1(°C)= 23°C
Temperature Correction Factor, A (from Table)=0.9993
Specific Gravity, $G_s = \dfrac{W_s}{W_1 + W_s - W_2} \times A = 2.64$

BLANK DATE SHEET

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(^{o}C)			
Temperature Correction Factor, A (from Table)			
Specific Gravity, G_s			

REPORT

Use the template provided to prepare your lab report for this experiment. Your report should include the following:

- Objective of the test
- Applications of the test
- Apparatus used
- Test procedures (optional)
- Analysis of test results – Complete the table provided and show one sample calculation
- Summary and conclusions – Comment on the specific gravity of the given soil sample
- Average specific gravity at 20°C should be reported to the nearest 0.01.

CHAPTER 3.

SIEVE ANALYSIS

INTRODUCTION

The grain size analysis test is performed to determine the percentage of each size of grain that is contained within a soil sample, and the results of the test can be used to produce the grain size distribution curve. This information is used to classify the soil and to predict its behavior. The two methods generally used to find the grain size distribution are:

- Sieve analysis which is used for particle sizes larger than 0.075 mm in diameter and
- Hydrometer analysis which is used for particle sizes smaller than 0.075 mm in diameter

Sieve analysis is a method that is used to determine the grain size distribution of soils that are greater than 0.075 mm in diameter. It is usually performed for sand and gravel but cannot be used as the sole method for determining the grain size distribution of finer soil. The sieves used in this method are made of woven wires with square openings. The list of the U.S. standard sieve numbers with their corresponding opening sizes are provided in Table 3.1.

Table 3.1: U.S. Sieve Size

Sieve No.	Opening (mm)	Sieve No.	Opening (mm)
4	4.75	35	0.500
5	4.00	40	0.425
6	3.35	45	0.355
7	2.80	50	0.300
8	2.36	60	0.250
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

PRACTICAL APPLICATION

- This test method is used primarily to grade aggregates. The results are used to determine the compliance of the particle size distribution with applicable specification requirements and to provide necessary data for controlling the production of various aggregate products and mixtures containing aggregates.

- The data may also be useful in developing relationships concerning porosity and packing. Information obtained from the particle size analysis (uniformity coefficient C_u, coefficient of curvature, C_c, and effective size, D_{10}, etc.) is used to classify the soil.
- Particle size is one of the criteria used to ascertain whether the soil is suitable for building roads, embankments, dams, etc.
- Information obtained from particle size analysis can be used to predict the soil-water movement if the permeability test is not available.

OBJECTIVE

- To obtain the grain size distribution curve for a given soil sample.

EQUIPMENT

- Stack of sieves with a cover,
- Mortar and pestle or a mechanical soil pulverized
- Balance, sensitive to 0.1 g
- Oven
- Mechanical sieve shaker
- Brush

STANDARD REFERENCE

- ASTM D6913: Standard Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis.

METHOD

1. Obtain a representative oven-dried soil sample.

Figure 3.1: Weighing some representative oven dried samples

Figure 3.2: Washing the sieves before the test

2. Pulverize the soil sample as finely as possible, using a mortar and pestle or a mechanical soil pulverizer.
3. Obtain a soil sample of about 500 g and determine its mass W_0 (g).
4. Stack the sieves so that those with larger openings (lower numbers) are placed above those with smaller openings (higher numbers). Place a pan under the last sieve (#200) to collect the portion of soil passing through it. The #4 and #200 sieves should always be included in the

stack.

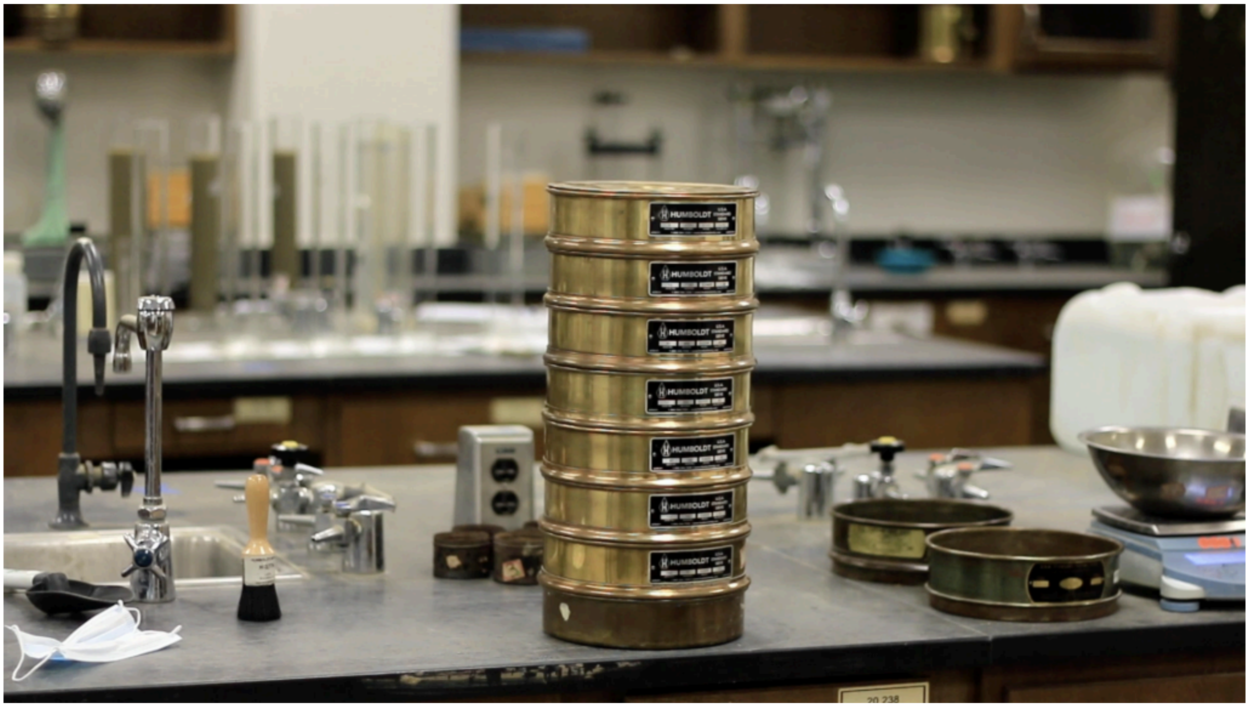

Figure 3.3: Stack of sieve in order

5. Make sure the sieves are clean, If soil particles are stuck in the openings, use a brush to poke them out.

Figure 3.4: Pouring the soil sample at the top of the sieves

6. Weigh the pan and all of the sieves separately.

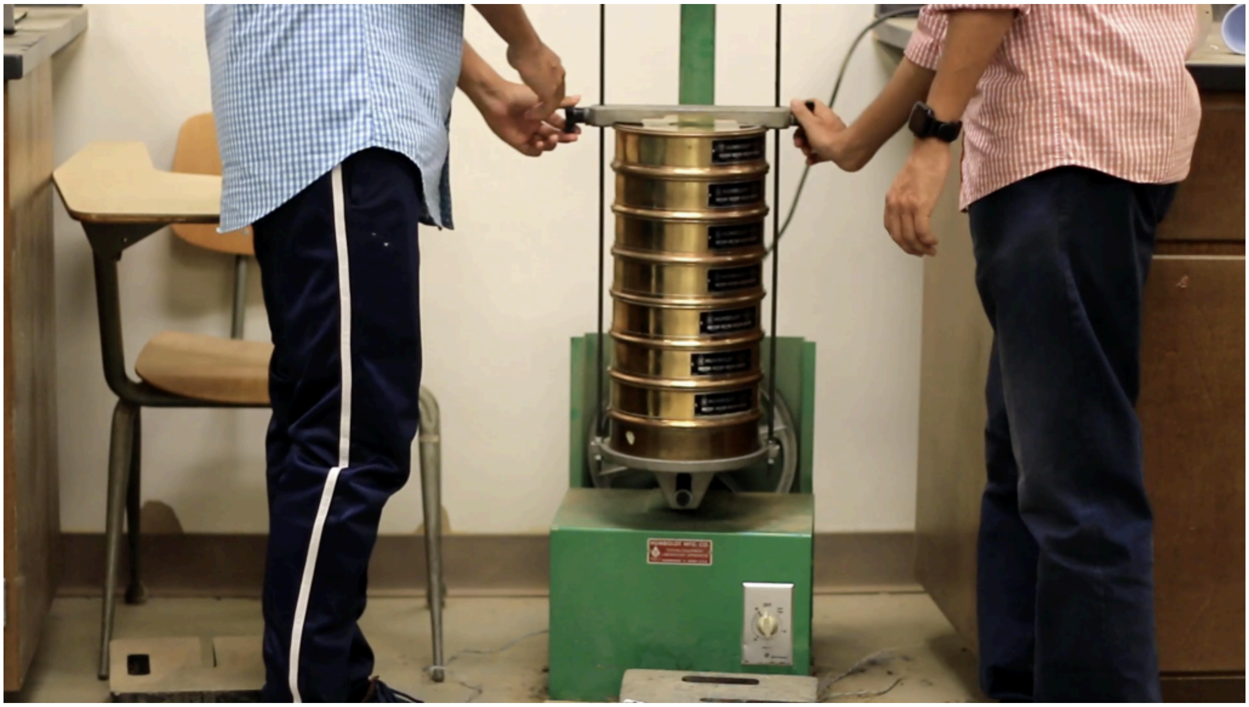

Figure 3.5: Sieve shaker

7. Pour the soil from above into the stack of sieves and place the cover on it. Put the stack in the sieve shaker, affix the clamps, set a timer for 10 to 15 minutes, and start the shaker.

Figure 3.6: Weighing of each sieve after shaking

8. Stop the sieve shaker and measure the mass of each sieve and retained soil.

VIDEO MATERIALS

LECTURE VIDEO

A PowerPoint presentation is created to understand the background and method of this experiment.

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DEMONSTRATION VIDEO

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RESULTS AND DISCUSSIONS

Sample Data Sheet

Sieve No	Opening (mm)	Sieve Wt. (gm)	Sieve + Soil Wt. (gm)	Wt. of soil retained (gm)	Percent retained	Cumulative percent retained	Percent finer
4	4.75	521	521	0	0	0	100
8	2.36	491.8	504	12.2	4.07	4.07	95.93
16	1.18	426	450.5	24.5	8.17	12.24	87.76
30	0.60	401.8	490	88.2	29.4	41.64	58.36
50	0.297	375.5	478	102.5	34.17	75.81	24.19
100	0.149	355.3	410	54.7	18.23	94.04	5.96
200	0.075	351.1	368.2	17.1	5.7	99.74	0.26
Pan	-	364.2	365	0.8	-	-	-

Sample Calculation

For #8 sieve,
Sieve weight = 491.8 gm
Sieve + soil weight = 504 gm
Weight of soil retained = (504 – 491.8) = 12.2 gm
Percent retained= $2.2/300 × 100 = 4.07%
Cumulative percent retained= 0 + 4.07 = 4.07%
Percent finer= 100 – 4.07= 95.93%

The grain-size distribution of the soil sample can be obtained by plotting the percent finer with the corresponding sieve on semi-log graph paper, as shown below. An example of the grain-size distribution curve is shown in Figure 3.7.

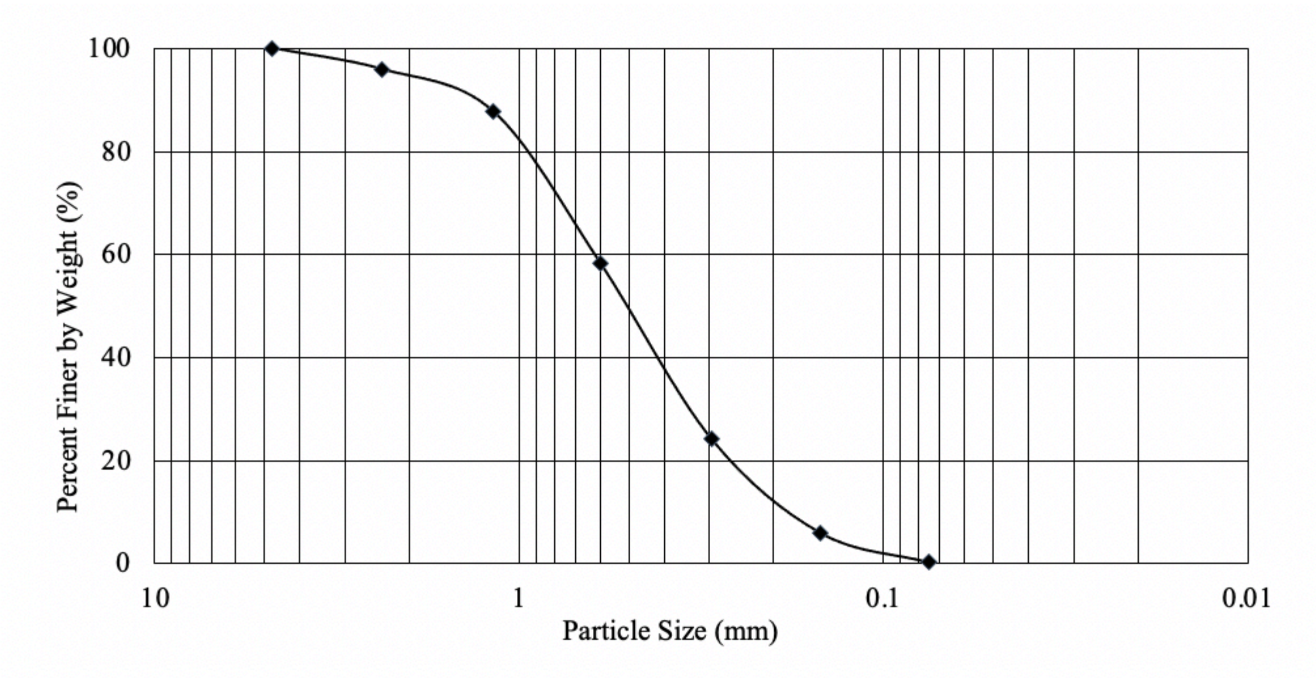

Figure 3.7: Particle size distribution curve

he values of D_{10}, D_{30}, and D_{60}, which are the diameters that correspond to the percentfiner of 10%, 30%, and 60%, respectively can be determined from the grain-size distributioncurve. The values of the uniformity coefficient C_u and the coefficient of gradation C_c can be calculated using the following equations:

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

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

The values of C_u and C_c are used to classify whether the soil is well-graded or not. Sand isconsidered well-graded, if C_u is greater than 6 and C_c is between 1 and 3. For gravel to be considered as well-graded, C_u should be greater than 4 and C_c should be between 1 and 3.

From Figure 3.5,

D_{10}= 0.18, D_{30}= 0.35, and D_{60}= 0.61

Uniformity coefficent, C_u=D_{60}/D_{10}=0.61/0.18=3.39

Coefficent of gradation, C_c= ($D^2{}_{30}$)/(D_{60}×D_{10})=$(0.35)^2$/(0.61×0.18) =1.12

Blank Data Sheet

Sieve No	Opening (mm)	Sieve Wt. (gm)	Sieve + Soil Wt. (gm)	Wt. of soil retained (gm)	Percent retained	Cumulative percent retained	Percent finer
4	4.75						
8	2.36						
16	1.18						
30	0.60						
50	0.297						
100	0.149						
200	0.075						
Pan	-						

REPORT

Use the template provided to prepare your lab report for this experiment. Your report should include the following:

- Objective of the test
- Applications of the test
- Apparatus used
- Test procedures (optional)
- Analysis of test results – Complete the table provided and show one sample calculation. Draw the grain size distribution curve. Calculate C_u and C_c
- Summary and conclusions – Comment on the shape of the grain size distribution curve of the given soil sample. Comment on whether the soil is well graded or poorly graded.

CHAPTER 4.

HYDROMETER ANALYSIS

INTRODUCTION

The particle size distribution of soil containing a significant number of finer particles (silt and clay) cannot be performed by sieve analysis. The hydrometer analysis is a widely used method of obtaining an estimate of the distribution of soil particle sizes from the #200 (0.075 mm) sieve to around 0.001 mm. The data are plotted on a semi-log plot of percent finer versus grain diameters to represent the particle size distribution. Both sieve analysis and hydrometer analysis are required to obtain the complete gradation curve of the coarse and fine fraction of many natural soils.

PRACTICAL APPLICATION

- Hydrometer analysis is essential for obtaining the complete particle size distribution of such soils. Particle size distribution obtained from sieve analysis may be combined with the data from a hydrometer analysis to produce a complete gradation curve. It is possible to approximate the percentage of silt and clay particles present in the finer portion from the hydrometer analysis.
- Particle size is one of the criteria used to determine whether a soil is suitable for building roads, embankments, dams, etc.
- Information obtained from a particle size analysis can be used to predict soil-water movement if a permeability test is not available.

OBJECTIVE

The objective of this experiment is:

- To determine the particle size distribution of fine-grained soil (smaller than 0.075 mm diameter grains), using a hydrometer.

EQUIPMENT

- Balance
- Mixer (blender)
- Hydrometer (152H model preferably,
- Sedimentation cylinder (1000 mL cylinder)
- Graduated 1000 mL cylinder for control jar
- Dispersing agent [sodium hexametaphosphate ($NaPO_3$) or sodium silicate ($NaSiO_3$)]

- Control cylinder
- Thermometer
- Beaker
- Timing device

STANDARD REFERENCE

- ASTM D7928: Standard Test Method for Particle-Size Distribution (Gradation) of Fine-Grained Soils Using the Sedimentation (Hydrometer) Analysis

METHOD

- Place 50 g of fine soil in a beaker, add 125 mL of the dispersing agent (sodium hexametaphosphate [40 g/L] solution) and stir the mixture until the soil is thoroughly wet. Let the soil soak for at least ten minutes.

Figure 4.1: Adding sodium hexametaphosphate solution

- While the soil is soaking, add 125 mL of the dispersing agent to the control cylinder and fill it to the mark with distilled water. (The reading at the top of the meniscus formed by the hydrometer stem and the control solution is called the zero connection.) Record a reading less than zero as a negative (-) correction and a reading between zero and sixty as a positive (+) 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 to mix the contents thoroughly. Insert the hydrometer and thermometer into the control cylinder and note the zero correction and temperature, respectively.

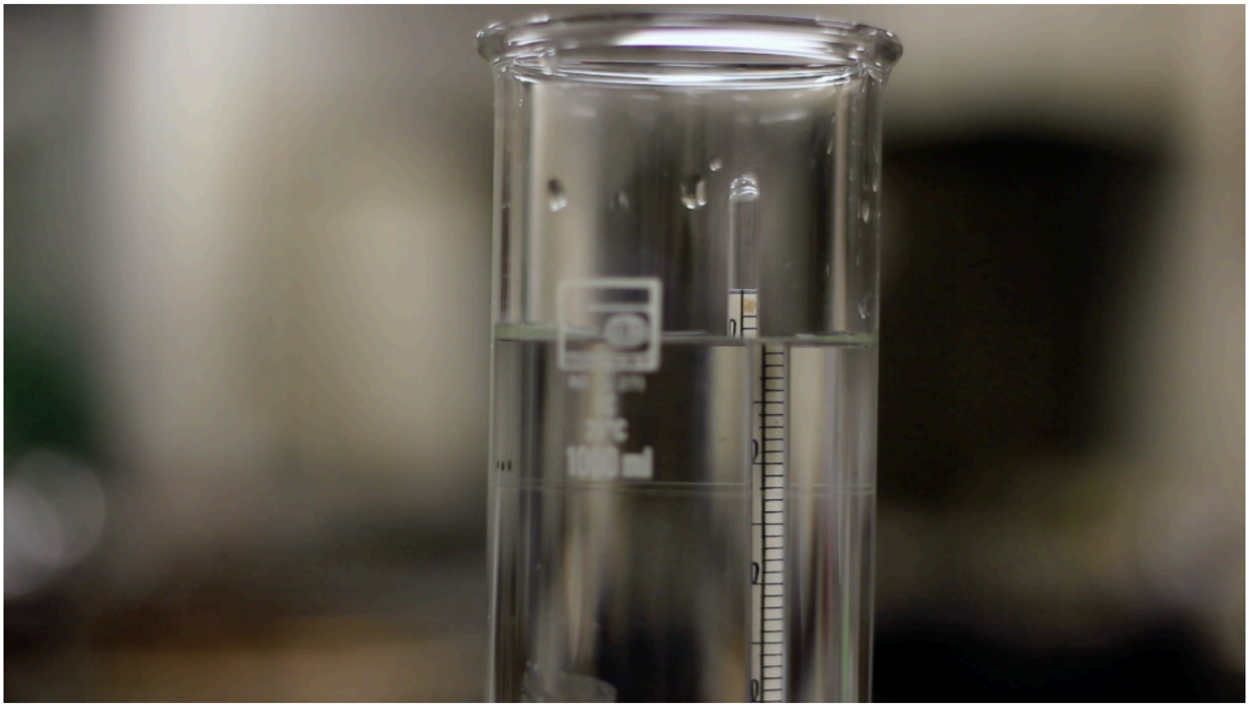

Figure 4.2: Taking zero and meniscuscorrection reading

- Transfer the soil slurry to a mixer by adding more distilled water, if necessary, until the mixing cup is at least half full. Then mix the solution for two minutes.

Figure 4.3: Soil slurry preparation using a mixer

- Immediately transfer the soil slurry into the empty sedimentation cylinder and add distilled water up to the mark.
- Cover the open end of the cylinder with a stopper and secure it with the palm of your hand. Alternate turning the cylinder upside down and back upright for one minute, inverting it

approximately 30 times.

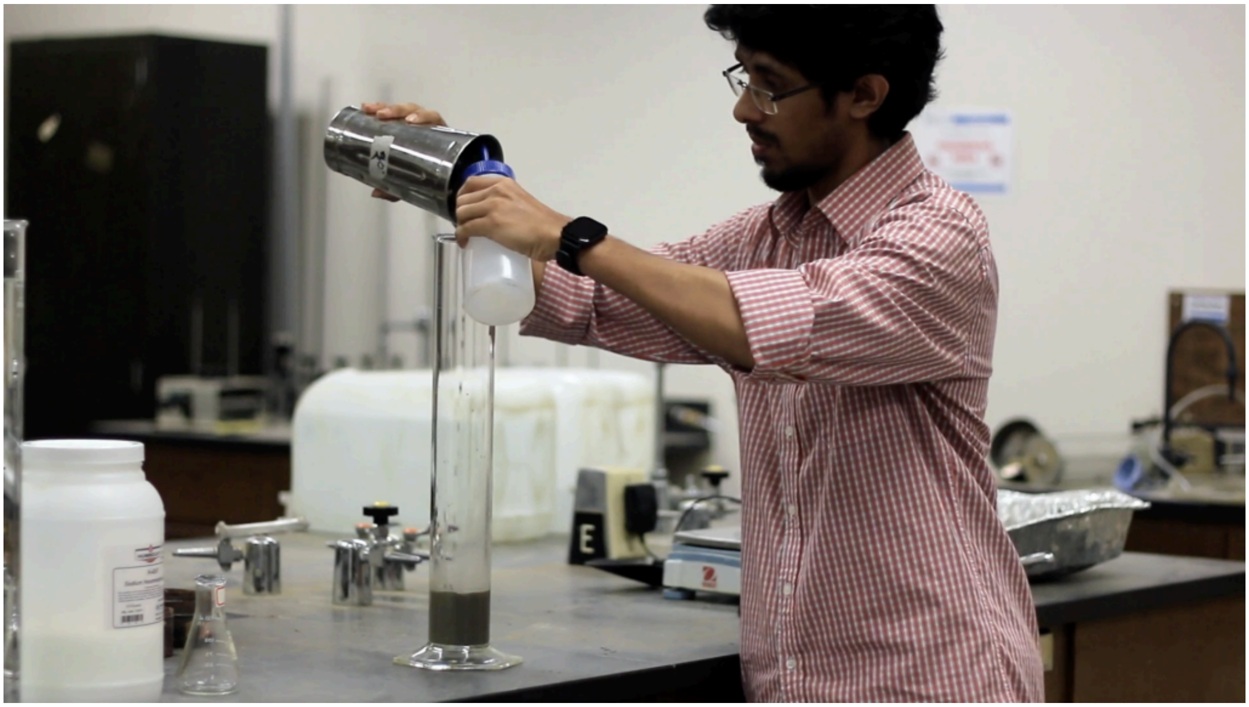

Figure 4.4: Pouring the soil sample into the sedimentation cylinder

- Set the cylinder down and record the time. Remove the stopper from the cylinder, and 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.)

Figure 4.5: Sedimentation cylinder and control cylinder during the hydrometer reading

- Take the reading by observing the top of the meniscus that was formed by the suspension and the hydrometer stem. Remove the hydrometer slowly and place it back into the control cylinder. Very gently spin it in the control cylinder to remove any particles that may have adhered to it.
- Take hydrometer readings at 15 sec, 30 sec, 1 min, 2 min, 4 min, 8 min, 15 min, 30 min, 1 hr., 2 hrs., 4 hrs., 8 hrs., 16 hrs., 24 hrs., and 48 hrs. These are approximate times that will usually give a satisfactory plot spread.
- Record the temperature of the soil-water suspension to the nearest 0.5°C for each hydrometer reading.

DATA ANALYSIS

- Apply the meniscus correction to the actual hydrometer reading.
- Obtain the effective hydrometer depth (L in cm) for the corrected meniscus reading from Table 4-1.
- Obtain the value of K from Table 4-2 if the G_s of the soil is known. If it is not known, assume that it is 2.65 for this purpose.
- Calculate the equivalent particle diameter by using the following formula:
  $$D = K \times \sqrt{\frac{L}{t}}$$
  Where t is given in minutes, and D is given in mm.
- Determine the temperature correction C_T from Table 4-3.
- Determine correction factor "a" from Table 4-4 using G_s.
- Calculate the corrected hydrometer reading as follows:
  $R_c = R_{ACTUAL} -$ Zero Correction $+ C_T$
- Calculate the percent finer as follows:
  $$P = \frac{R_c \times a}{W_s} \times 100$$
  Where, W_S is the weight of the soil sample in grams.
- Adjuste the percent fines as follows:
  $$P_A = \frac{P \times F_{200}}{100}$$
  Where, F_{200}= % finer of #200 sieve as a percent
- Plot the grain size curve D versus the adjusted percent finer on the semilogarithmic sheet.

VIDEO MATERIALS

LECTURE VIDEO

A PowerPoint presentation is created to understand the background and method of this experiment.

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://uta.pressbooks.pub/soilmechanics/?p=186#oembed-1

DEMONSTRATION VIDEO

A short video is executed to demonstrate the experiment procedure and sample calculation.

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://uta.pressbooks.pub/soilmechanics/?p=186#oembed-2

RESULTS AND DISCUSSIONS

Sample Data Sheet

Test date: September 15, 2002
Hydrometer Number: 152H
Specific Gravity of Soil: 2.56
% finer of #200 sieve as a percent, F_{200}= 43.9%
Dispersing Agent: Sodium Hexametaphosphate
Weight of Soil Sample: 50.0 gm
Zero Correction: +6
Meniscus Correction: +1
Table 4.1: Values of effective depth based on hydrometer and sedimentation cylinder of specific sizes
For Hydrometer 151H

Corrected Hydrometer Reading	Effective Depth, L (cm)	Corrected Hydrometer Reading	Effective Depth, L (cm)
1.000	16.3	1.020	11.0
1.001	16.0	1.021	10.7
1.002	15.8	1.022	10.5
1.003	15.5	1.023	10.2
1.004	15.2	1.024	10.0
1.005	15.0	1.025	9.7
1.006	14.7	1.026	9.4
1.007	14.4	1.027	9.2
1.008	14.2	1.028	8.9
1.009	13.9	1.029	8.6
1.010	13.7	1.030	8.4
1.011	13.4	1.031	8.1
1.012	13.1	1.032	7.8
1.013	12.9	1.033	7.6
1.014	12.6	1.034	7.3
1.015	12.3	1.035	7.0
1.016	12.1	1.036	6.8
1.017	11.8	1.037	6.5
1.018	11.5	1.038	6.2
1.019	11.3	1.039	5.9

For Hydrometer 152H

Corrected Hydrometer Reading	Effective Depth, L (cm)	Corrected Hydrometer Reading	Effective Depth, L (cm)
0	16.3	31	11.2
1	16.1	32	11.1
2	16.0	33	10.9
3	15.8	34	10.7
4	15.6	35	10.6
5	15.5	36	10.4
6	15.3	37	10.2
7	15.2	38	10.1
8	15.0	39	9.9
9	14.8	40	9.7
10	14.7	41	9.6
11	14.5	42	9.4
12	14.3	43	9.2
13	14.2	44	9.1
14	14.0	45	8.9
15	13.8	46	8.8
16	13.7	47	8.6
17	13.5	48	8.4
18	13.3	49	8.3
19	13.2	50	8.1
20	13.0	51	7.9
21	12.9	52	7.8
22	12.7	53	7.6
23	12.5	54	7.4
24	12.4	55	7.3
25	12.2	56	7.1
26	12.0	57	7.0
27	11.9	58	6.8
28	11.7	59	6.6
29	11.5	60	6.5
30	11.4		

Table 4.2: Values of k for computing diameter of particle in hydrometer analysis

Temperature	Specific Gravity of Soil Particles								
	2.45	2.5	2.55	2.6	2.65	2.7	2.75	2.8	2.85
16	0.0151	0.01505	0.01481	0.01457	0.01435	0.01414	0.01394	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	0.0129	0.01269	0.01249	0.0123	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

Temperature (C)	factor (CT)
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

Unit Weight of Soil Solids, g/cm3	Correction factor, a
2.85	0.96
2.8	0.97
2.75	0.98
2.7	0.99
2.65	1
2.6	1.01
2.55	1.02
2.5	1.04

Sample Data Sheet

Date	Time	Elapsed Time (min)	Temp	Actual Hydr. Rdg. R_a	Hydr. Corr. for Meniscus	L from Table 4.1	K from Table 4.2	D mm	C_T from Table 4.3	a from Table 4.4	Corr. Hydr. Rdg. R_c	% Finer, P	% Adjusted Finer, P_A
15-Sep	4:06 PM	0	25	55	56	7.1	0.01326	0	1.3	1.018	-	-	-
	4:07	1	25	47	48	8.4	0.01326	0.03029	1.3	1.018	42.3	86.1	37.8
	4:08	2	25	42	43	9.2	0.01326	0.02844	1.3	1.018	37.3	75.9	33.3
	4:10	4	25	40	41	9.6	0.01326	0.02054	1.3	1.018	35.3	71.9	31.6
	4:14	8	25	37	38	10.1	0.01326	0.01490	1.3	1.018	32.3	65.8	28.6
	4:22	16	25	32	33	10.9	0.01326	0.01094	1.3	1.018	27.3	55.6	24.1
	4:40	34	25	28	29	11.5	0.01326	0.00771	1.3	1.018	23.3	47.4	20.8
	6:22	136	23	22	23	12.5	0.01356	0.00411	0.7	1.018	16.7	34	14.9
16-Sep	5:24 PM	1518	22	15	16	13.7	0.01366	0.00130	0.4	1.018	9.4	19.1	8.4

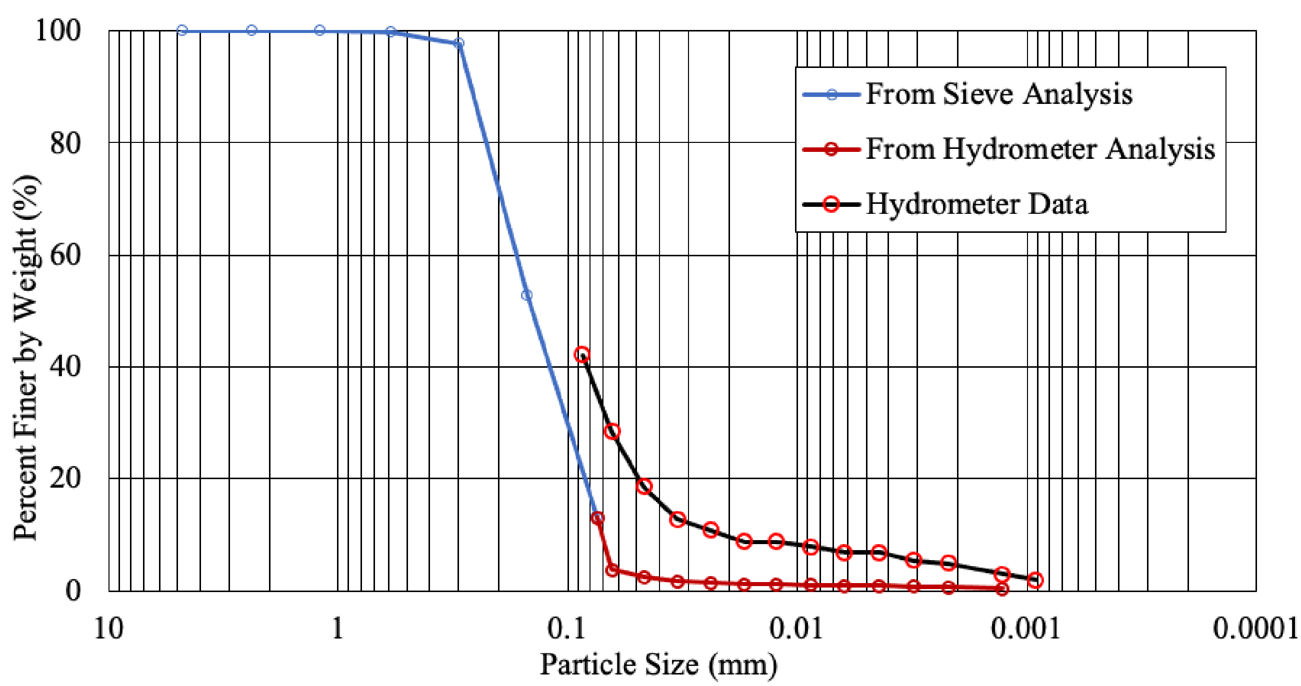

Figure 4.6: A typical grain-size distribution curve (From sieve and hydrometer analysis)

Blank Data Sheet

Test date:
Hydrometer Number:
Specific Gravity of Soil:

% finer of #200 sieve as a percent, F_{200}:
Dispersing Agent:
Weight of Soil Sample:
Zero Correction:
Meniscus Correction:

Date	Time	Elapsed Time (min)	Temp	Actual Hydr. Rdg. R_a	Hydr. Corr. for Meniscus	L from Table 4.1	K from Table 4.2	D mm	C_T from Table 4.3	a from Table 4.4	Corr. Hydr. Rdg. R_c	% Finer, P	% Adjusted Finer, P_A

REPORT

Use the template provided to prepare your lab report for this experiment. Your report should include the following:

- Objective of the test
- Applications of the test
- Apparatus used
- Test procedures (optional)
- Analysis of the test results – Complete the table provided and show one sample calculation. Draw the grain size distribution curve for the data from the hydrometer analysis only and the combined grain-size distribution curve.
- Summary and conclusions – Comment on the shape of grain size distribution curve of the given soil sample

CHAPTER 5.

ATTERBERG LIMIT TEST

INTRODUCTION

The Atterberg limit refers to the liquid limit and plastic limit of soil. These two limits are used internationally for soil identification, classification, and strength correlations. When clay minerals are present in fine-grained soil, the soil can be remolded in the presence of some moisture without crumbling. This cohesiveness is caused by the adsorbed water surrounding the clay particles. At a very low moisture content, soil behaves more like a solid; at a very high moisture content, the soil and water may flow like a liquid. Hence on an arbitrary basis, depending on the moisture content, the behavior of soil can be divided into the four basic states shown in Figure 5-1: solid, semisolid, plastic, and liquid.

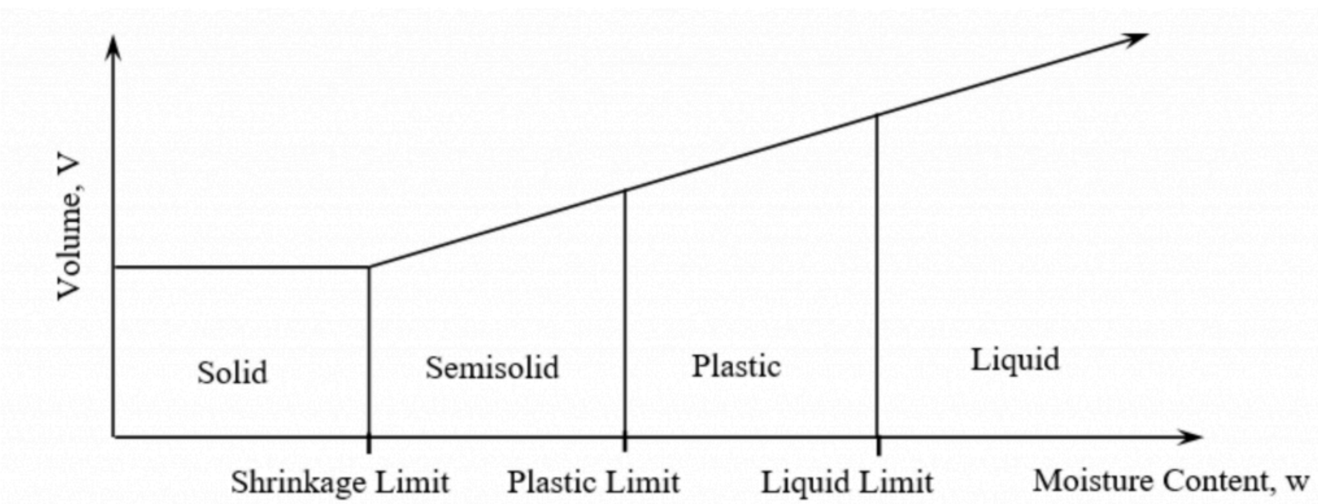

Figure 5.1: Qualitative positions of Atterberg limits on a moisture content scale

The percent of moisture content at which the transition from solid to semi-solid state takes place is defined as the shrinkage limit (SL). The moisture content at the point of transition from semi-solid to plastic state is the plastic limit (PL), and from plastic to liquid state is the liquid limit (LL). These parameters are also known as Atterberg limits. The liquid and plastic limits of a soil and its water content can be used to express its relative consistency or liquidity index. The plasticity index and the percentage finer than 2- μm particle size can be used to determine its activity number.
The liquid limit of a soil containing substantial amounts of organic matter decreases dramatically when the soil is oven-dried before testing. A comparison of the liquid limit of a sample before and after oven-drying can, therefore, be used as a qualitative measure of the organic matter content of a soil.

PRACTICAL APPLICATION

- This test method is used as an integral part of several engineering classification systems (USCS, AASHTO, etc.) to characterize the fine-grained fractions of soils and to specify the fine-grained fraction of construction materials.
- The liquid limit, plastic limit, and plasticity index of soils are also used extensively, either individually or with other soil properties to correlate with engineering behavior such as compressibility, hydraulic conductivity (permeability), shrink-swell, and shear strength.
- This method is sometimes used to evaluate the weathering characteristics of clay-shale materials. When subjected to repeated wetting and drying cycles, the liquid limits of these materials tend to increase. The amount of increase is considered to be a measure of the shale's susceptibility to weathering.

OBJECTIVE

The objective of this experiment is:

- To determine the liquid limit (LL), plastic limit (PL), and the plasticity index (PI) of fine-grained cohesive soils.

EQUIPMENT

- Balance
- Casagrande's liquid limit device
- Grooving tool
- Mixing dishes
- Spatula
- Oven
- Texas Department of Transportation's (TxDOT's) recommended plastic limit rolling device

STANDARD REFERENCE

- ASTM D4318: Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
- TEX-105-E: Determining plastic limit of soils

METHOD

LIQUID LIMIT TEST

- Determine the mass of each of the three moisture cans (W_1).
- Calibrate the drop of the cup, using the end of the grooving tool not meant for cutting, so that there is consistency in the height of the drop.
- Put about 250 g of air-dried soil through a # 40 sieve into an evaporating dish and with a

plastic squeeze bottle, add enough water to form a uniform paste.

Figure 5.2: Preparation of soil slurry

- Place the soil in the Casagrande's cup and use a spatula to smooth the surface so that the maximum depth is about 8mm.

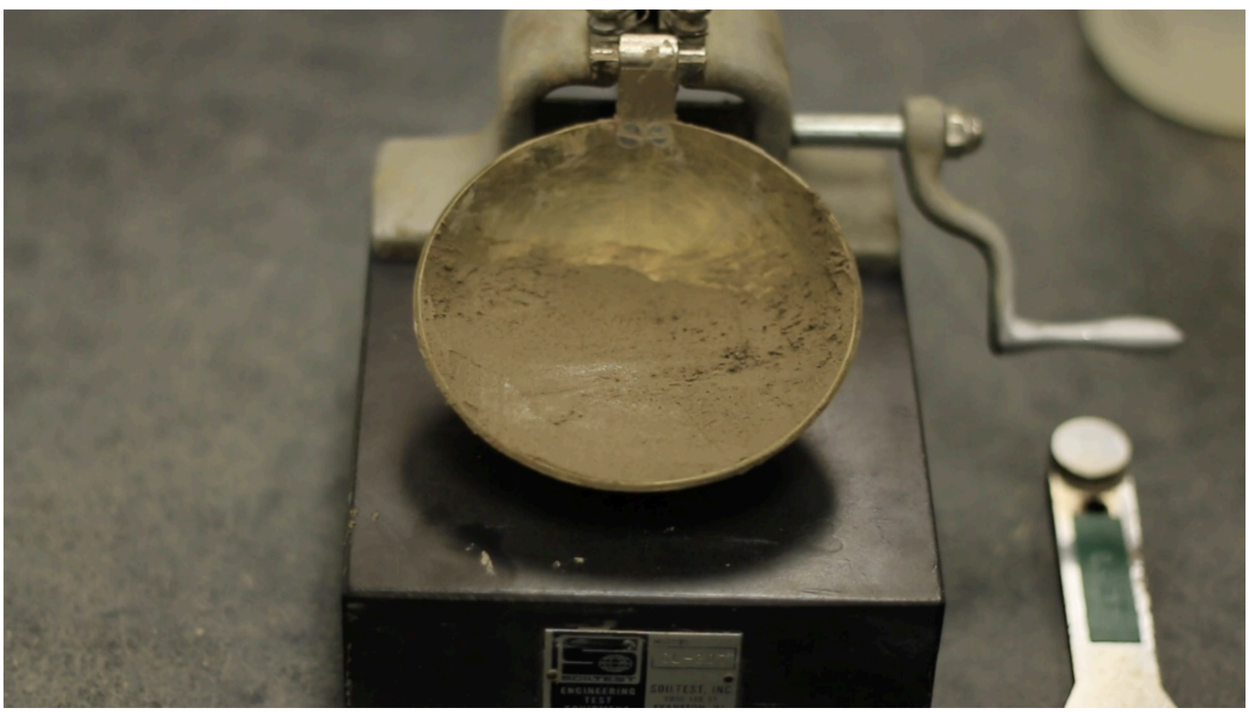

Figure 5.3: Placing the soil paste on the Casagrande apparatus

- Using the grooving tool, cut a groove at the center line of the soil cup.

Figure 5.4: Cutting a groove at the middle of the soil paste with a standard grooving tool

- Crank the device at a rate of 2 revolutions per second until there is a clear visible closure of 1/2" or 12.7 mm in the soil pat placed in the cup. Count the number of blows (N) that caused the closure. (Make the paste so that N begins with a value higher than 35.)

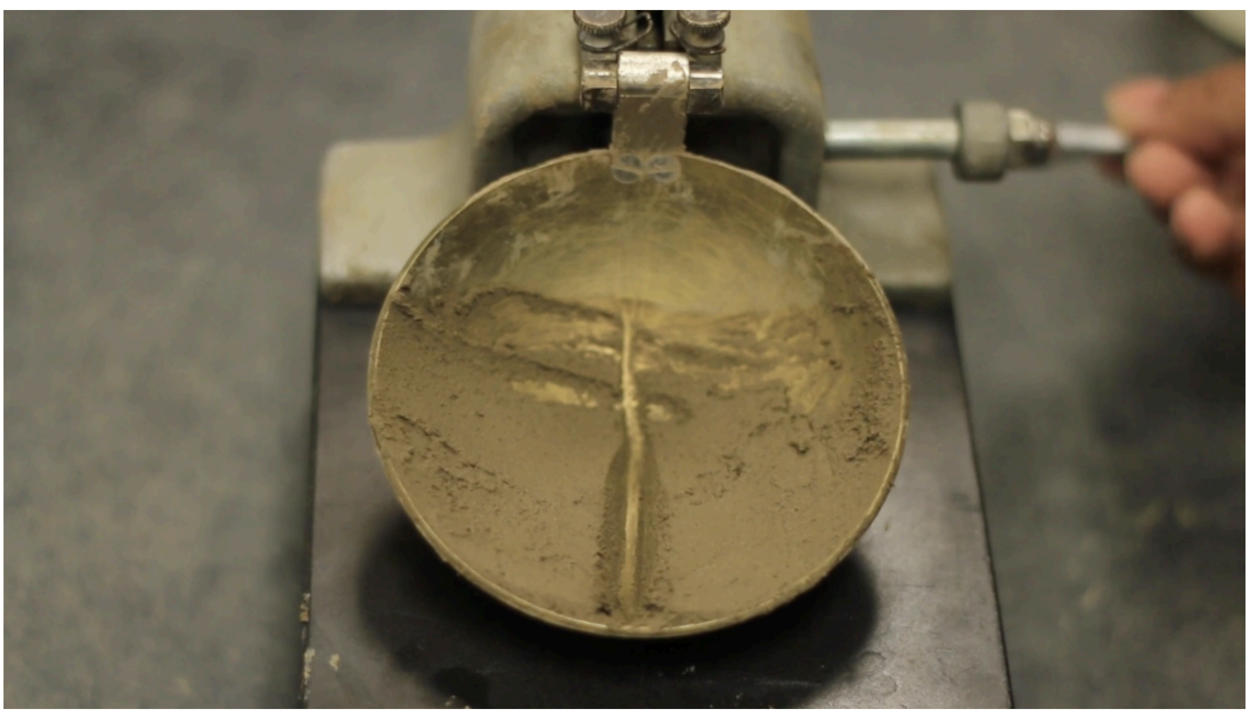

Figure 5.5: The groove at the middle of the soil sample before the application of the blows

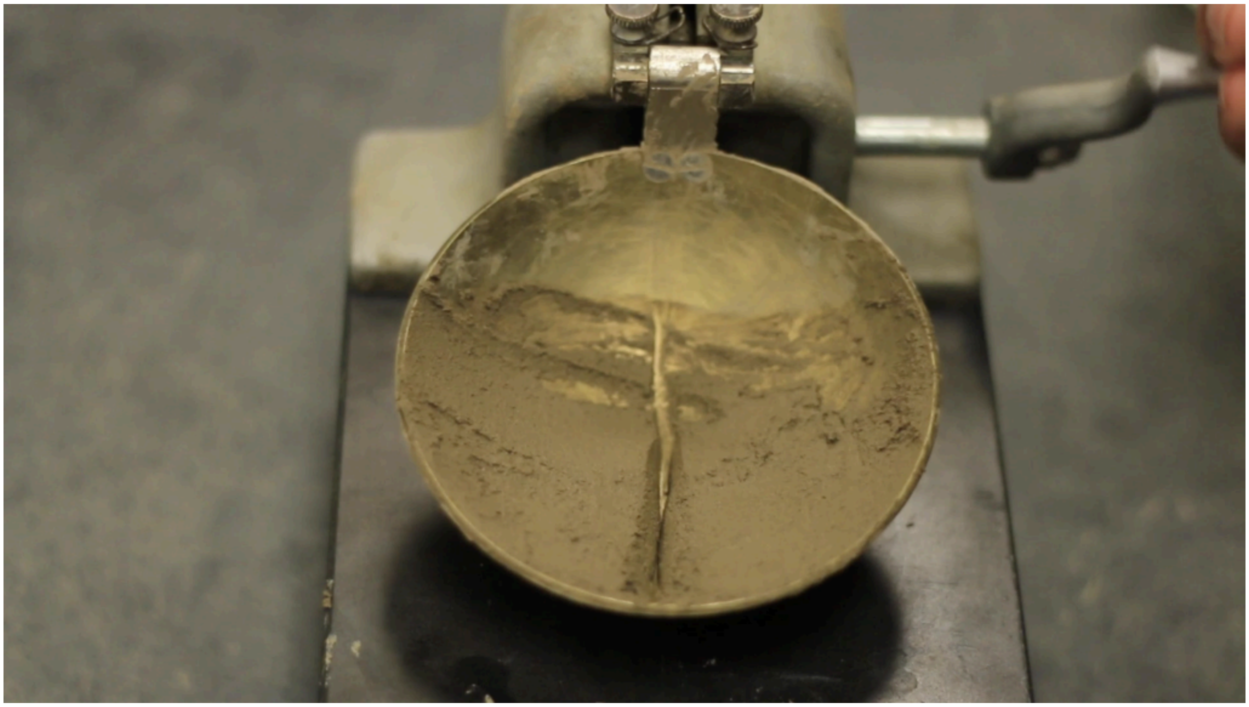

Figure 5.6: The groove at the middle of the soil sample after the application of the blows

- If N= 15 to 40, collect the sample from the closed part of the cup using a spatula and determine the water content weighing the can + moist soil (W_2). If the soil is too dry, N will be higher and will reduce as water is added.
- Do not add soil to the sample to make it dry. Instead, expose the mix to a fan or dry it by continuously mixing it with the spatula.
- Perform a minimum of three trials with values of N-15 to 40, cleaning the cap after each trial.
- Determine the corresponding w% after 24 hours (W_3) and plot the N vs w%, which is called the "flow curve".

PLASTIC LIMIT TEST

- Mix approximately 20 g of dry soil with water from the plastic squeeze bottle.
- Determine the weight of the empty moisture can, (W_1).
- Prepare several small, ellipsoidal-shaped masses of soil and place them in the plastic limit device. Place two fresh sheets of filter paper on either face of the plates.

Figure 5.7: Sample preparation for the plastic limit test

- Roll the upper half of the device which has a calibrated opening of 3.18 mm with the lower half plate.

Figure 5.8: A sample thread of 3mm in diameter

- If the soil crumbles forming a thread approximately the size of the opening between the plates (around 3 mm diameter), collect the crumbled sample, and weigh it in the moisture can (W_2) to determine the water content. Otherwise, repeat the test with the same soil, but dry it by rolling it between your palms.

- Determine the weight of the dry soil + moisture can, (W_3).
- The water content obtained is the plastic limit.

SHRINKAGE LIMIT TEST

- A reduction in the amount of moisture past the plastic limit does not decrease the volume of the soil.
- The sample changes from semi-solid to solid state at the shrinkage limit (boundary water content). Beyond this point the sample begins to dry up.
- The figure below depicts the phenomena of volume change.
- Plot point A, using the values of LL and PI determined experimentally, and extend it to meet O.
- The intercept of the line AO on the X- axis gives the shrinkage limit.

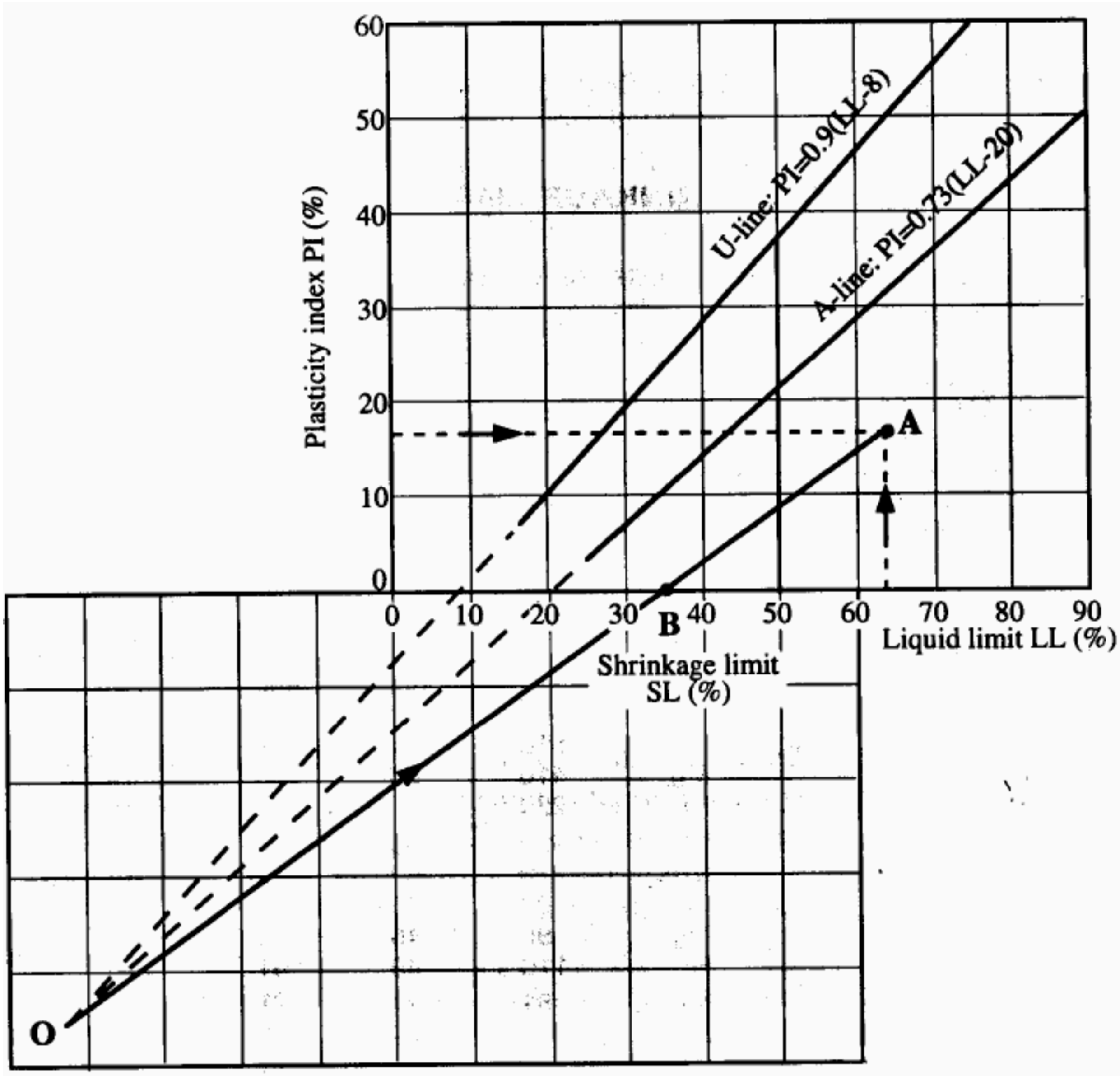

Figure 5.9: Determination of shrinkage limit from liquid limit and plasticity index

VIDEO MATERIALS

LECTURE VIDEO

A PowerPoint presentation is created to understand the background and method of this experiment.

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://uta.pressbooks.pub/soilmechanics/?p=194#oembed-1

DEMONSTRATION VIDEO

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RESULTS AND DISCUSSIONS

LIQUID LIMIT TEST

Sample Data Sheet

Trial no.	1	2	3	4	5
No. of blows	15	21	25	31	35
Wt. of container in gm.	7.7	11.3	11.1	7.0	7.3
Wt. of container + wet soil, gm	27.6	28.3	31.7	26.7	26.6
Wt. of container + dry soil, gm	19.2	21.5	23.7	19.2	19.4
Wt. of water, W_w in gm.	8.4	6.8	8.0	7.5	7.2
Wt. of dry soil, W_s in gm.	11.5	10.2	12.6	12.2	12.1
Water content, w in %	73.0	66.7	63.5	61.5	59.5

Sample Calculation

For Trial No. 01,
Number of blow, N= 15 (recorded during test)
Wt. of container = 7.7 gm
Wt. of container + wet soil = 27.6 gm
Wt. of container + dry soil = 19.2 gm
Wt. of water, W_w= 27.6-19.2 = 8.4 gm
Wt. of dry soil, W_s =19.2- 7.7 = 11.5 gm
Water content, w = 73.0%
The flow curve, an example of which is shown in the Figure 5.10 below, can be obtained by plotting the water content with the corresponding number of blows on semi-log graph paper. The liquid limit of the soil sample can be obtained from this figure.

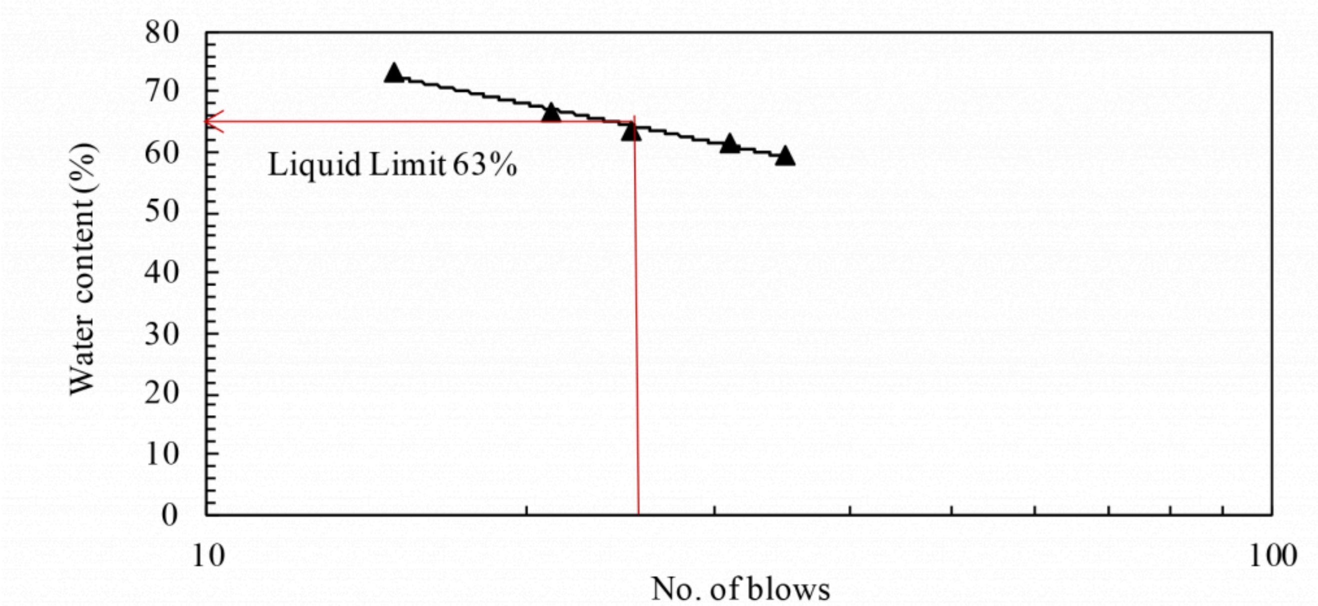

Figure 5.10: Flow Curve for Liquid Limit determination

Blank Data Sheet

Trial no.	1	2	3	4	5
No. of blows					
Wt. of container in gm.					
Wt. of container + wet soil, gm					
Wt. of container + dry soil, gm					
Wt. of water, W_w in gm.					
Wt. of dry soil, W_s in gm.					
Water content, w in %					

PLASTIC LIMIT TEST

Sample Data Sheet

Trial no.	1	2	3
Wt. of container in gm.	7.7	7.3	6.9
Wt. container + wet soil, gm	23.2	20.2	19.9
Wt. container + dry soil, gm	20.9	18.4	17.9
Wt. of water in gm.	2.3	1.8	2
Wt. of dry soil in gm.	13.2	11.1	11
Water content, w in %	17.42	16.22	18.18

Sample Calculation

For Trial No. 01,
Wt. of container = 7.7 gm
Wt. of container + wet soil = 23.2 gm

Wt. of container + dry soil = 20.9 gm
Wt. of water, W_w = 23.2-20.9 = 2.3 gm
Wt. of dry soil, W_s =20.9- 7.7 = 13.2 gm
Water content, w = 17.42%
Plastic Limit is the average of moisture content of all trials.
Plasticity Index (PI)=Liquid Limit (LL)–Plastic limit (PL)

Blank Data Sheet

Trial no.	1	2	3
Wt. of container in gm.			
Wt. container + wet soil, gm			
Wt. container + dry soil, gm			
Wt. of water in gm.			
Wt. of dry soil in gm.			
Water content, w in %			

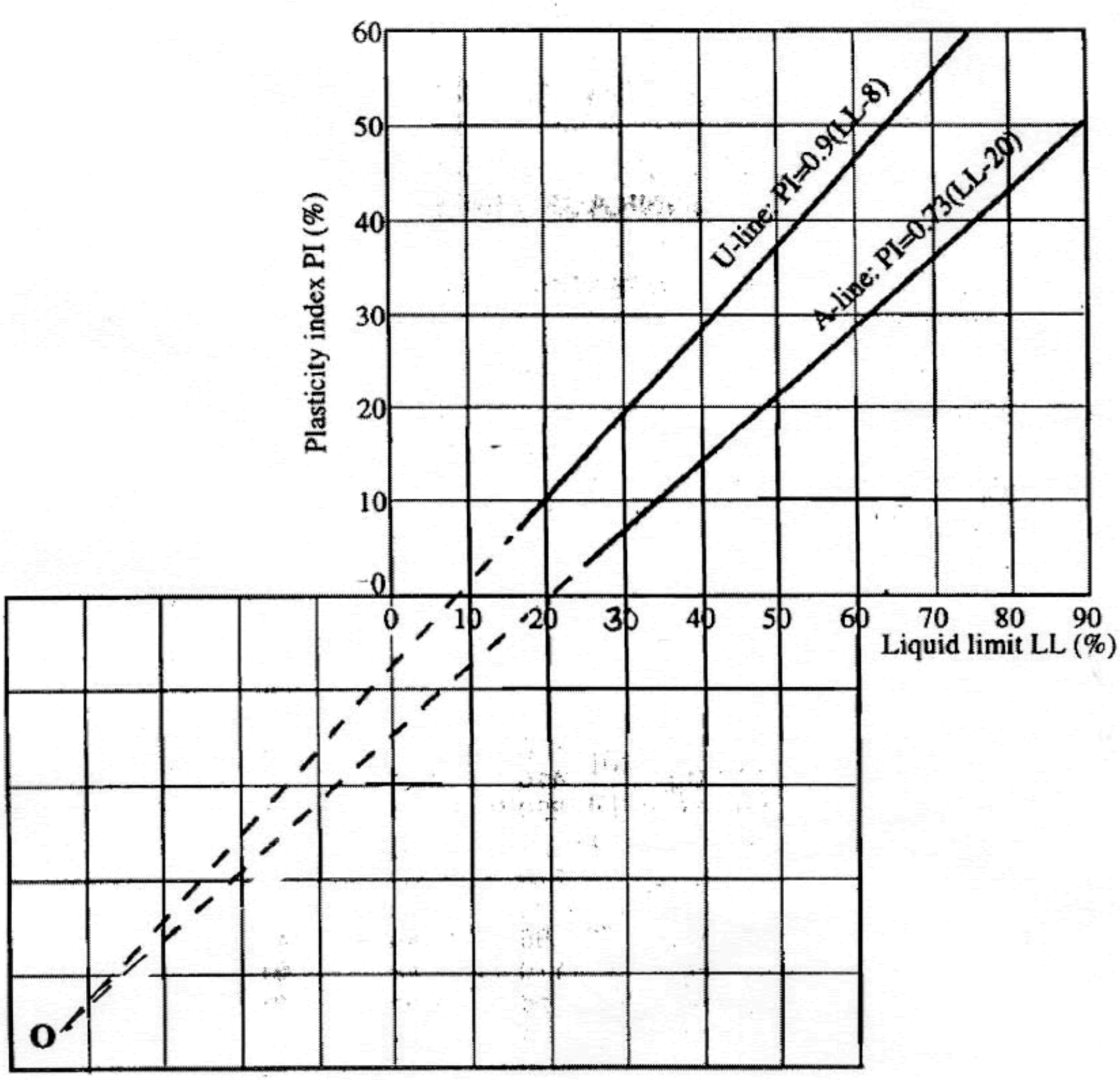

Figure 5.11: Blank graph for shrinkage limit determination

*Use this chart for your results to determine the shrinkage limit.

REPORT

Use the template provided to prepare your lab report for this experiment. Your report should include the following:

- Objective of the test
- Applications of the test
- Apparatus used

- Test procedures (optional)
- Analysis of test results – Complete the table provided and show one sample calculation.
- Calculate the value for liquid limit, flow index, plastic limit, plasticity index and shrinkage limit.
- Summary and conclusions – Comment on the Atterberg limit values of the given soil sample.

CHAPTER 6.

COMPACTION TEST

INTRODUCTION

This laboratory test is performed to determine the relationship between the moisture content and the dry density of soil for a specified 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 and methodology developed by R. R. Proctor in 1933.

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 by using the three different methods, 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 is filled with three equal layers of soil. Each layer is subjected to 25 drops of the hammer. The modified Proctor test is similar to the standard Proctor test, but the mold is filled with five 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^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 6.1).

Table 6.1: 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 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

Note: Volume of 4″ diameter mold = 944 cm^3 and volume of 6” diameter mold = 2123 cm^3; verify these values prior to testing.

PRACTICAL APPLICATION

- Soil placed as engineering fill (embankments, foundation pads, road bases) is compacted to a dense state to obtain satisfactory engineering properties such as, shear strength, compressibility, or permeability.
- 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, $\gamma_{d(max)}$ 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

STANDARD REFERENCE

- ASTM D698: Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort

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.

Figure 6.1: Adding water to soil sample

Figure 6.2: Mixing soil with a trowel

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.

Figure 6.3: Placing the soil sample into standard proctor mold

Figure 6.4: Hammering the soil sample

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.)

Figure 6.5: Compacting the soil sample at the third layer

Figure 6.6: Trimming extra soil above the mold with a trowel

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.

Figure 6.7: Removal of the compacted sample with an extruder

Figure 6.8: Taking specimen for moisture content determination

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 cm^3.

- 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,

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

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

ϱ_d = dry density of soil grams per cm^3
G_s = specific gravity of the soil being tested (assume 2.70 if not given)
ϱ_w = density of water in grams per cm^3 (approximately 1 g/cm^3)
w_{sat} = moisture content in percent for complete saturation

Example Calculations:

G_s = 2.7 (given)

ϱ_w = 1.0 g/cm^3

Assumed $w_{sat}\%$	Calculated $\rho_d(g/cm^3)$
8	2.22
10	2.13
12	2.04
14	1.96
16	1.89
18	1.82

- Identify and report the optimum moisture content and the maximum dry density. Make sure that you have recorded the method of compaction used on the data sheet (e.g., standard Proctor, Method A.)

VIDEO MATERIALS

LECTURE VIDEO

A PowerPoint presentation is created to understand the background and method of this experiment.

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://uta.pressbooks.pub/soilmechanics/?p=284#oembed-1

DEMONSTRATION VIDEO

A short video is executed to demonstrate the experiment procedure and sample calculation.

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://uta.pressbooks.pub/soilmechanics/?p=284#oembed-2

RESULTS AND DISCUSSIONS

SAMPLE DATA SHEET

Soil type: Low plastic clay (CL)

Specific gravity of soil, G_s = 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	

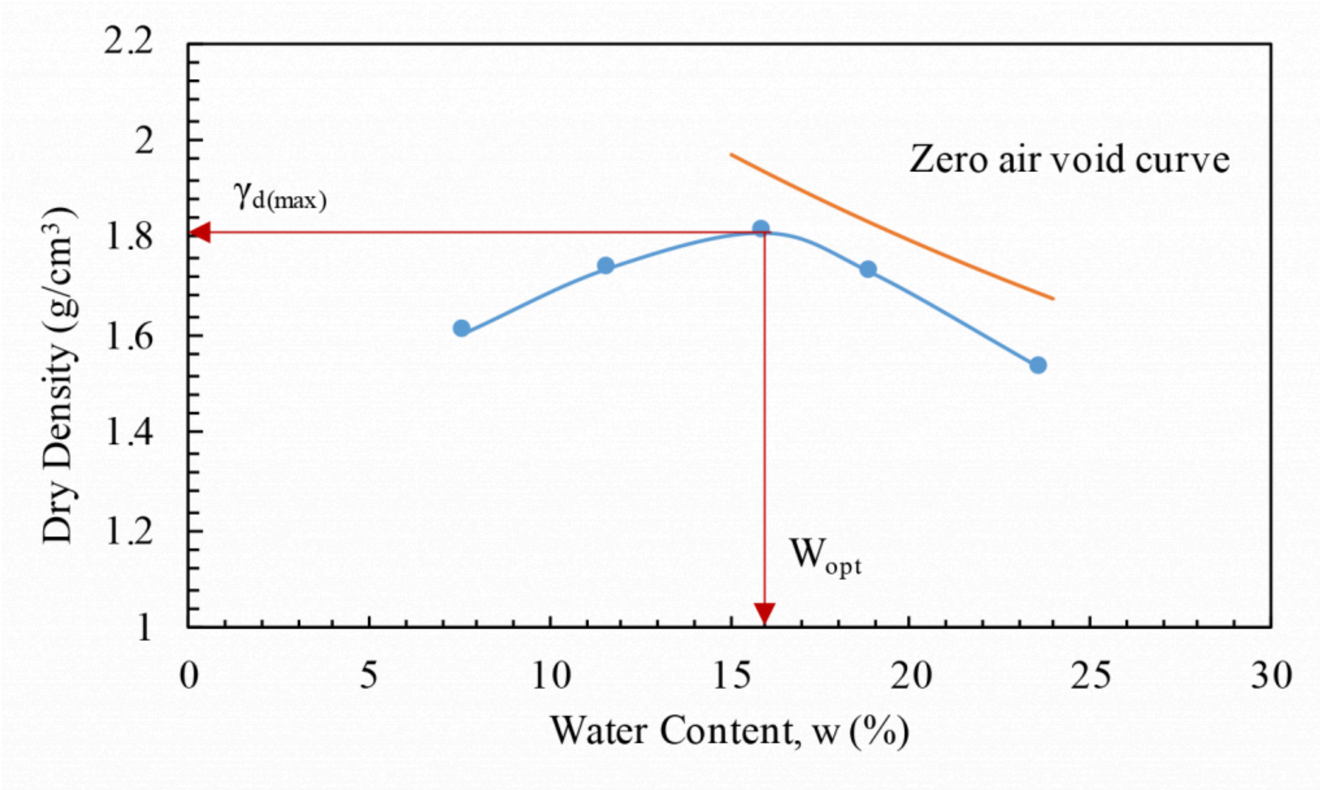

Figure 6.9: Compaction curve and zero air void curve

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)	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, $\gamma_{d(max)}$ = 1.81 g/cm^3
Optimum moisture content, w_{opt} = 15.9 %

BLANK DATA SHEET

Soil type: Low plastic clay (CL)
Specific Gravity of soil, G_s = 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)					

REPORT

Use the template provided to prepare your lab report for this experiment. Your report should include the following

1. Objective of the test
2. Applications of the test
3. Apparatus used
4. Test procedures (optional)
5. Analysis of test results – Complete the table provided and show one sample calculation. Determine the optimum moisture content and the maximum dry density of the given soil sample.
6. Summary and conclusions – Comment on the optimum moisture content and maximum dry density of the given soil sample

CHAPTER 7.

IN-SITU DENSITY

INTRODUCTION

The dry density of the compacted soil or pavement material is a common measure of the amount of compaction achieved during construction. It can be calculated from the field density and field moisture content data; therefore, field density or the in-situ density test is an important field control test for the compaction of soil or any other pavement layers.

The in-situ density of material is determined by the weight of the excavated material divided by the in-situ volume. The volume of the excavated hole can be determined from the weight of sand with known density filling in the hole. There are several methods for determining the field density of soils: core cutter method, sand replacement method, rubber balloon method, heavy oil method, etc. The sand replacement test is simple and is the most popular method, and it is followed in this manual.

PRACTICAL APPLICATION

- In-situ density is widely used to control the field compaction of earthworks and pavement layers.
- Knowing the field density of the soil enables the estimation of the soil-bearing capacity, evaluation of the pressure on underlying strata, and computation of the settlement and stability of a natural slope.

OBJECTIVE

The objective of this experiment is

- To determine the in-situ density of soil using the sand replacement method.

EQUIPMENT

- Sand cone apparatus
- Base plate
- Tools for excavating a hole in the ground
- Proctor compaction model
- Balance

STANDARD REFERENCE

- ASTM D1556: Standard Test Method for Density and Unit Weight of Soil in Place by Sand-

Cone Method

METHOD

Calibration of sand cone apparatus

1. Measure the weight of the Proctor mold + base, W_1
2. Pour the sand into the compaction mold and level off the surface, being careful not to disturb the mold, as that might rearrange the sand and cause it to become compacted. Measure the weight of Proctor mold + base + sand, W_2

Figure 7.1: Pouring the sand into the compaction mold

3. Measure the weight of the plastic gallon container + cone + sand, W_3 (before use)
4. Close the valve that is attached to the cone. Turn the cone and gallon container upside down on the tray and open the valve so that the sand flows from the container to the cone. After the flow stops, close the valve, and take the gallon + cone from the tray. Measure the weight of the plastic gallon + cone + sand, W_4 (after use)

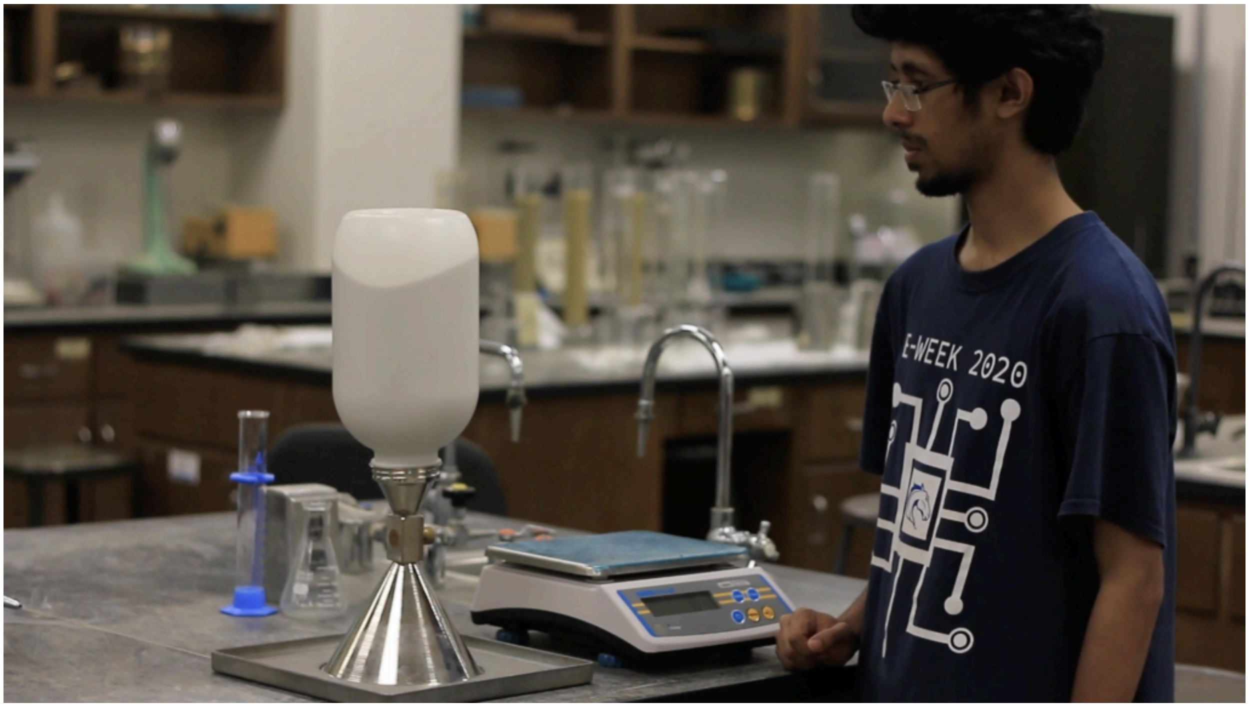

Figure 7.2: Calibration of the sand cone apparatus

5. Measure the weight of the plastic gallon + cone + sand, W_5 (before use)

Field in-situ density test

1. In the field where the soil's unit weight is to be measured, position the metal tray and fasten the four screws.
   Dig a 10 to 15 cm deep hole and put the retrieved soil, including the soft soil at the bottom of the hole, into a plastic bag to prevent a loss of moisture.

Figure 7.3: Collection of the soil sample from the hole

2. With the valve closed, turn the gallon + cone upside down, place the cone in the center hole of the tray, and open the valve so that the sand flows down to the hole.
3. After the flow of sand stops, close the valve, and pick up the assembly. Pour the sand in the cone into the tray and leave it in the field.

Figure 7.4: Placement of sand cone apparatus above the hole

4. Measure the weight of the plastic gallon + cone + sand, W_6 (after use)

5. Measure the weight of the evaporating dish, W_7
6. Measure the weight of the evaporating dish + wet soil from the field, W_8

Figure 7.5: Removing the sand cone apparatus after filling the hole with standard sand

7. Put the evaporating dish + wet soil in the oven for 24 hrs., then weigh it again, W_9
8. Perform the calculations, using the data you have entered into the table.

VIDEO MATERIALS

LECTURE VIDEO

A PowerPoint presentation is created to understand the background and method of this experiment.

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://uta.pressbooks.pub/soilmechanics/?p=291#oembed-1

DEMONSTRATION VIDEO

A short video is executed to demonstrate the experiment procedure and sample calculation.

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://uta.pressbooks.pub/soilmechanics/?p=291#oembed-2

RESULTS AND DISCUSSIONS

SAMPLE DATA SHEET

Test Steps	Quantity	Unit
Obtaining the unit weight of the sand used		
1. Weight of Proctor mold, W_1	4.234	kg
2. Weight of proctor mold + Sand, W_2	5.982	kg
3. Volume of the mold, V_1	0.00095	m3
4. Dry unit weight, $\gamma_{d(sand)}$ = (W_2 - W_1) / V_1	1840	kg/m^3
Calibration cone		
5. Weight of plastic Gallon + Cone + Sand (before use), W_3	5.124	kg
6. Weight of plastic Gallon + Cone + Sand (after use), W_4	3.965	kg
7. Weight of the sand to fill the cone, W_c = W_3- W_4	1.159	kg
Results from field tests		
8. Weight of plastic Gallon + Cone + Sand (before use), W_5	7.854	kg
9. Weight of plastic Gallon + Cone + Sand (after use), W_6	4.23	kg
10. Volume of hole, V_2 = (W_5-W_6-W_c)/ $\gamma_{d(sand)}$	0.001340	m^3
11.Weight of plastic bag, W_7	0.069	kg
12. Weight of plastic bag + wet soil from the field, W_8	2.334	kg
13. Weight of wet soil, W_9 = W_8-W_7	2.265	kg
14. Moist unit weight of the soil in the field, $\gamma_{t(in-situsoil)}$ = W_9 / V2	1690.71	kg/m^3
15. Weight of moisture can, W_{10}	0.056	kg
16. Weight of moisture can + wet soil, W_{11}	0.162	kg
17. Weight of moisture can + dry soil after 24 hrs., W_{12}	0.159	kg
18. Water content in the field, w(%)= (W_{11} - W_{12}) / (W_{12}- W_{10})× 100	2.91	%
19. Dry unit weight in the field, $\gamma_{d(in-situsoil)}$= [t (Row 14)] / [1+ w(%) / 100]	1642.86	kg/m^3

BLANK DATA SHEET

Test Steps	Quantity	Unit
Obtaining the unit weight of the sand used		
1. Weight of Proctor mold, W_1		kg
2. Weight of proctor mold + Sand, W_2		kg
3. Volume of the mold, V_1		m3
4. Dry unit weight, $\gamma_{d(sand)}$ = (W_2 - W_1) / V_1		kg/m^3
Calibration cone		
5. Weight of plastic Gallon + Cone + Sand (before use), W_3		kg
6. Weight of plastic Gallon + Cone + Sand (after use), W_4		kg
7. Weight of the sand to fill the cone, $W_c = W_3$- W_4		kg
Results from field tests		
8. Weight of plastic Gallon + Cone + Sand (before use), W_5		kg
9. Weight of plastic Gallon + Cone + Sand (after use), W_6		kg
10. Volume of hole, V_2 = (W_5-W_6-W_c)/ $\gamma_{d(sand)}$		m^3
11.Weight of plastic bag, W_7		kg
12. Weight of plastic bag + wet soil from the field, W_8		kg
13. Weight of wet soil, $W_9 = W_8$-W_7		kg
14. Moist unit weight of the soil in the field, $\gamma_{t(in-situsoil)} = W_9$ / V_2		kg/m^3
15. Weight of moisture can, W_{10}		kg
16. Weight of moisture can + wet soil, W_{11}		kg
17. Weight of moisture can + dry soil after 24 hrs., W_{12}		kg
18. Water content in the field, w(%)= (W_{11} - W_{12}) / (W_{12}- W_{10})$\times$ 100		%
19. Dry unit weight in the field, $\gamma_{d(in-situsoil)}$= [t (Row 14)] / [1+ w(%) / 100]		kg/m^3

REPORT

Use the template provided to prepare your lab report for this experiment. Your report should include the following

- Objective of the test
- Applications of the test
- Apparatus used
- Test procedures (optional)
- Analysis of test results – Complete the table provided and show one sample calculation. Calibrate the sand cone apparatus and determine the in-situ density and moisture content.
- Summary and conclusions – Comment on the in-situ moisture content and in-situ density of soil obtained from the field.

CHAPTER 8.

PERMEABILITY TEST

INTRODUCTION

Soil permeability (hydraulic conductivity) is the rate at which water flows through soil materials. It is an essential characteristic across a broad spectrum of engineering and earth-science disciplines. The coefficient of permeability (k) is a constant of proportionality relating to the ease with which fluid passes through a porous medium.
Two general types of permeability test methods 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 cohesionless and more permeable soils ($k>10^{-4}$ cm/s) and the falling head test is mainly used for cohesive or less permeable soils ($k<10^{-4}$ cm/s). The constant head permeability method is espoused in this manual for determining the permeability of sandy soil.

PRACTICAL APPLICATION

- Data related to the permeability of soil is necessary for calculating the amount of seepage through earthen dams or under sheet pile walls, the seepage rate from waste storage facilities (landfills, ponds, etc.), and the settlement of clayey soil deposits.
- Geotechnical and civil engineers, hydrogeologists, and soil and environmental scientists use this information for projects such as structural foundations, embankments, earthen dams, flood management, effluent infiltration, and more.

OBJECTIVE

The objective of this experiment is

- To determine the permeability of sandy soil

EQUIPMENT

- Permeameter
- Tamper, balance
- Scoop
- 1000 mL
- Graduated cylinders
- Watch (or stopwatch)
- Thermometer

- Filter paper

STANDARD REFERENCE

- ASTM D2434: Standard Test Method for Permeability of Granular Soils (Constant Head).

METHOD

- Measure the initial mass of the pan along with the dry soil (M_1). 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 the upper and lower chambers. Calculate the average inside diameter of the permeameter (D).
- 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.
- Mix the soil with enough distilled water to prevent the particle sizes from segregating while they are being placed into the permeameter. Add enough water that the mixture can flow freely. Using a scoop in a circular motion to form a uniform layer, pour the prepared soil into the lower chamber, filling it to a depth of 1.5 cm.
- Use the tamping device to compact the layer of soil, applying 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.

Figure 8.1: Compacting the soil sample in the permeability mold

- Replace the upper chamber section, being sure to place the rubber gasket between the chamber sections. Be careful not to disturb the soil that has already been compacted. Continue the placement operation until the level of the soil is about 2 cm. below the rim of the upper chamber. Level the top surface of the soil, place a filter paper on it, and then put the upper porous stone on top.

Figure 8.2: Filling the permeability mold in three layers

- 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.
- Measure the sample length at four locations around the circumference of the permeameter, compute the average length, and record it as the sample length.
- Keep the pan with the remaining soil in the drying oven.
- 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.
- Connect the flexible tube from the tail of the funnel to the bottom outlet of the permeameter and keep the valves on top of the permeameter open. Run tubing from the top outlet to the sink to collect any water that is emitted. Open the bottom valve and allow the water to flow into the permeameter.

Figure 8.3: Soil sample is being saturated

- As soon as the water begins to flow out of the top control (de-airing) valve, close the control valve, letting water flow out of the outlet for some time. Close the bottom outlet valve and disconnect the tubing at the bottom. Connect the funnel tubing to the top side port.

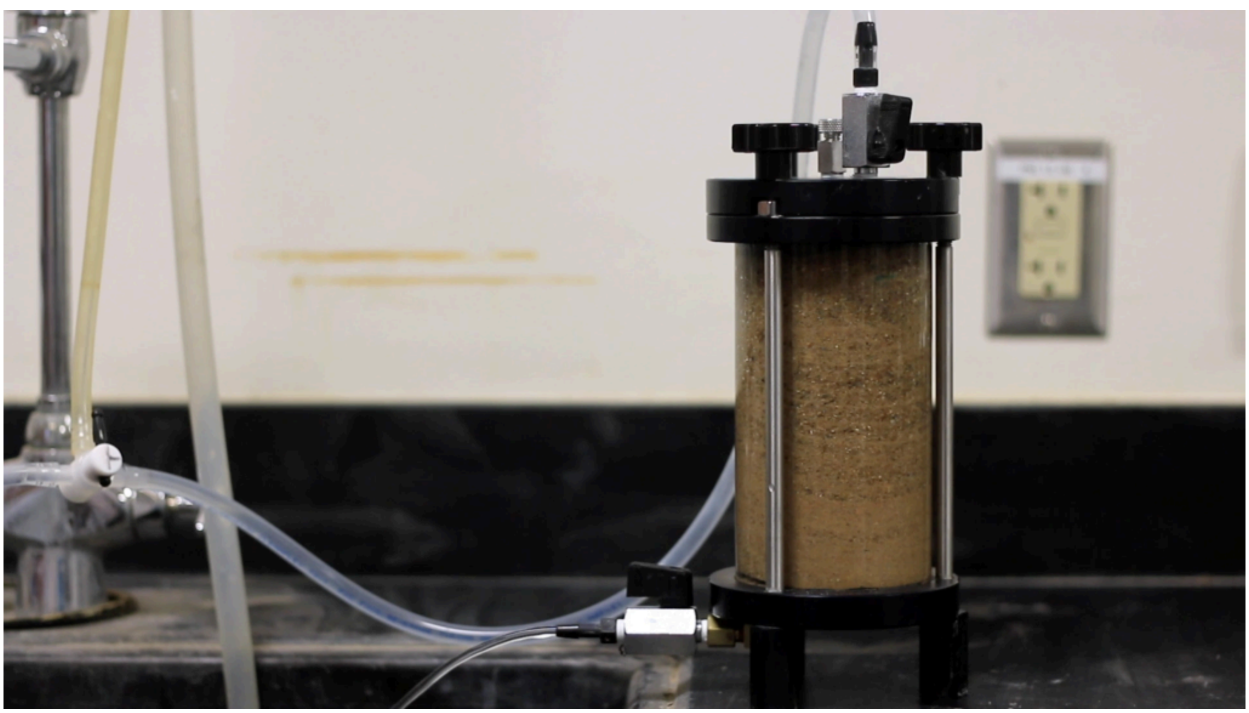

Figure 8.4: Saturated soil sample

- Open the bottom outlet valve and raise the funnel to a convenient height to get a reasonably steady flow of water. Allow adequate time for the flow pattern to stabilize.
- 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.

Figure 8.5: Measuring the volume of the water with time

- Measure the vertical distance between the funnel head level and the chamber outflow level, and record the distance as H.

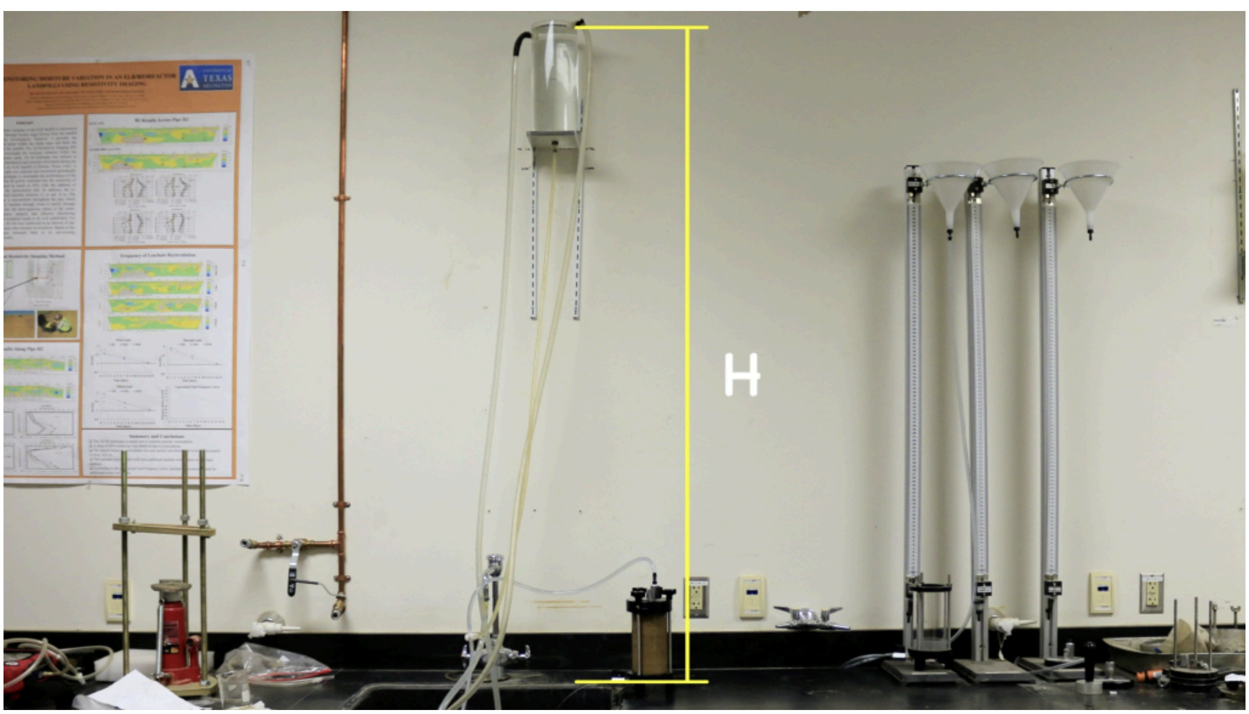

Figure 8.6: Head difference between the top of the water source and exit point of the permeability apparatus

- Remove the pan from the drying oven and measure the final mass of the pan along with the dry soil (M_2).

VIDEO MATERIALS

LECTURE VIDEO

A PowerPoint presentation is created to understand the background and method of this experiment.

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DEMONSTRATION VIDEO

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RESULTS AND DISCUSSIONS

Sample calculation

Calculate the permeability, using the following equation:

$$K_T = \frac{QL}{Ath}$$

Where,
K_T = coefficient of permeability at temperature T, cm/sec.
L = length of the 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
h = hydraulic head difference across length L, in cm of water;
The viscosity of the water changes with the temperature. As the temperature increases, the 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 K_{20} by the following ratio:
$K_{20}=K_T \times \eta_T/\eta_{20}$
Where,
η_T and η_{20} are the viscosities at the temperature T of the test and at 20° C, respectively.
Compute the volume of soil used from, V = LA.
Compute the mass of dry soil used in the permeameter (M) = initial mass – final mass:

$M = M_1 - M_2$
Compute the dry density (γ_d) of soil
$\gamma_d = M/V$
Table 8.1: Properties of Distilled water (η= absolute)

Temperature (C)	Density (g/cm^3)	Viscosity (Poise)
4	1	0.01567
16	0.99897	0.01111
17	0.9988	0.01083
18	0.99862	0.01056
19	0.99844	0.0103
20	0.99823	0.01005
21	0.99802	0.00981
22	0.9978	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

Sample Data Sheet

Initial dry mass of Soil + Pan (M_1) = 1675.0 g
Length of Soil Specimen, L = 17 cm
Diameter of the Soil Specimen (Permeameter), D = 6.4 cm
Final Dry Mass of Soil + Pan (M_2) = 865.6 g
Dry Mass of Soil Specimen (M)= 809.4 g
Volume of Soil Specimen (V) = 846.9 cm^3
Dry Density of Soil (γ_d) = 1.48 g/cm^3

Trial Number	Constant Head, h (cm)	Elapsed Time, t (seconds)	Outflow Volume, Q (cm^3)	Water Temp., T (C)	K_T cm/sec	K_{20} cm/sec
1	30	84	750	22	0.157	0.149
2	50	55	750	22	0.144	0.137
3	60	48	750	22	0.137	0.130
4	70	38	750	22	0.149	0.142

Average K_{20} = 0.139 cm/sec

Blank Data Sheet

Initial dry mass of Soil + Pan (M_1) =
Length of Soil Specimen, L =
Diameter of the Soil Specimen (Permeameter), D =
Final Dry Mass of Soil + Pan (M_2) =

Dry Mass of Soil Specimen (M)=
Volume of Soil Specimen (V) =
Dry Density of Soil (γ_d) =

Trial Number	Constant Head, h	Elapsed Time, t	Outflow Volume, Q	Water Temp., T	K_T cm/sec	K_{20} cm/sec

Average K_{20} =

REPORT

Use the template provided to prepare your lab report for this experiment. Your report should include the following:

- Objective of the test
- Applications of the test
- Apparatus used
- Test procedures (optional)
- Analysis of test results – Complete the table provided and show one sample calculation. Determine the permeability of the given soil sample at 20°C.
- Summary and conclusions – Comment on the permeability of the soil sample based on the range of k for different types of soil.

CHAPTER 9.

DIRECT SHEAR TEST

INTRODUCTION

Shear strength is defined as the maximum resistance that a material can withstand when subjected to shearing, and the direct shear test is an experimental procedure that is used to determine the shear strength of soil materials. It is one of the simplest, most common, quickest, and inexpensive tests implemented to derive the strength of a soil. It can be carried out on undisturbed or remolded samples and is often used when a quick and rough estimate is needed. It cannot, however, provide the actual scenario of the shear strength of a soil sample because the failure plane is forced to occur at the predetermined joint in the shear box, which may not be the weakest plate. Consequently, triaxial tests, rather than direct shear tests, are often performed for important projects where the accurate estimation of shear strength parameters is important.

PRACTICAL APPLICATION

Estimation of shear strength is needed for engineering situations such as assessing the stability of slopes or cuts, finding the bearing capacity of foundations, and determining the earth pressure exerted by a soil on a retaining wall.

OBJECTIVE

The objective of this experiment is

- To estimate the angle of friction and cohesion of soils

EQUIPMENT

- Direct shear device
- Load and deformation dial gauges
- Calipers
- Balance

STANDARD REFERENCE

ASTM D3080: Standard Test Method for Direct Shear Test of Soils Under Consolidated Drained Conditions.

METHOD

- Weigh the initial mass of soil in the pan.

- Measure the diameter and height of the shear box. Compute 15% of the diameter in millimeters.
- 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.

Figure 9.1: Shear box apparatus

- 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.

Figure 9.2: Shear box assembly in the direct shear device

Figure 9.3: Placing filter paper

- Remove the large alignment screws from the shear box. Using the gap screws, open the gap between the shear box halves to approximately 0.025 in., and then back out the gap screws.

Figure 9.4: Pouring sand

- Weigh the pan of soil again and compute the mass of soil used.
- 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.

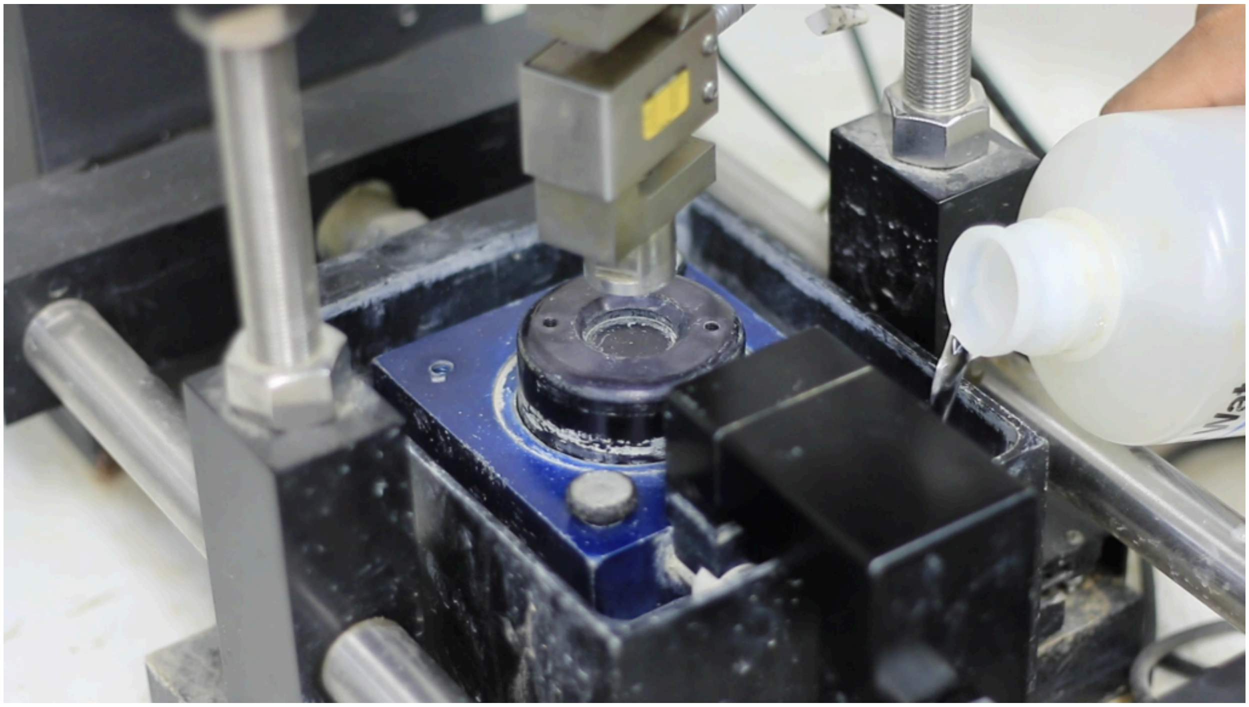

Figure 9.5: Direct shear device

- Set the vertical load (or pressure) to a predetermined value, and then close the bleeder valve and apply the load to the soil specimen by raising the toggle switch.
- Start the motor at the selected speed so that the rate of shearing is at a selected 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.)
- Continue taking readings until the horizontal shear load peaks and then falls, or the horizontal displacement reaches 15% of the diameter.

VIDEO MATERIALS

LECTURE VIDEO

A PowerPoint presentation is created to understand the background and method of this experiment.

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://uta.pressbooks.pub/soilmechanics/?p=302#oembed-1

DEMONSTRATION VIDEO

A short video is executed to demonstrate the experiment procedure and sample calculation.

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://uta.pressbooks.pub/soilmechanics/?p=302#oembed-2

RESULTS AND DISCUSSIONS

Sample Data Sheet

Height of sample (H_0) =1 in
Diameter of sample (d_0) = 2.5 in
Area of sample (A_0) = 4.9087 in^2
Volume, (V_0) = 80.4398 cm^3
Specific gravity, G_s = 2.67
Calibration factor for proving dial: 0.30239 lb/0.0001 inch +0.20636
Table 9.1: Data sheet for normal stress 14.3 psi

Elapsed time, min	Shear dial (0.001 in.)	Shear displacement, in	Proving dial (0.0001 in.)	Shear Force, lbs	Shear Stress (psi)
0	0	0	0	0.00	0.00
0.25	9	0.009	75	22.89	4.66
0.5	23	0.023	102	31.05	6.33
0.75	38	0.038	123	37.40	7.62
1	54	0.054	139	42.24	8.60
1.25	72	0.072	152	46.17	9.41
1.5	88	0.088	164	49.80	10.14
1.75	105	0.105	173	52.52	10.70
2	121	0.121	179	54.33	11.07
	141	0.141	182	55.24	11.25
	161	0.161	182	55.24	11.25
	181	0.181	181	54.94	11.19
	201	0.201	179	54.33	11.07

Table 9.2: Data sheet for normal stress 28.9 psi

Elapsed time, min	Shear dial (0.001 in.)	Shear displacement, in	Proving dial (0.0001 in.)	Shear Force, lbs	Shear Stress (psi)
0	0	0	0	0.00	0.00
0.25	6	0.006	110	33.47	6.82
0.5	16	0.016	160	48.59	9.90
0.75	30	0.03	200	60.68	12.36
1	45	0.045	228	69.15	14.09
1.25	60	0.06	253	76.71	15.63
1.5	75	0.075	278	84.27	17.17
1.75	91	0.091	295	89.41	18.21
2	107	0.107	312	96.08	19.57
	127	0.127	330	108.03	22.01
	147	0.147	338	113.34	23.09
	167	0.167	341	115.33	23.50
	187	0.187	340	114.67	23.36
	207	0.207	335	111.35	22.68
	227	0.227	330	108.03	22.01

Table 9.3: Data sheet for normal stress 43.5 psi

Elapsed time, min	Shear dial (0.001 in.)	Shear displacement, in	Proving dial (0.0001 in.)	Shear Force, lbs	Shear Stress (psi)
0	0	0	0	0	0.00
0.25	3	0.003	128	38.91	7.93
0.5	13	0.013	196	59.47	12.12
0.75	25	0.025	254	77.01	15.69
1	38	0.038	295	89.41	18.21
1.25	52	0.052	330	108.03	22.01
1.5	66	0.066	358	126.62	25.79
1.75	82	0.082	377	139.23	28.36
2	91	0.091	386	145.20	29.58
	111	0.111	397	152.50	31.07
	131	0.131	404	157.15	32.01
	151	0.151	410	161.13	32.83
	171	0.171	414	163.79	33.37
	191	0.191	416	165.12	33.64
	211	0.211	412	162.46	33.10
	231	0.231	406	158.48	32.29

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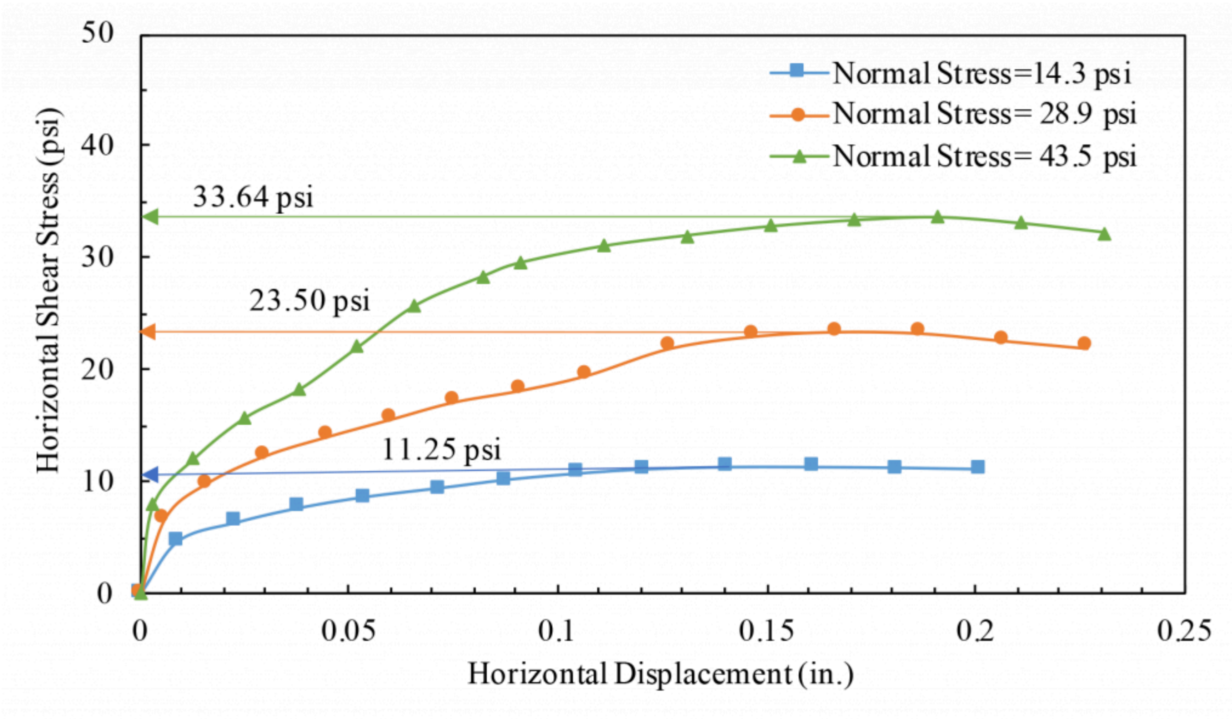

Figure 9.6: Variation of shear stress with displacement for different normal stress conditions

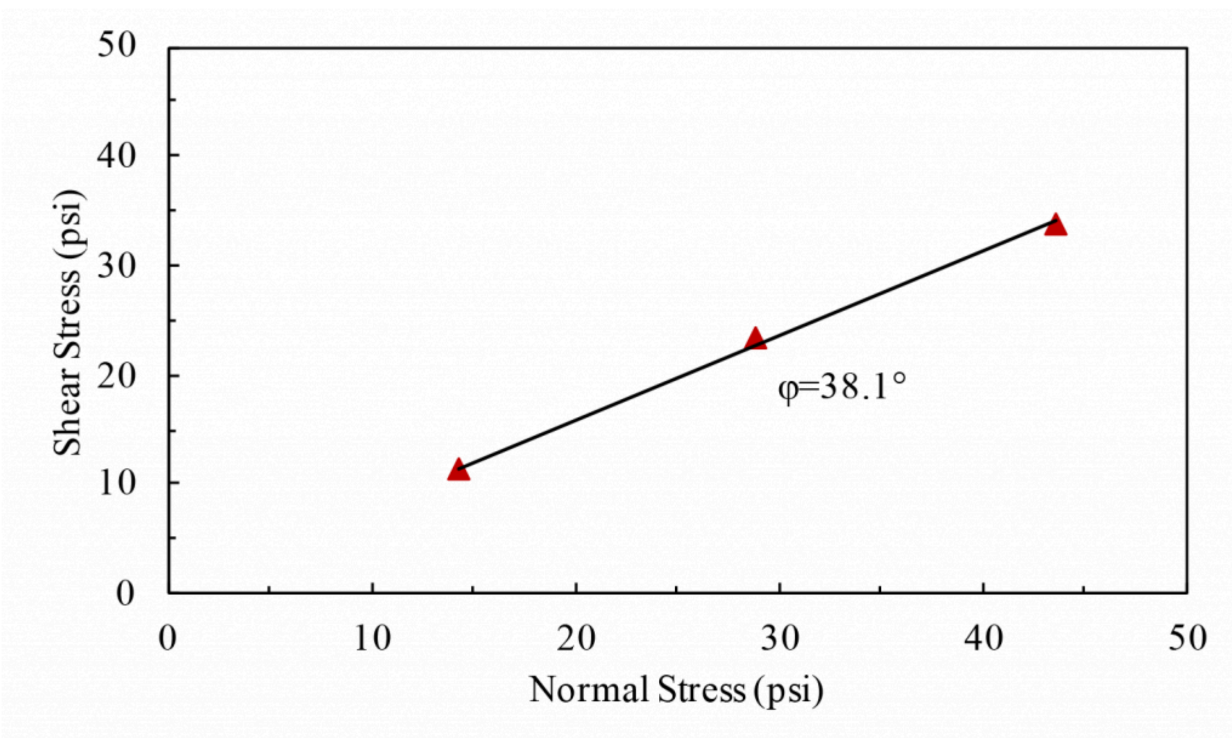

Figure 9.7: Shear stress vs normal stress plot

REPORT

Use the template provided to prepare your lab report for this experiment. Your report should include the following:

- Objective of the test
- Applications of the test
- Apparatus used
- Test procedures (optional)
- Analysis of test results – Complete the table provided and show one sample calculation. Determine the cohesion and angle of internal friction of the given soil sample.
- Summary and conclusions – Comment on the shear strength parameter of the tested soil.

CHAPTER 10.

TRIAXIAL TEST

INTRODUCTION

The triaxial shear test is the most versatile of all of the methods for testing the shear strength of soil and finding its cohesion (c) and angle of internal friction (ϕ). It can measure the total, as well as the effective stress parameters, and can be conducted on any type of soil. Drainage conditions can be controlled, and pore water pressure and volume changes can be measured accurately. The failure plane is not forced in this test, and the stress distribution of the failure plane is fairly uniform. Specimens can fail on any weak plane or can simply bulge.
The three primary triaxial tests conducted in the laboratory each allow the soil response for differing engineering applications to be observed. These are:

- Unconsolidated undrained test (UU)
- Consolidated undrained test (CU)
- Consolidated drained test (CD)

The unconsolidated undrained (UU) test is the simplest and fastest. The soil specimens are loaded, and only the total stresses are controlled and recorded. This allows determination of the undrained shear strength, c_u, which is suitable for assessing the soil stability in the short-term (e.g., during or directly following a construction project). The test is generally performed on cohesive soil specimens; however, remolded sand samples can also be tested. The consolidated drained (CD) test describes the long-term loading response, and provides the strength parameters determined under effective stress control (i.e. ϕ and c'). It can take a significant time to complete when using cohesive soil, because the shear rate must be slow enough to allow negligible pore water pressure changes. Finally, the consolidated undrained (CU) test is the most common triaxial procedure, as it allows strength parameters to be determined based on the effective stresses (i.e., ϕ' and c') while permitting a faster rate of shearing than the CD test. This is achieved by recording the excess pore pressure change that occurs within the specimen as shearing takes place. In this manual, the basics of the UU triaxial test is covered.

PRACTICAL APPLICATION

The triaxial test, which determines the shear strength and stiffness of soil and rock, is one of the most versatile and widely performed geotechnical laboratory tests that is used in geotechnical design.
Two parameters of shear strength are required for the design of slopes and for many other analyses: calculation of the bearing capacity of any strata, and calculation of the consolidation parameters.

OBJECTIVE

The objective of this experiment is

- To determine the soil strength parameters

EQUIPMENT

- Triaxial test setup
- Sample tubes
- Rubber ring
- Open ended cylindrical section
- Weighing balance

STANDARD REFERENCE

- ASTM D4767: Standard Test Method for Consolidated Undrained Triaxial Compression Test for Cohesive Soils

METHOD

The general triaxial test procedure is discussed below.

SPECIMEN & SYSTEM PREPARATION

After a test specimen has been prepared from a soil sample, it is placed it into the triaxial cell. For cohesive soils, this may involve trimming undisturbed specimens extruded from Shelby tubes or cut from block samples. Granular soil specimens may require preparation directly on the pedestal, using a split-part mold. A membrane suction stretcher can be used to place the rubber membrane around the soil specimen once it is in position on the pedestal. Note that disturbance to the specimen should be kept to a minimum during the specimen preparation.
The triaxial cell other system components are assembled after placement of the specimen. During this stage, the cell is filled with fluid, the pressure/volume controllers are connected, and transducer readings are set.

SATURATION

The saturation process is designed to ensure that all voids within the test specimen are filled with water, and that the pore pressure transducer and drainage lines are properly de-aired. This may be achieved by applying a partial vacuum to the specimen to remove air and draw water into the transducer and drainage lines, followed by a linear increase of the cell and back pressures. At no point should the effective stress increase above the value required for shearing, as this leads to specimen over-consolidation. To assist the specimen in reaching full saturation, the following steps may be taken:

- Use de-aired water to fill voids in the specimens.

- Increase the back pressure to force air into the solution.

Before moving to the consolidation stage, a short test is performed to determine Skempton's B value to see whether the specimen's degree saturation is sufficiently high. This is called a B-check and requires that the specimen drainage is closed while the cell pressure is raised by approximately 50 kPa. Note, however, that B is soil-dependent, so while a normally consolidated soft clay will produce $B \approx 1.00$ at full saturation, a very dense sand or stiff clay may only show $B \approx 0.91$, even if full saturation has been reached.

CONSOLIDATION

The consolidation stage is used to bring the specimen to the effective stress state required for shearing. It is typically conducted by increasing the cell pressure while maintaining a constant back pressure that is often equal to the pore pressure reached during the final saturation B-check. This process is continued until the volume change (ΔV) of the specimen is no longer significant and at least 95% of the excess pore pressure has dissipated. The consolidation response can also be used to estimate a suitable rate of strain when shearing cohesive specimens.

SHEARING

The soil is sheared by applying an axial strain, ε_a, to the test specimen at a constant rate through upward (compression) or downward (extension) movement of the load frame platen. This rate, along with the specimen drainage condition, is dependent on the type of triaxial test being performed. Specimen response during the shear stage is typically monitored by plotting the deviator stress q or effective principal stress ratio (σ_1/σ_3) against the axial strain, ε_a. This stage is continued until a specified failure criterion has been reached, which may include identifying the peak deviator stress or peak effective principal stress ratio; observing the constant stress and excess pore pressure/ volume change values; or simply reaching a specific value of axial strain.

Figure 10.1: Measuring the specimen

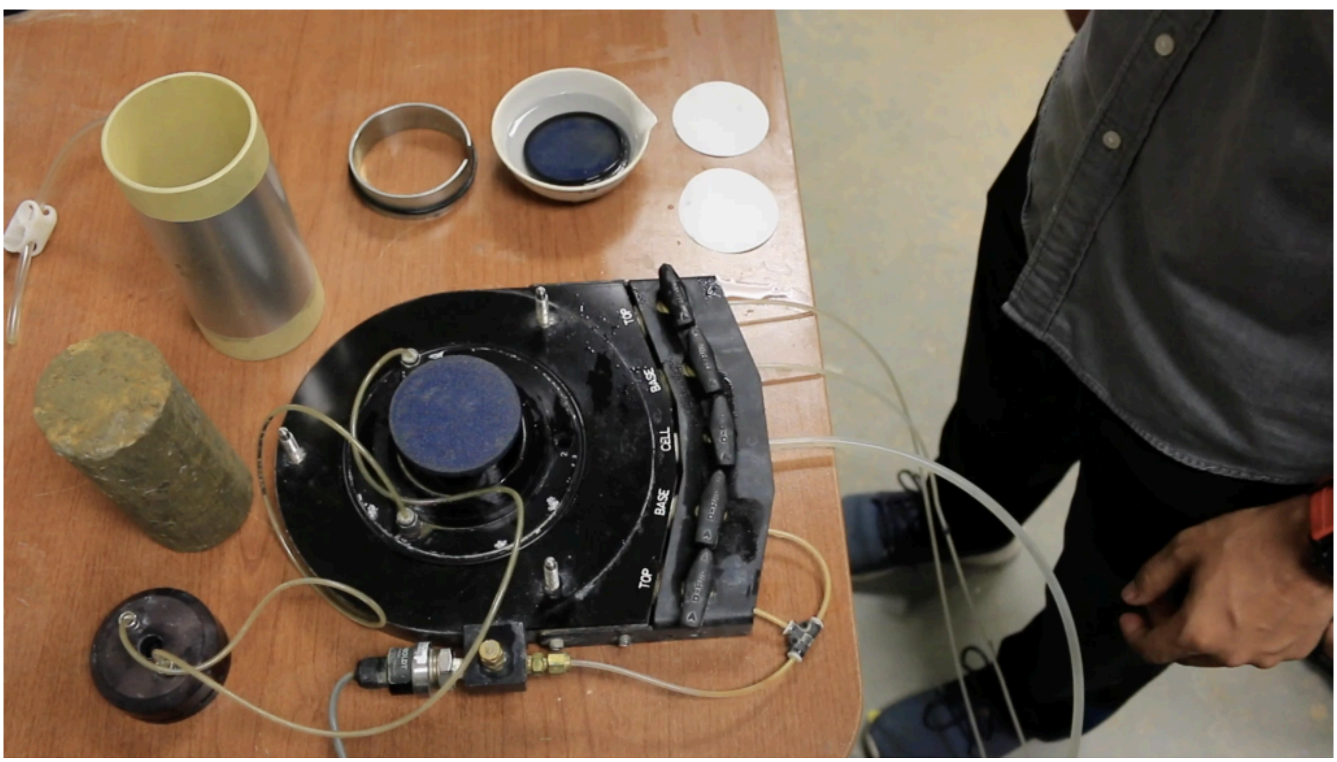

Figure 10.2: Triaxial test apparatus

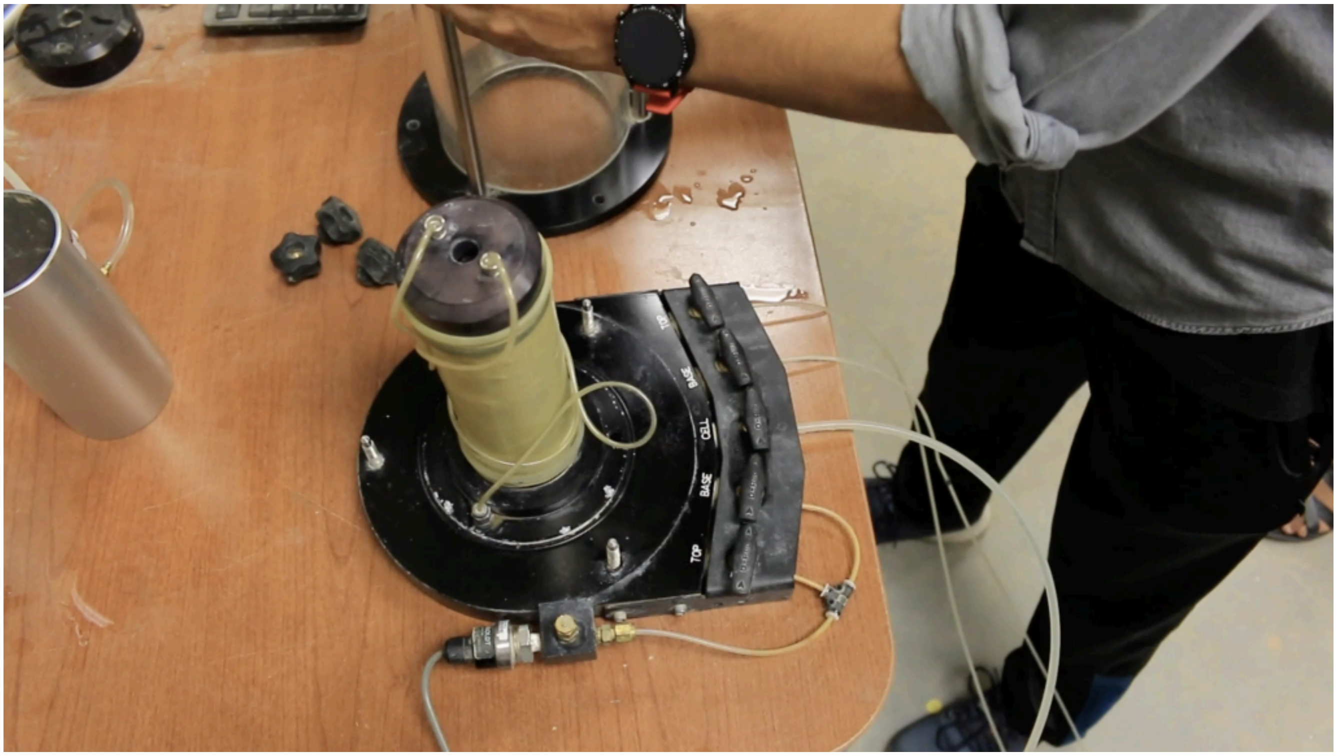

Figure 10.3: Placing the specimen on the triaxial base

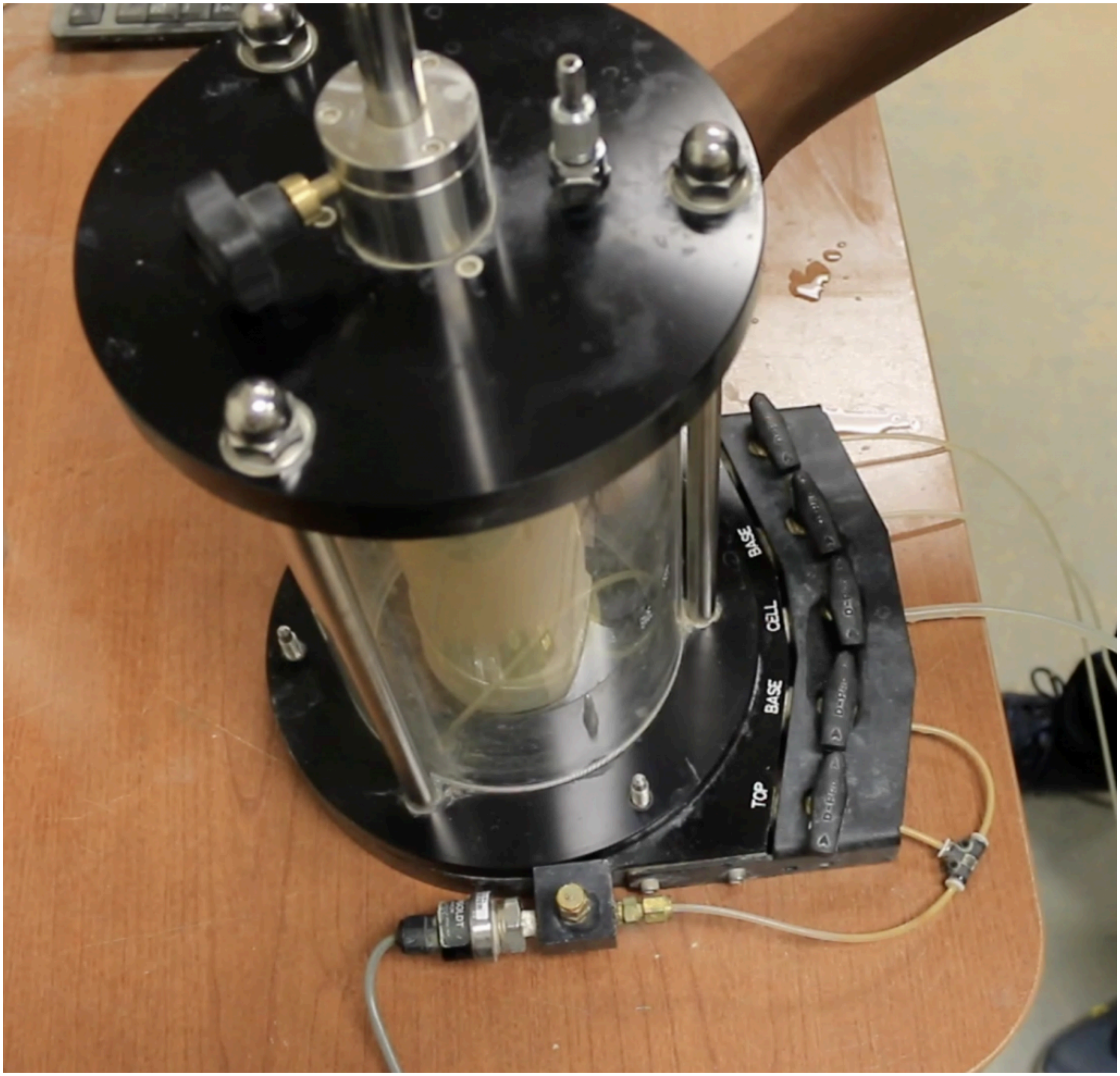

Figure 10.4: Setting up the apparatus

Figure 10.5: Triaxial control panel

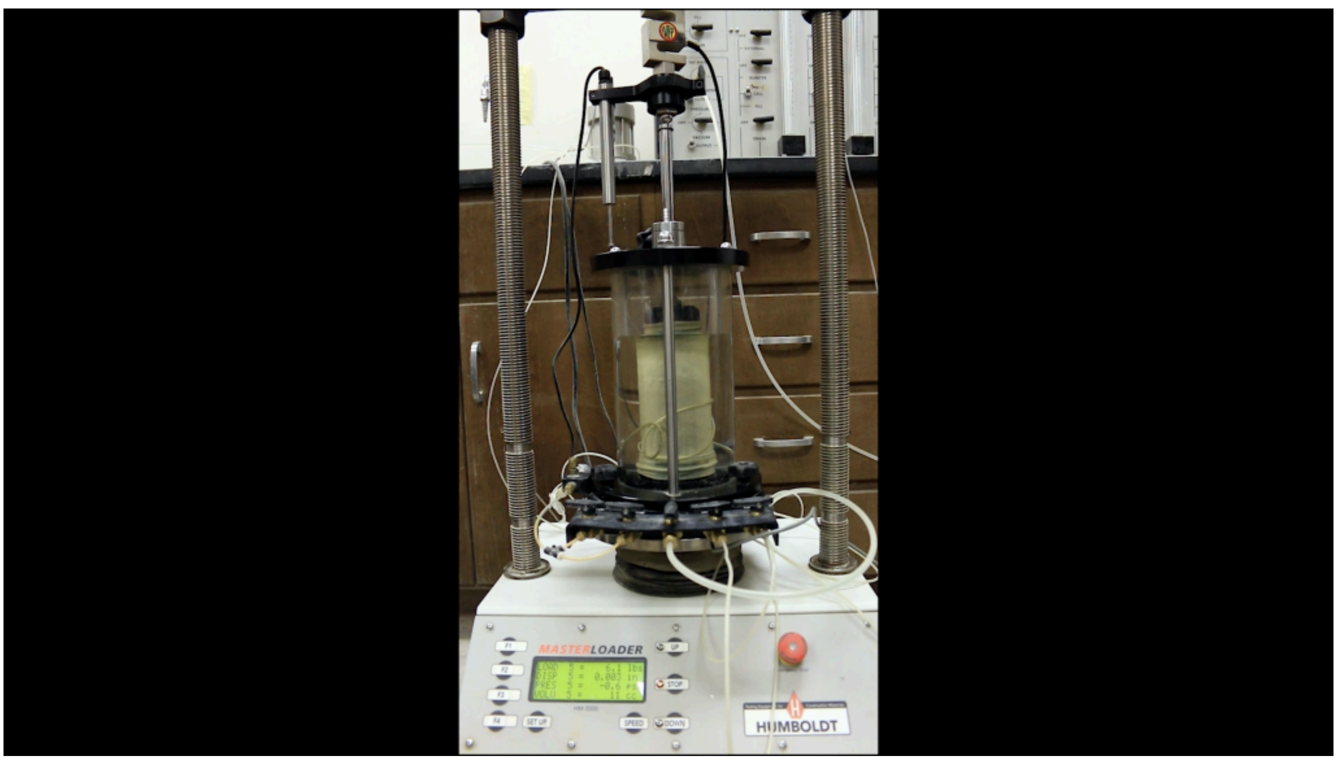

Figure 10.6: Triaxial loading base

VIDEO MATERIALS

LECTURE VIDEO

A PowerPoint presentation is created to understand the background and method of this experiment.

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://uta.pressbooks.pub/soilmechanics/?p=307#oembed-1

DEMONSTRATION VIDEO

A short video is executed to demonstrate the experiment procedure and sample calculation.

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://uta.pressbooks.pub/soilmechanics/?p=307#oembed-2

RESULTS AND DISCUSSIONS

A sample calculation is shown for the unconsolidated undrained triaxial test.

CALCULATE AXIAL STRAIN:

$\varepsilon = \Delta L / L$
Where,
ΔL = change in length of specimen as read from deformation indicator, mm (in.)
L_0 = initial length of specimen minus any change in length prior to loading, mm (in.)
Calculate the average cross-sectional area for a given applied axial load (A_p):
$A_p = A_o/(1-\varepsilon)$
Determine the principal stresses at failure:
Minor principal stress (3):
σ_3= Chamber pressure
Major principle stress (1):
σ_1= Deviator stress at failure plus chamber pressure
Calculate the deviator stress for a given applied load: $(\sigma_1 - \sigma_3) = P/A_p$
Where,
A_p = initial average cross-sectional area of the specimen, m^2($in.^2$)
P = given applied axial load (corrected for uplift and piston friction, if required), kPa (psi).
Graph the relationship between deviator stress (principal stress difference) and axial strain, plotting the deviator stress as ordinate and axial strain as abscissa. When testing a large number of samples,

failure occurs when the same stresses are obtained for three or more consecutive strain readings. Graph the circle of stress as shown in Figure 10.7.

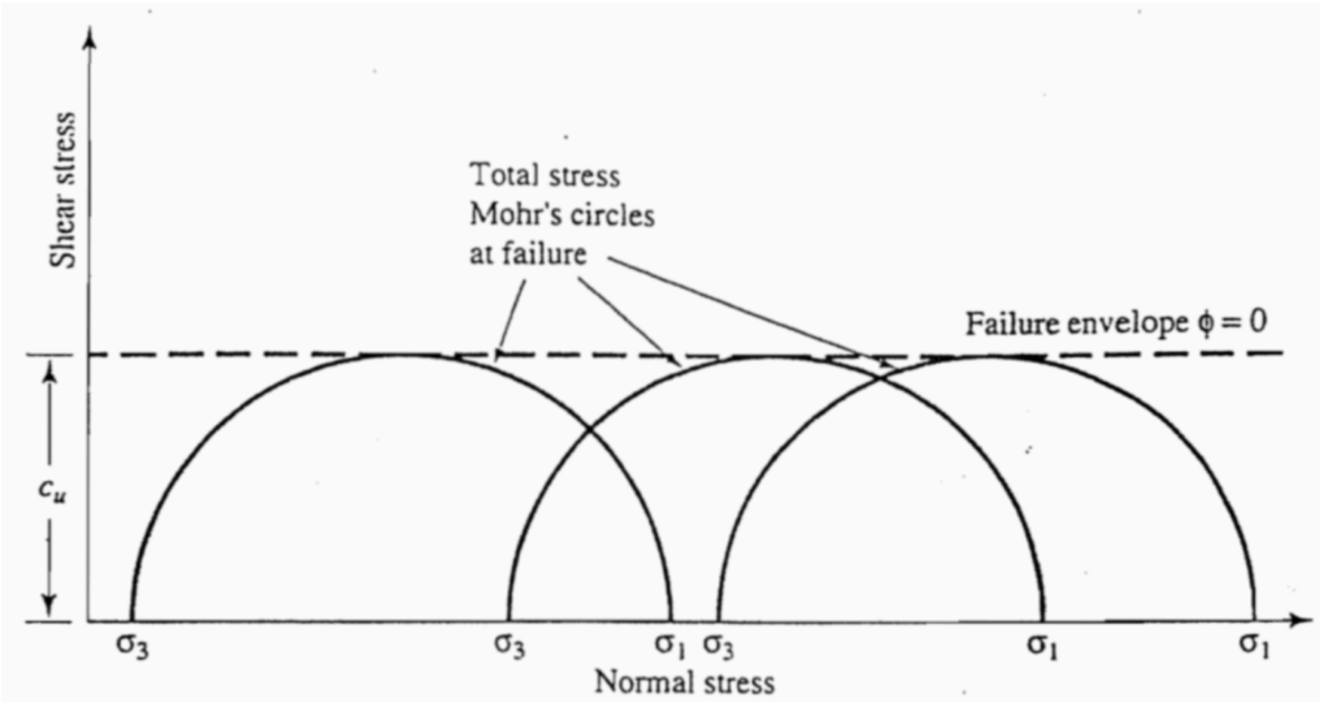

Figure 10.7: Total stress Mohr's circles and failure envelope(ϕ=0)obtained from unconsolidated undrained triaxial tests on fully saturated cohesive soil

REPORT

Use the template provided to prepare your lab report for this experiment. Your report should include the following:

- Objective of the test
- Applications of the test
- Apparatus used
- Test procedures (optional)
- Analysis of test results – Complete the table provided and show one sample calculation.
- Summary and conclusions – Comment on the shear strength value of the soil.

CHAPTER 11.

UNCONFINED COMPRESSIVE STRENGTH TEST

INTRODUCTION

The unconfined compression test is the most popular method of soil shear testing because it is one of the fastest and least expensive methods of measuring shear strength. It is used primarily for saturated, cohesive soils recovered from thin-walled sampling tubes. The test is not applicable to cohesionless or coarse-grained soils.

The unconfined compression test is strain-controlled, and when the soil sample is loaded rapidly, the pore pressures (water within the soil) undergo changes that do not have enough time to dissipate. Hence it is representative of soils in construction sites where the rate of construction is very fast and the pore waters do not have time to dissipate.

PRACTICAL APPLICATION

The test is used in all geotechnical engineering designs (e.g., design and stability analysis of foundations, retaining walls, slopes, and embankments) to obtain a rough estimate of the soil strength and determine the viable construction techniques.

OBJECTIVE

The objective of this experiment is

- To determine the unconfined compressive strength (q_u) of the soil

EQUIPMENT

- Unconfined compression testing machine (triaxial machine)
- Specimen preparation equipment
- Sample extruder
- Balance

STANDARD REFERENCE

- ASTM D2166: Standard Test Method for Unconfined Compressive Strength of Cohesive Soil

METHOD

- Remolded specimens are prepared in the laboratory and are dependent upon the Proctor data pertaining to the required molding water content.
- If testing undisturbed specimens retrieved from the ground by various sampling techniques,

trim the samples into regular triaxial specimen dimensions (2.8 inch x 5.6 inch)

Figure 11.1: Measuring the specimen width

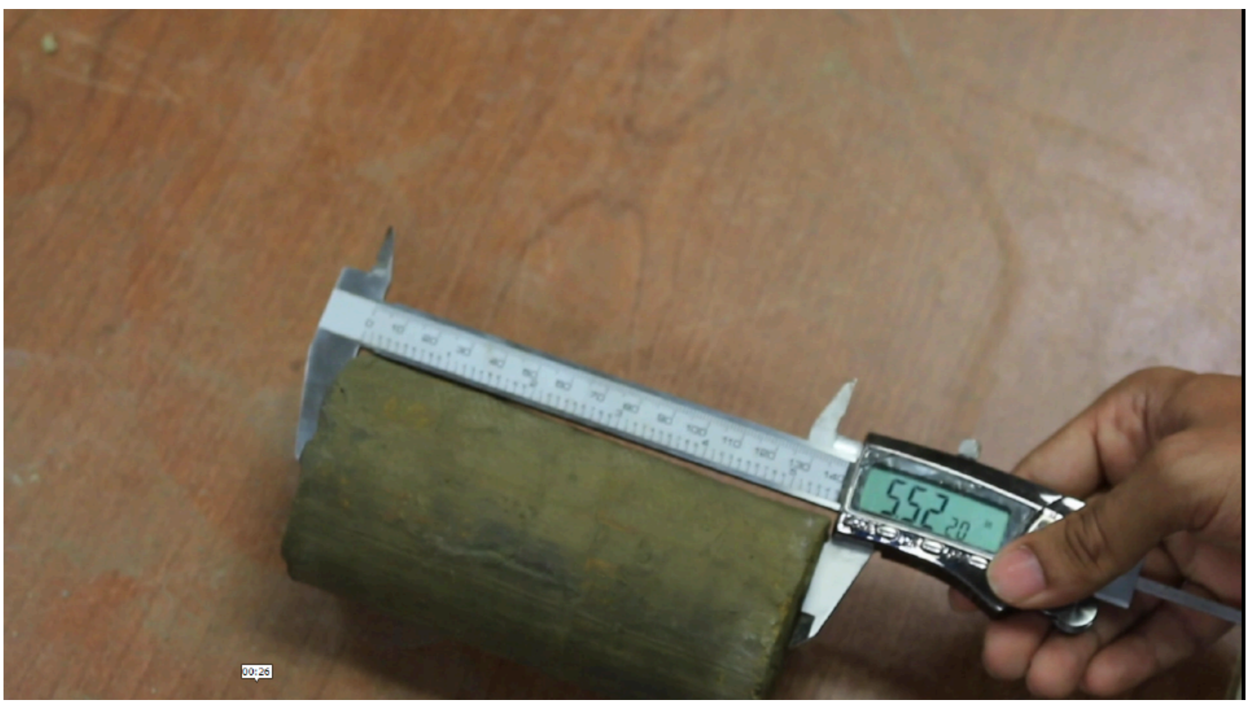

Figure 11.2: Measuring the specimen height

- There will be significant variations in the strength of undisturbed and remolded samples. Measure the diameter and length of the specimen to be tested
- If curing the soil samples (treated soils), wrap them in a geotextile and put them in a ziplock bag. Place the sample in a humidity room maintained at a relative humidity of 90%.

Figure 11.3: Unconfined compression

- Prior to testing, avoid any moisture loss in the sample, and place it on an acrylic triaxial base. The ends of the sample are assumed to be frictionless.
- Without applying confinement, place the triaxial cell above the sample.
- Maintain the rate of strain at 1.2700 mm/min, as per ASTM specifications.

Figure 11.4: Broken specimen

- Stop the test when you observe a drop in the strain versus load plot. The data acquisition system collects real-time data.

VIDEO MATERIALS

LECTURE VIDEO

A PowerPoint presentation is created to understand the background and method of this experiment.

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://uta.pressbooks.pub/soilmechanics/?p=312#oembed-1

DEMOSTRATION VIDEO

A short video is executed to demonstrate the experiment procedure and sample calculation.

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://uta.pressbooks.pub/soilmechanics/?p=312#oembed-2

RESULTS AND DISCUSSIONS

SAMPLE DATA SHEET

Diameter (d) = 7.29 cm
Length (L_0) = 14.78 cm
Mass = 1221.4 g

Table 11.1: Moisture content determination

Sample No.	1
Moisture can number- Lid number	A
M_C= Mass of empty, clean can + lid (grams)	15.6
M_CMS= Mass of can, lid, and moist soil (grams)	45.7
M_CDS= Mass of Can, lid, and dry soil (grams)	39.5
M_S= Mass of soil solids (grams)	23.9
M_W = Mass of pore water (grams)	6.2
W = Water content	25.94

Area (A_o)= p/ × (7.29)= 41.74 cm^2
Volume= p/4 × (7.29)2 × 14.78$= 616.9 cm^2

Wet density= 1221.4/616.9 = 1.98 g/cm^3
Water content (w%) = 25.9%
Dry density (γ_d) = 1.98/(1+25.9/100) =1.57 g/cm^3

Table 11.2: Unconfined Compression Test Data (Deformation Dial: 1 unit = 0.10mm; LoadDial: 1 unit = 0.3154 lb)

Deformation Dial Reading	Load Dial Reading	Sample Deformation (mm)	Strain	% Strain	Corrected Area, A	Load (lb)	Load (kN)	Stress (kPa)
0	0	0	0	0	41.7	0.0	0.0	0.0
20	4	0.2	0.001	0.1	41.8	1.3	56.1	1.3
40	9	0.4	0.003	0.3	41.9	2.8	126.3	3.0
60	12	0.6	0.004	0.4	41.9	3.8	168.4	4.0
80	19	0.8	0.005	0.5	42.0	6.0	266.6	6.4
100	21	1	0.007	0.7	42.0	6.6	294.7	7.0
120	24	1.2	0.008	0.8	42.1	7.6	336.8	8.0
140	26	1.4	0.009	0.9	42.1	8.2	364.9	8.7
160	29	1.6	0.011	1.1	42.2	9.1	406.9	9.6
180	33	1.8	0.012	1.2	42.3	10.4	463.1	11.0
200	36	2	0.014	1.4	42.3	11.4	505.2	11.9
250	45	2.5	0.017	1.7	42.5	14.2	631.5	14.9
300	54	3	0.020	2.0	42.6	17.0	757.8	17.8
350	64	3.5	0.024	2.4	42.8	20.2	898.1	21.0
400	74	4	0.027	2.7	42.9	23.3	1038.4	24.2
450	84	4.5	0.030	3.0	43.1	26.5	1178.8	27.4
500	93	5	0.034	3.4	43.2	29.3	1305.0	30.2
550	102	5.5	0.037	3.7	43.4	32.2	1431.3	33.0
600	112	6	0.041	4.1	43.5	35.3	1571.7	36.1
650	120	6.5	0.044	4.4	43.7	37.9	1683.9	38.6
700	129	7	0.047	4.7	43.8	40.7	1810.2	41.3
750	138	7.5	0.051	5.1	44.0	43.5	1936.5	44.0
800	144	8	0.054	5.4	44.1	45.4	2020.7	45.8
850	152	8.5	0.058	5.8	44.3	48.0	2133.0	48.2
900	160	9	0.061	6.1	44.4	50.5	2245.2	50.5
950	166	9.5	0.064	6.4	44.6	52.4	2329.4	52.2
1000	171	10	0.068	6.8	44.8	53.9	2399.6	53.6
1100	182	11	0.074	7.4	45.1	57.4	2554.0	56.6
1200	192	12	0.081	8.2	45.4	60.6	2694.3	59.3
1300	202	13	0.088	8.8	45.8	63.7	2834.6	61.9
1400	209	14	0.095	9.5	46.1	65.9	2932.8	63.6
1500	217	15	0.101	10.1	46.5	68.5	3045.1	65.6
1600	223	16	0.108	10.8	46.8	70.3	3129.3	66.9
1700	229	17	0.115	11.5	47.2	72.2	3213.5	68.1
1800	234	18	0.122	12.2	47.5	73.8	3283.7	69.1
1900	240	19	0.129	12.9	47.9	75.7	3367.9	70.3

2000	243	20	0.135	13.5	48.3	76.7	3410.0	70.6
2200	250	22	0.149	14.9	49.0	78.9	3508.2	71.5
2400	253	24	0.162	16.2	49.8	79.8	3550.3	71.2
2600	255	26	0.176	17.6	50.6	80.4	3578.3	70.7
2800	256	28	0.189	18.9	51.5	80.8	3592.4	69.8
3000	254	30	0.203	20.3	52.4	80.1	3564.3	68.1

Unconfined compressive strength, q_u = 71.5 kPa
Undrained cohesion, $c_u = q_u/2$= 35.75 kPa

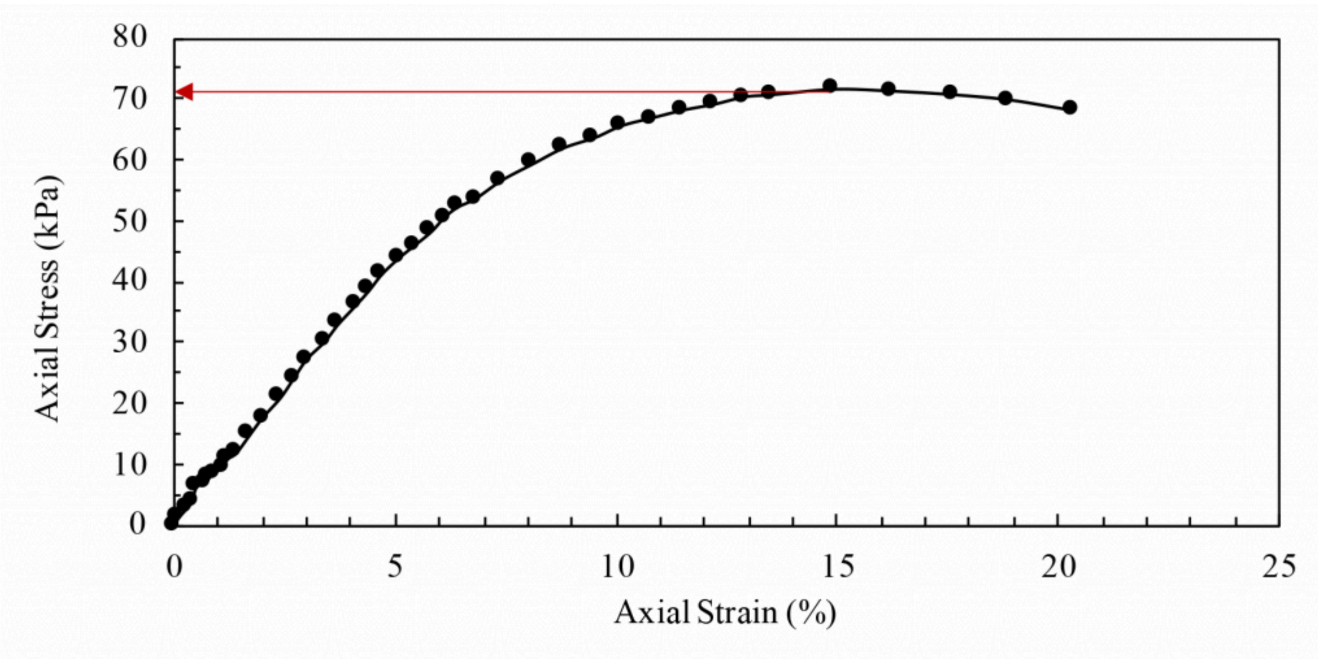

Figure 11.5: Axial stress vs axial strain graph

REPORT

Use the template provided to prepare your lab report for this experiment. Your report should include the following:

- Objective of the test
- Applications of the test
- Apparatus used
- Test procedures (optional)
- Analysis of test results – Complete the table provided and show one sample calculation.
- Summary and conclusions – Comment on the cohesion value of the tested sample.

CHAPTER 12.

CONSOLIDATION TEST

INTRODUCTION

Soil consolidation refers to the process by which the volume of a partially or fully saturated soil decreases due to an applied stress. When a load is applied to a low permeability soil, it is initially carried by the water that exists in the porous saturated soil and result in a rapid increase of pore water pressure. This excess pore water pressure is dissipated as water drains away from the soil's voids and the pressure is transferred to the soil skeleton, which is gradually compressed, resulting in settlements. The consolidation procedure lasts until the excess pore water pressure is dissipated.

PRACTICAL APPLICATION

The consolidation properties determined from the consolidation test are used to estimate the magnitude and rate of both primary and secondary consolidation settlement of a structure or an earth fill.
Estimates of this type are of key importance in the design of engineered structures and the evaluation of their performance.

OBJECTIVE

The objective of this experiment is

- To determine the consolidation parameters of soil for estimating the magnitude of settlement.

EQUIPMENT

- Consolidation device (including ring, porous stones, water reservoir, and load plate)
- Dial gauge (0.0001 inch = 1.0 on dial)
- Sample trimming device
- Glass plate,
- Metal straight edge
- Clock
- Moisture can
- Filter paper

STANDARD REFERENCE

- ASTM D2435: Standard Test Methods for One-Dimensional Consolidation Properties of

Soils Using Incremental Loading

METHOD

- Weigh the empty consolidation ring with the glass plate.
- Measure the height (h) of the ring and its inside diameter (d).
- Extrude the soil sample from the sampler, generally thin-walled Shelby tube. Determine the initial moisture content and the specific gravity of the soil.

Figure 12.1: Weight of the ring

- Cut an approximate a three-inch long sample. Place the sample on the consolidation ring and cut the sides of the sample to be approximately the same as the outside diameter of the ring. Rotate the ring and pare off the excess soil with the cutting tool so that the sample is reduced to the same inside diameter of the ring. It is important to keep the cutting tool in the correct horizontal position during this process.

Figure 12.2: Weight of the ring + sample

- As the trimming progresses, press the sample gently into the ring and continue until the sample protrudes a short distance through the bottom of the ring. Be careful throughout the trimming process to ensure that there is no void space between the sample and the ring.
- Turn the ring over carefully and remove the portion of the soil protruding above the ring. Using the metal straight edge, cut the soil surface flush with the surface of the ring. Remove the final portion with extreme care.
- Place the previously weighed Saran-wrap-covered glass plate on the freshly cut surface, turn the ring over again, and carefully cut the other end in a similar manner.

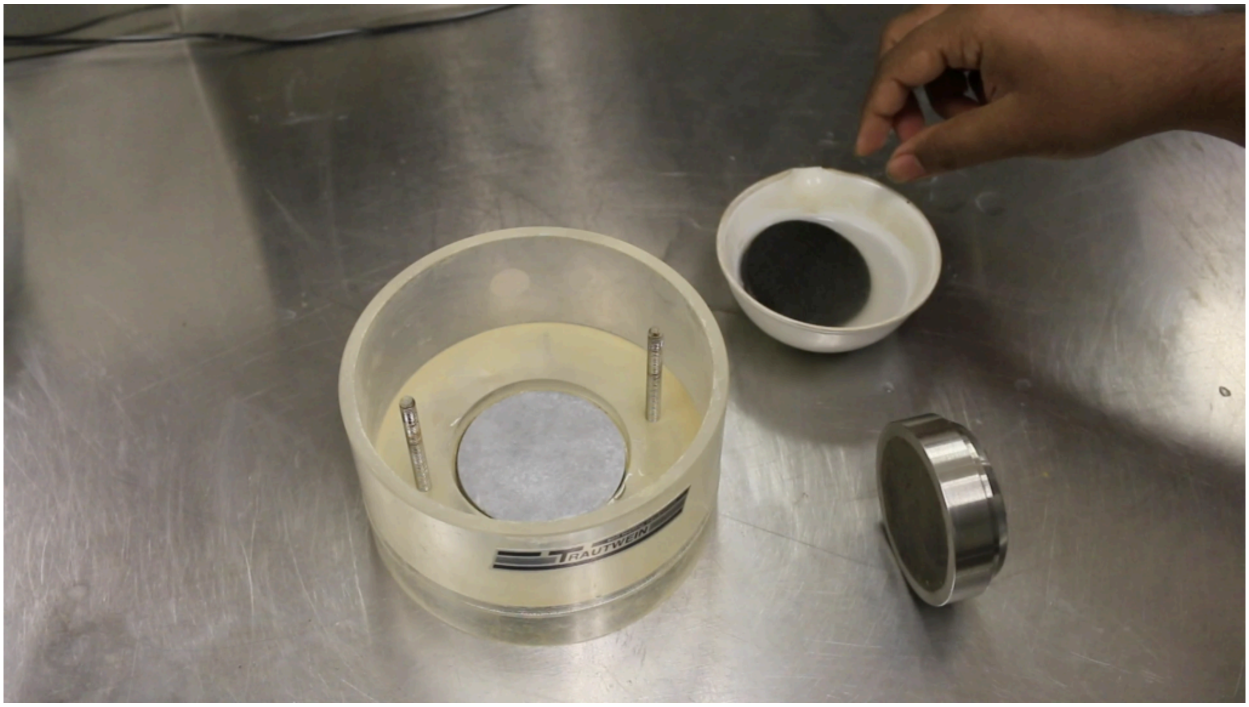

Figure 12.3: Specimen assembly

- Weigh the specimen plus ring plus glass plate.
- Carefully remove the ring with the specimen from the Saran-wrapped glass plate and peel the Saran wrap from the specimen surface. Center the porous stones that have been soaking, on the top and bottom surfaces of the test specimen. Place the filter papers between the porous stones and the soil specimen, pressing very lightly to ensure that the stones adhere to the sample. Lower the assembly carefully into the base of the water reservoir. Fill the water reservoir with water until the specimen is completely covered and saturated.

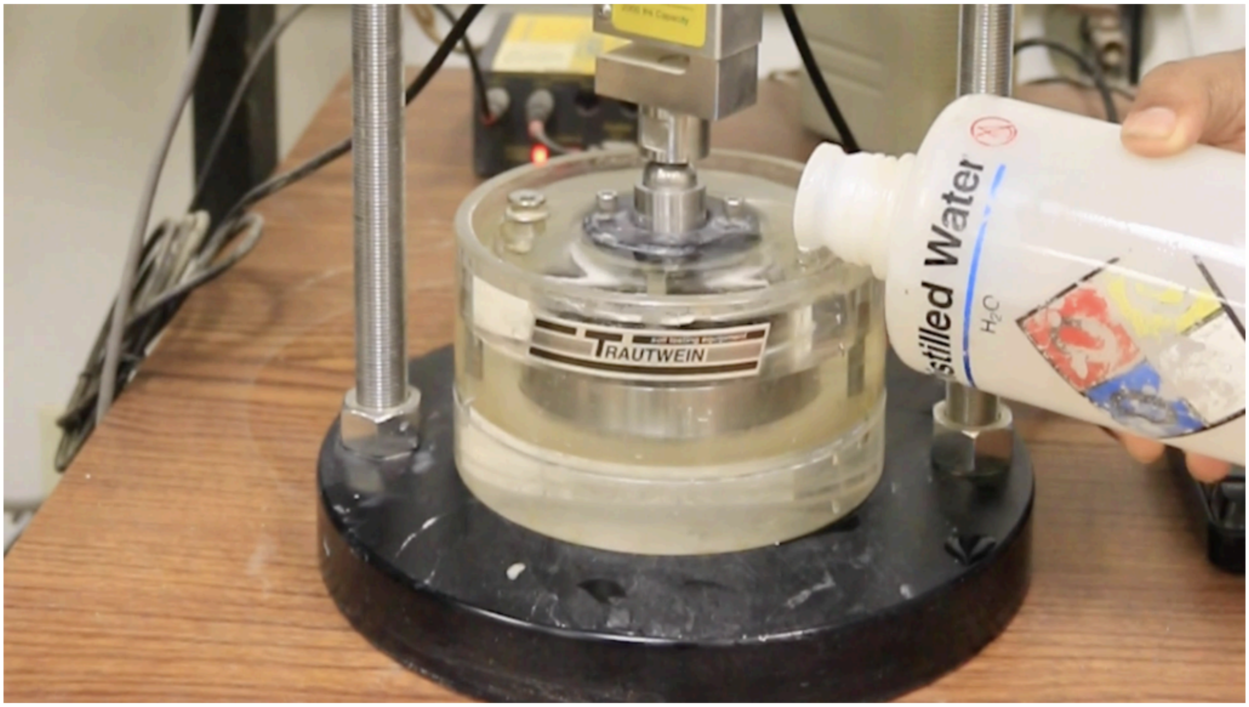

Figure 12.4: Pouring distilled water

- Being careful to prevent movement of the ring and porous stones, place the load plate in the center of the upper porous stone and adjust the loading device.
- Adjust the dial gauge to a zero reading.
- Set the pressure gauge dial (based on calibration curve) to result in an applied pressure of 0.5 tsf.
- Record the consolidation dial readings at the elapsed times given on the data sheet.
- The process needs to be repeated for different pre-selected pressures, which generally include loading pressures of 1.0, 2.0, 4.0, 8.0, and 16.0 tsf and unloading pressures of 8.0, 4.0, 2.0, 1.0 and 0.5 tsf.
- At the last elapsed time reading, record the final consolidation dial reading and time, release the load, and quickly disassemble the consolidation device and remove the specimen. Quickly but carefully blot the surfaces dry with paper toweling. (The specimen will tend to absorb water after the load is released.)

Figure 12.5: Consolidation device

- Place the specimen and ring on the glass plate and, weigh them together.
- Weigh a large empty moisture can and lid.
- Carefully remove the specimen from the consolidation ring, being sure not to lose too much soil, and place the specimen in the previously weighed moisture can. Place the moisture can containing the specimen in the oven and let it dry for 12 to 18 hours.
- Weigh the dry specimen in the moisture can.

ANALYSIS

- Calculate the initial water content and the specific gravity of the soil.
- For each pressure increment, construct a semi log plot of the consolidation dial readings versus the log time (in minutes). Determine D_0, D_{50}, D_{100}, and the coefficient of consolidation (c_v) using Casagrande's logarithm of time fitting method. See example data. Also calculate the coefficient of secondary compression based on these plots.
- Calculate the void ratio at the end of primary consolidation for each pressure increment (see example data). Plot the log pressure versus the void ratio. Based on this plot, calculate the compression index, recompression index, and preconsolidation pressure (maximum past pressure).
- Summarize and discuss the results.

VIDEO MATERIALS

LECTURE VIDEO

A PowerPoint presentation is created to understand the background and method of this experiment.

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://uta.pressbooks.pub/soilmechanics/?p=318#oembed-1

DEMONSTRATION VIDEO

A short video is executed to demonstrate the experiment procedure and sample calculation.

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://uta.pressbooks.pub/soilmechanics/?p=318#oembed-2

RESULTS AND DISCUSSIONS

SAMPLE CALCULATIONS

Weight of the ring = 156.8 g
Inside diameter of the ring = 2.5 in (6.35 cm)
Height of specimen, H_i = 1 in (2.54 cm)
Area of specimen, A = 31.67 cm^2
Mass of specimen + ring = 312.1 g
Initial moisture content of specimen, w_i (%) = 28.9%
Specific gravity of solids, G_s = 2.67
Final moisture content of specimen (after test), w_f= 27.3%
Weight of solids (before test) =155.3 g
Water content (before test) = 28.9%
Weight of dry specimen = 120.5 g
Specific gravity of soil, G_s= 2.72
Height of solids, $H_s = M_s/(A \times G_s \times \rho_w)$ =120.5/(31.67×2.72×1)= 1.40 cm (0.55 in)
Change in height of specimen after test, H =0.24 cm
(H for all pressures – see t vs Dial Reading plots)
Height of specimen after test, $H_f = H_i - H$ = 2.54-0.24 = 2.3 cm
Void ratio before test, $e_0 = (H_i-H_s)/H_s$ = (2.54-1.4)/1.4 = 0.816
Void ratio after test, $e_f = (H_f-H_s)/H_s$ = (2.3-1.4)/1.4 = 0.645
The sample calculation depicts only one time-settlement graph (for 400 kPa), but it needs to be drawn for each pressure increments. From these graphs, t_{50} can be determined which is useful for determining the coefficient of consolidation (c_v) values.

SOIL USED

Soil : Light Grey Clay

BH No: 05
Depth: 7 ft

SPECIMEN CONDITIONS

Specific gravity, G_s =2.72
Vol. of solids = 2.7035 in^3
Ht. of Solid ($2H_0$) = 0.5507 in
Ht. of Void (H_v) = 0.4493 in
Initial void ratio (e_0) =0.8157
Tare weight = 8.50 lbs.
Deformation Dial Constant = 0.0001 inch/div.

EQUIPMENT USED

Height of ring= 1 in.
Dia. Of ring = 2.5 in.
Area of sample= 4.9087 in^2
Wt. of ring= 156.8 gm
Wt. of ring+soil (before test)= 312.10 gm
Wt. of soil (before test)= 155.3 gm
Water Content (before test)= 28.9%
Wt. of dry specimen= 120.50 gm

Scale load lbs.	Applied load, lbs	Pressure, kPa	Final Dial reading	Dial change in.	Sample Ht. (2H), in.	Void Ht. (2H-$2H_o$)	Void ratio
8.5	0.00	0.00	706	0	1	0.4493	0.816
15.62	7.12	10.00	874	0.0168	0.9832	0.4325	0.785
26.30	17.80	25.00	965	0.0091	0.9741	0.4234	0.769
44.10	35.60	50.00	1093	0.0128	0.9613	0.4106	0.745
79.70	71.20	100.01	1275	0.0182	0.9431	0.3924	0.712
150.90	142.40	200.01	1505	0.023	0.9201	0.3694	0.671
293.30	284.80	400.03	1815	0.031	0.8891	0.3384	0.614
578.10	569.60	800.06	2197	0.0382	0.8509	0.3002	0.545
293.30	284.80	400.03	2149	-0.0048	0.8557	0.3050	0.554
79.70	71.20	100.01	1981	-0.0168	0.8725	0.3218	0.584
15.62	7.12	10.00	1645	-0.0336	0.9061	0.3554	0.645

RESULTS

Compression Index (C_c) = 0.23
Re-compression Index (C_r) = 0.06
Preconsolidation Pressure (P_c) or Maximum Past Pressure (v_{max}) = 115 kPa
Coefficient of Consolidation (C_v)= 4.2 to 7.25 m^2/year (depends on the pressure)

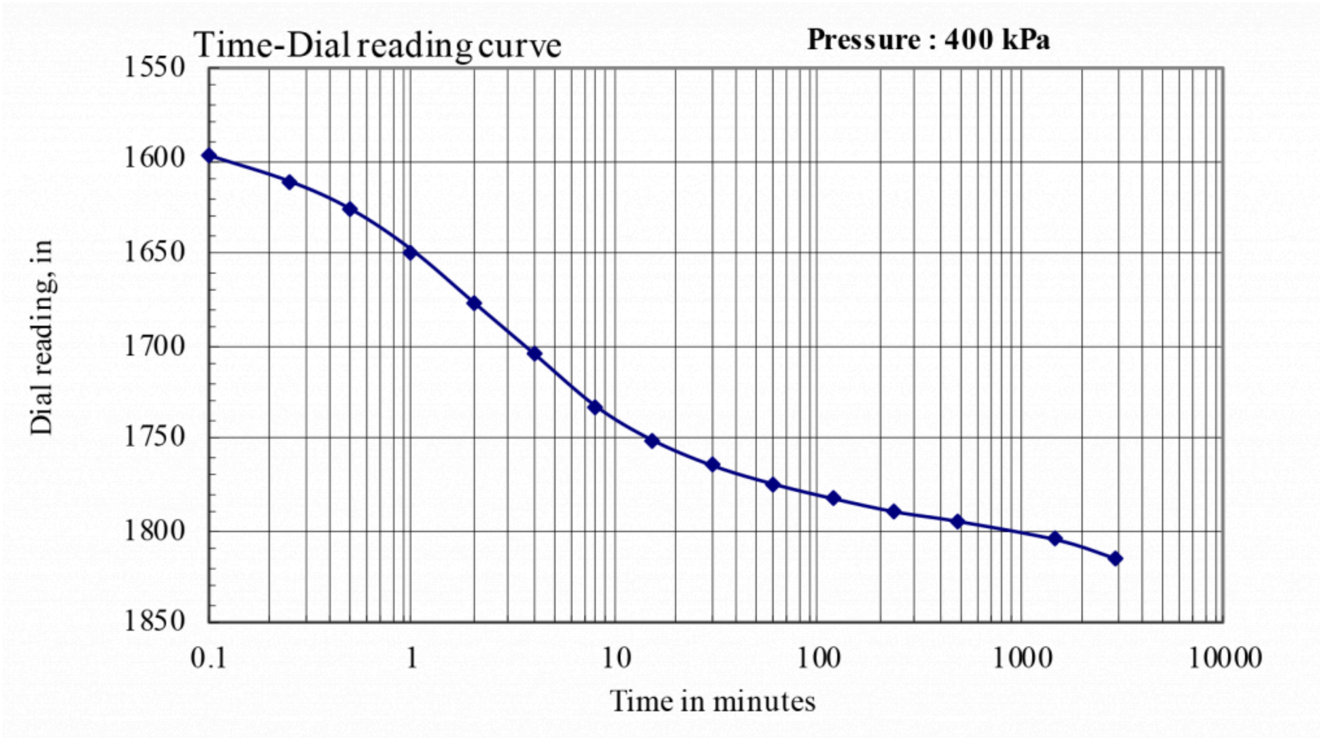

Figure 12.6: Time settlement graph (for 400 kPa pressure)

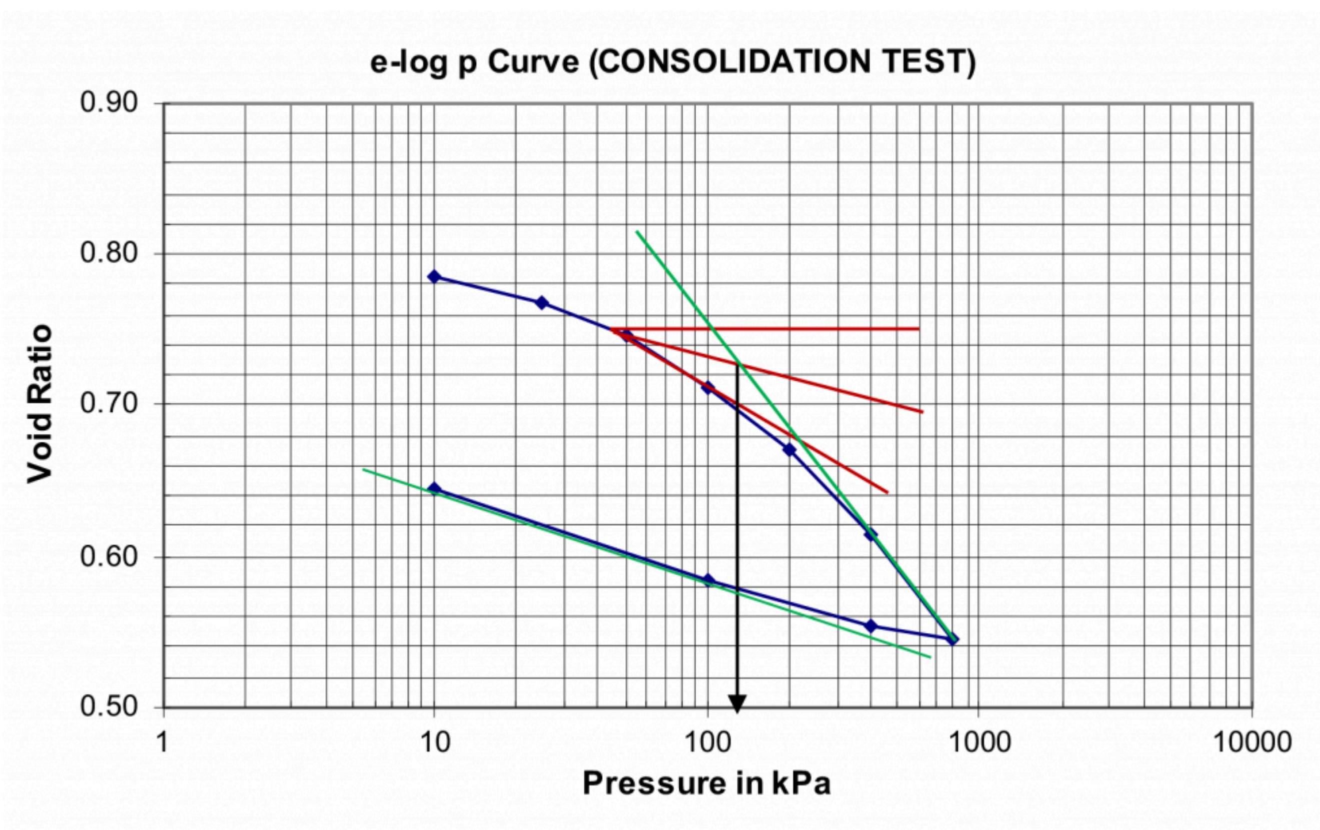

Figure 12.7: e-logP curve

REPORT

Use the template provided to prepare your lab report for this experiment. Your report should include the following

- Objective of the test
- Applications of the test
- Apparatus used
- Test procedures (optional)
- Analysis of test results – Complete the table provided and show one sample calculation. Draw the e-logP curve and determine C_c, C_r and the preconsolidation pressure.
- Summary and conclusions – Comment on the results. Discuss how the obtained value will be helpful for determining the consolidation settlement in the field.

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LINKS BY CHAPTER

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LECTURE VIDEO

Experiment #1: Determination of Moisture Content (https://youtu.be/1Rb1kW_mWmA)

Experiment #2: Specific Gravity Test (https://youtu.be/vDMxA8mWuKM)

Experiment #3: Sieve Analysis (https://youtu.be/tM2NXWqAGB8)

Experiment #4: Hydrometer Analysis (http://youtu.be/JuTDHmzAB7U)

Experiment #5: Atterberg Limit Test (http://youtu.be/AhyxdEXnJ2U)

Experiment #6: Compaction Test (https://youtu.be/CXe66jSGceM)

Experiment #7: In-Situ Density (https://youtu.be/RTBug3YGrC4)

Experiment #8: Permeability Test (https://youtu.be/-gn5G23AAKo)

Experiment #9: Direct Shear Test (http://youtu.be/HCOmWVQsWFo)

Experiment #10: Triaxial Test (http://youtu.be/ggf7QkHxd9k)

Experiment #11: Unconfined Compressive Strength Test (https://youtu.be/FTX51D7hQxc)

Experiment #12: Consolidation Test (http://youtu.be/ikOoIXPmDGA)

DEMONSTRATION VIDEO

Experiment #1: Determination of Moisture Content (https://youtu.be/fobs0J9kK5I)

Experiment #2: Specific Gravity Test (https://youtu.be/GJKVRnXhbo8)

Experiment #3: Sieve Analysis (https://youtu.be/s5LVA5LDiFo)

Experiment #4: Hydrometer Analysis (http://youtu.be/TT0gbVJSuTw)

Experiment #5: Atterberg Limit Test (http://youtu.be/9tBa-NQKnso)

Experiment #6: Compaction Test (https://youtu.be/Xo7bY60sF3M)

Experiment #7: In-Situ Density (https://youtu.be/MXTye3qTruc)

Experiment #8: Permeability Test (http://youtu.be/P1NUBmO8F_Q)

Experiment #9: Direct Shear Test (http://youtu.be/M61WTJIdqXA)

Experiment #10: Triaxial Test (http://youtu.be/SnlG5ZwF5I0)

Experiment #11: Unconfined Compressive Strength Test (https://youtu.be/E98zD4FgbH4)

Experiment #12: Consolidation Test (http://youtu.be/fzMCYC1sfmE)