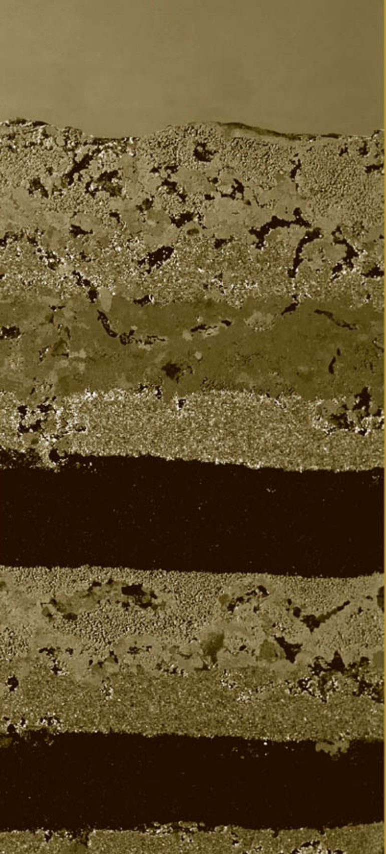

MICHAEL E. KALINSKI

SOIL Mechanics

LAB MANUAL

2nd Edition

NOTATION

Letters

A = cross-sectional area
c' = effective cohesion
C_c = compression index
C_r = recompression index
c_v = coefficient of vertical consolidation
D = particle size
e = void ratio
F = shear force
g = gravitational acceleration constant
G_s = specific gravity of soil solids
h = head
i = hydraulic gradient
k = hydraulic conductivity
LL = liquid limit
M = total mass of soil
M_s = mass of solids in soil
M_w = mass of water in soil
n = porosity
N = normal force
P = percent of soil solids finer than D
PI = plasticity index
PL = plastic limit
q = flow rate
Q = flow volume
q_u = unconfined compressive strength
S = degree of saturation
s_u = undrained shear strength
t = time
u = pore pressure
V = total volume of soil
V_s = volume of solids in soil
V_v = volume of voids in soil
V_w = volume of water in soil
v_D = Darcian velocity
v_s = seepage velocity
W = total weight of soil
w = moisture content
w_{opt} = optimum moisture content
W_s = weight of solids in soil
W_w = weight of water in soil

Symbols

$\Delta\sigma$ = deviator stress
ε = axial strain
ϕ' = effective friction angle
γ = total unit weight
γ_d = dry unit weight
γ_{dmax} = dry unit weight corresponding to w_{opt}
γ_w = unit weight of water
σ = total stress
σ' = effective stress
σ_1 = major principal stress
σ_3 = minor principal stress
σ'_{max} = max. previous consolidation pressure
τ = shear stress
τ_f = shear strength

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SOIL MECHANICS LAB MANUAL

2nd Edition

Michael E. Kalinski, Ph.D., P.E.
University of Kentucky

WILEY

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PREFACE

This manual is written for the laboratory component of a typical one-semester undergraduate soil mechanics course as part of a typical civil engineering undergraduate curriculum. The manual is written as a stand-alone document, but supporting media have also been prepared to enhance the learning process. These resources are available online at www.wiley.com/college/kalinski, and include the following:

- **Video Demonstrations.** Brief (10-20 minutes) video demonstrations have been produced for each laboratory test. Each video describes the basic purpose of the test, lists the required materials, demonstrates the step-by-step procedure, and details methods for reducing the data. Viewing these videos prior to the lab will help prepare the students for the lab exercise, and ultimately enhance the students' learning experiences.

- **Laboratory Data Sheets.** Generic laboratory data sheets have been prepared for each exercise, and are included at the end of each chapter. These data sheets are intended for use by students, researchers, or practicing engineers. These forms can also be downloaded off of the website listed above.

Michael E. Kalinski
University of Kentucky

ACKNOWLEDGMENTS

This soil mechanics laboratory manual was inspired by the undergraduate students that I have taught over the past 15 years at the University of Texas at Austin and the University of Kentucky. They taught me what is important and what is effective with respect to laboratory instruction, and those lessons have helped to shape this manual. To them, I express my utmost gratitude.

I would also like to extend my gratitude to all of my friends and colleagues who have helped to make this manual possible. Dave Daniel, Roy Olson, Ken Stokoe, Priscilla Nelson, and Steven Wright at the University of Texas at Austin inspired me as a graduate student to learn about soil mechanics and become an instructor. Bobby Hardin, Issam Harik, and Jerry Rose provided ample guidance and encouragement to me as a young professor here at UK. Erwin Supranata provided valuable input and suggestions as a graduate student at UK working in the soils lab. Bettie Jones, Jim Norvell, Ruth White, Shelia Williams, and Gene Yates have provided administrative assistance and support in the lab, without which this manual would not have been possible. Darchelle Leggett, Mary Moran, Wendy Perez, and Jenny Welter provided guidance and encouragement to help me through the publication process with Wiley. Seven of my colleagues who reviewed the manual, including Joe Caliendo, Jeffrey Evans, and Robert Johnson, provided constructive criticism and suggestions that greatly enhanced the quality and usefulness of this manual. Terry Edin, Kelan Griffin, and Stuart Reedy provided valuable assistance and resources at UK during the production of the video demonstrations that accompany this manual.

Finally, I would like to thank my family: Pamela, Jackson, and Lucas, for bringing me happiness every day. This manual is dedicated to them.

Michael E. Kalinski
University of Kentucky

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1. INTRODUCTION

1.1. THE IMPORTANCE OF LABORATORY SOIL MECHANICS TESTING

Soil can exist as a naturally occurring material in its undisturbed state, or as a compacted material. Geotechnical engineering involves the understanding and prediction of the behavior of soil. Like other construction materials, soil possesses mechanical properties related to strength, compressibility, and permeability. It is important to quantify these properties to predict how soil will behave under field loading for the safe design of soil structures (e.g. embankments, dams, waste containment liners, highway base courses, etc.), as well as other structures that will overly the soil. Quantification of the mechanical properties of soil is performed in the laboratory using standardized laboratory tests.

1.2. OVERVIEW OF MANUAL CONTENTS

The main objectives of a laboratory course in soil mechanics are to introduce soil mechanics laboratory techniques to civil engineering undergraduate students, and to familiarize the students with common geotechnical test methods, test standards, and terminology. The procedures for all of the tests described in this manual are written in accordance with applicable American Society for Testing and Materials (ASTM) standards. It is important to be familiar with these standards to understand, interpret, and properly apply laboratory results obtained using a standardized method. Each test described in this manual has an associated ASTM standard number as summarized in Table 1.1.

Each chapter in the manual describes one test, but the instructor may choose to combine more than one test during a given laboratory session. For example, the moisture content and specific gravity laboratory exercises are relatively short, so it would be reasonable to combine these exercises into one three-hour laboratory period. Each chapter is structured in the same manner, and includes the following sections:

- Section 1 – Applicable ASTM Standards;
- Section 2 – Purpose of Measurement;
- Section 3 – Definitions and Theory;
- Section 4 – Equipment and Materials;
- Section 5 – Procedure;
- Section 6 – Expected Results (for quantitative measurements);
- Section 7 – Likely Sources of Error;
- Section 8 – Additional Considerations; and
- Section 9 – Suggested Exercises.

Laboratory data sheets are included at the end of each chapter. Data sheets are written to be used for practical purposes as well as educational purposes, with places to insert information regarding project, boring number, and soil Recovery Depth/Method.

Additional data sheets can be found on the companion website that accompanies this manual (www.wiley.com/college/kalinski). When accessing the website, you will need your registration code, which can be found on the card inside the envelope just inside the front cover of the manual.

Table 1.1—List of laboratory exercises and applicable ASTM standards

Laboratory Exercise	Chapter	Applicable ASTM Standard(s)
Moisture Content of Soil	2	D2216
Specific Gravity of Soil Solids	3	D854
Liquid Limit and Plastic Limit of Soil	4	D4318
Analysis of Grain Size Distribution	5	D422, D1140
Laboratory Classification of Soil	6	D2488
Field Classification of Soil	7	D2487
Laboratory Soil Compaction	8	D698, D1557
Field Measurement of Dry Unit Weight	9	D1556, D2167
Hydraulic Conductivity of Granular Soil Using a Fixed Wall Permeameter	10	D2434
One-Dimensional Consolidation Test of Cohesive Soil	11	D2435
Direct Shear Strength Test of Granular Soil	12	D3080
Unconfined Compressive Strength Test	13	D2166
Unconsolidated-Undrained Triaxial Shear Strength Test of Cohesive Soil	14	D3018

1.3. REVIEW OF WEIGHT-VOLUME RELATIONSHIPS IN SOILS

Soil is a porous medium consisting of soil solids (mineral grains) and voids. Some of the voids are filled with air, and some are filled with water. The different components of soil (soil solids, water-filled voids, and air-filled voids) each possess weight and volume as defined in Fig. 1.1.

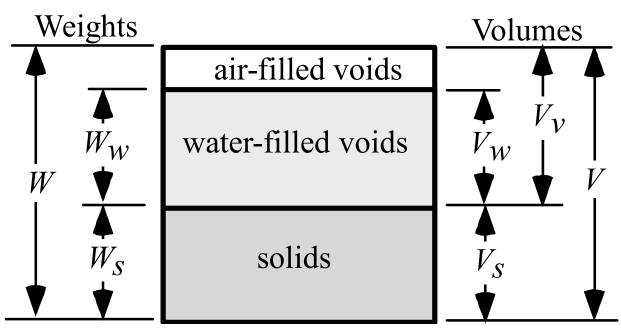

Fig. 1.1—Definitions of parameters used for weight-volume calculations in soil.

Throughout this manual, you will be required to perform weight-volume calculations of soil. Discussion of weight-volume relationships (a.k.a. phase relationships) is standard material for undergraduate soil mechanics lecture courses, but is also included in this manual for your information. This review does not present an exhaustive list of equations for you to remember. It simply includes a "toolbox" of basic definitions and relationships that you can use to perform most weight-volume relationship calculations. In soil mechanics, we define several terms based on the parameters shown in Fig. 1.1. These terms form the basis for weight-volume calculations, and are defined in Table 1.2.

Table 1.2—Basic terms used in weight-volume relationships in soil.

Term	Equation	Typical Range in Soil
Total Unit Weight	$\gamma = \frac{W}{V}$	90-140 lbs/ft^3 (pcf)
Dry Unit Weight	$\gamma_d = \frac{W_s}{V}$	80-130 pcf
Moisture Content	$w = \frac{W_w}{W_s} \text{ x } 100\%$	10-50%
Unit Weight of Water	$\gamma_w = \frac{W_w}{V_w}$	62.4 pcf
Specific Gravity of Soil Solids	$G_s = \frac{W_s}{\gamma_w V_s}$	2.65-2.80
Void Ratio	$e = \frac{V_v}{V_s}$	0.3-1.5
Porosity	$n = \frac{V_v}{V} \text{ x } 100\%$	25-60%
Degree of Saturation	$S = \frac{V_w}{V_v} \text{ x } 100\%$	10-100%

1.3. PREPARATION OF PROFESSIONAL-QUALITY GRAPHS

Many students have difficulty creating professional-quality graphs of experimental data simply because they have not received any formal guidance and instruction. With the widespread use of commercial graphics and spreadsheet software to create graphs, many students just assume the computer will automatically create an acceptable graph with the given data. However, this is usually not the case. One goal of this laboratory is to teach students how to present experimental data in a professional manner. An acceptable graph must satisfy all of the following criteria:

- Title that describes the test performed and the data presented;
- Date and name of creator;

- Major axes at a sensible interval;
- Use of appropriate scale (either logarithmic or linear);
- Axes labeled and units given; and
- Data that fill up most of the graph space.

Examples of acceptable and unacceptable graphs are shown in Figs. 1.2 and 1.3.

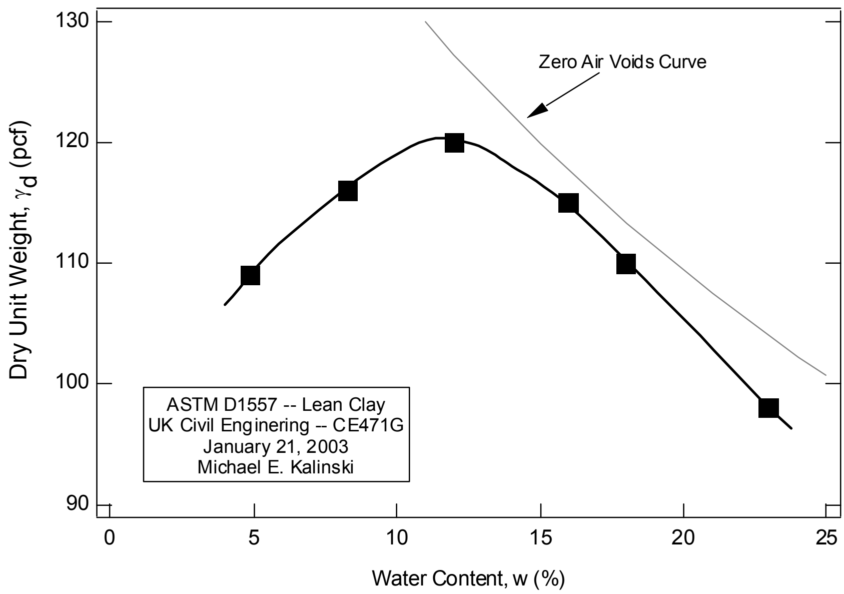

Fig. 1.2—Example of an acceptable graph.

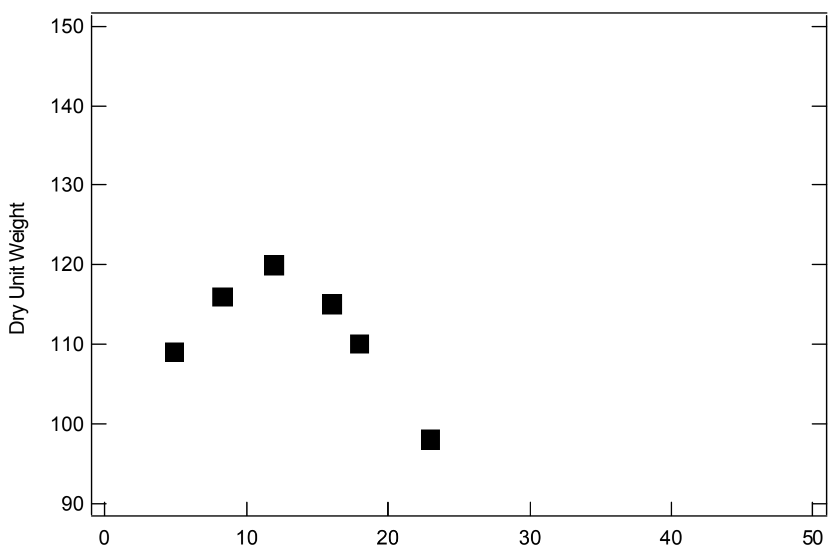

Fig. 1.3—Example of an unacceptable graph (axis label missing, units missing, graph title missing, and data do not fill the graph space).

When used properly, commercial software is a very valuable tool for graphically presenting data. When using commercial software, be careful when applying any automatic curve-fitting utility. Students often use this utility to obtain nonsensical results, which they blindly submit as part of their laboratory report without considering the validity of the curve fit. If an automatic curve-fitting utility is used, you should always check the curve fit against the expected trend.

1.4. VIDEO DEMONSTRATIONS

Brief video demonstrations of each lab can be found on the companion website that accompanies this manual (www.wiley.com/college/kalinski). When accessing the website, you will need your registration code, which can be found on the card inside the envelope just inside the front cover of the manual. Each demonstration includes a brief background of the test, required equipment, and step-by-step procedure for the measurement and reduction of experimental data. These demonstrations are not intended to replace the demonstrations and guidance provided by your laboratory instructor, but are merely intended to serve as a supplement to your educational experience. Nevertheless, it is recommended that you take the time to view each demonstration prior to the laboratory.

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2. MEASUREMENT OF MOISTURE CONTENT

2.1. APPLICABLE ASTM STANDARD

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

2.2. PURPOSE OF MEASUREMENT

Moisture content measurement is primarily used for performing weight-volume calculations in soils. Moisture content is also a measure of the shrink-swell and strength characteristics of cohesive soils as demonstrated in liquid limit and plastic limit testing.

2.3. DEFINITIONS AND THEORY

The mass of a given volume of moist soil is the sum of the mass of soil solids, M_s, and the mass of water in the soil, M_w. Moisture content, w, is defined as:

$$w = \frac{M_w}{M_s} x\,100\% . \qquad (2.1)$$

Moisture content is typically expressed as a percentage using two significant figures (e.g. 12%, 9.2%, etc.). Moisture content can range from a few percent for "dry" sands to over 100% for highly plastic clays. Even soils that appear to be "dry" possess some moisture.

2.4. EQUIPMENT AND MATERIALS

The following equipment and materials are required for moisture content measurements:

- Disturbed sample of moist soil;
- scale capable of measuring to the nearest 0.01 g;
- soil drying oven set at $110^{o} \pm 5\,^{o}$ C;
- 3 oven-safe containers; and
- permanent marker for labeling containers.

2.5. PROCEDURE[1]

The moisture content calculation is based on three measurements:

[1] Don't forget to visit www.wiley.com/college/kalinski to view the lab demo!

1) Mass of container, M_c;
2) mass of moist soil plus container before drying, M_1; and
3) mass of dry soil plus container after drying, M_2.

Moist soil is placed in an oven-safe container and dried for 12-16 hours in a soil drying oven. It is helpful to use an oven mitt or tongs to insert and remove the containers from the oven. The soil-filled container is weighed before and after drying to obtain M_1 and M_2, respectively, and w is calculated as:

$$w = \frac{M_w}{M_s} x\, 100\% = \frac{M_1 - M_2}{M_2 - M_c} x\, 100\% . \quad (2.2)$$

2.6. EXPECTED RESULTS

In coarse-grained soils such as sands and gravels, w may range from a few percent in drier soils to over 20% in saturated soils. In fine-grained soils such as silts and clays, the possible range in w is much higher due to the ability of clay minerals to adsorb water molecules. Moisture content in fine-grained soils may be as low as a few percent, to over 100% in higher-plasticity clays.

2.7. LIKELY SOURCES OF ERROR

For moisture content measurement, likely sources of error may include inadequate drying, or excessive drying beyond the recommended 12-16 hour drying period. According to ASTM D2216, soil should be dried at 110^{o}C for 12-16 hours. However, for soils containing a significant amount of organic material or hydrous minerals such as gypsum, some of the water is bound by the soil solids, so excessive drying will effectively drive some of the soil solids away and produce erroneous results. In these cases, the oven temperature should be reduced to 60^{o}C.

2.8. ADDITIONAL CONSIDERATIONS

With respect to moisture content measurements and specimen size, the recommended amount of soil required to obtain an accurate measurement increases with increasing maximum particle size, with a minimum of 20 g, as shown in Fig. 2.1.

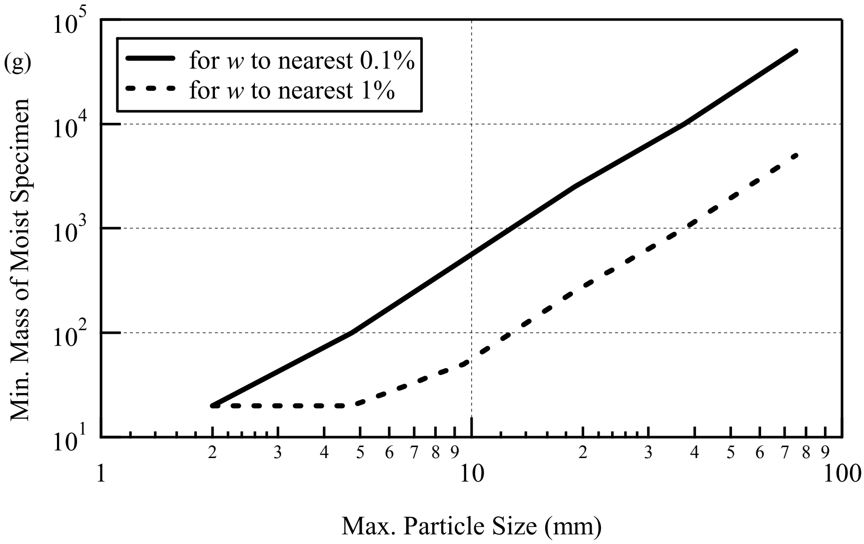

Fig. 2.1—Recommended minimum sample mass for moisture content testing based on maximum particle size.

2.9. SUGGESTED EXERCISES

1) Perform moisture content measurement of three specimens of the soil supplied by your instructor, and present your results using the Measurement of Moisture Content Laboratory Data Sheet at the end of this chapter (additional data sheets can be found on the CD-ROM that accompanies this manual).

2) What temperature should be used to dry most soil specimens for moisture content measurement? What exceptions exist, and what temperatures should be used for those exceptions?

3) How long should most specimens be dried to obtain an accurate moisture content measurement?

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MEASUREMENT OF MOISTURE CONTENT (ASTM D2216)
LABORATORY DATA SHEET

I. GENERAL INFORMATION

Tested by:	Date tested:
Lab partners/organization:	
Client:	Project:
Boring no.:	Recovery depth:
Recovery date:	Recovery method:
Soil description:	

II. TEST DETAILS

Oven temperature:	Drying time:
Scale type/precision/serial no.:	
Notes, observations, and deviations from ASTM D2216 test standard:	

III. MEASUREMENTS AND CALCULATIONS

Container ID:			
Mass of container (M_c):			
Mass of moist soil + container (M_1):			
Mass of dry soil + container (M_2):			
Mass of moisture (M_w):			
Mass of dry soil (M_s):			
Moisture content (w):			
Average moisture content:			

IV. EQUATION AND CALCULATION SPACE

$$w = \frac{M_1 - M_2}{M_2 - M_c} \times 100\%$$

3. MEASUREMENT OF SPECIFIC GRAVITY OF SOIL SOLIDS

3.1. APPLICABLE ASTM STANDARD

- ASTM D854: Standard Test Method for Specific Gravity of Soils

3.2. PURPOSE OF MEASUREMENT

Specific gravity of soil solids is used for performing weight-volume calculations in soils.

3.3. DEFINITIONS AND THEORY

Specific gravity of soil solids, G_s, is the mass density of the mineral solids in soil normalized relative to the mass density of water. Alternatively, it can be viewed as the mass of a given volume of soil solids normalized relative to the mass of an equivalent volume of water. Specific gravity is typically expressed using three significant figures. For sands, G_s is often assumed to be 2.65 because this is the specific gravity of quartz. Since the mineralogy of clay is more variable, G_s for clay is more variable, and is often assumed to be somewhere between 2.70 and 2.80 depending on mineralogy.

3.4. EQUIPMENT AND MATERIALS

The following equipment and materials are required for specific gravity of soil solids measurements:

- Oven-dried soil sample;
- scale capable of measuring to the nearest 0.01 g;
- 500-ml etched flask;
- distilled or demineralized water;
- squeeze bottle;
- thermometer capable of reading to the nearest 0.5^{o} C;
- funnel;
- stopper and tubing for connecting flask to vacuum supply; and
- vacuum supply capable of achieving a gauge vacuum of 660 mm Hg (12.8 psi).

Figure 3.1 is a photograph of the flask along with the stopper and tubing.

Fig. 3.1—Etched flask along with stopper and tubing for connecting to vacuum source.

3.5. PROCEDURE[1]

The procedure presented herein is consistent with ASTM D854 Test Method A, where an oven-dried specimen of soil is used. The specific gravity calculation is based on three measurements:

1) Mass of the flask filled with distilled water to the etch mark, M_a;
2) mass of the flask filled with water and soil to the etch mark, M_b; and
3) mass of the dry soil, M_o.

Specific gravity of soil solids, G_s, is calculated based on these three parameters:

$$G_s = \frac{M_o}{M_o + (M_a - M_b)} . \qquad (3.1)$$

Since the density of water is temperature-dependent, a temperature correction factor, K, may be applied to report G_s at a standard temperature of 20°C. The temperature-corrected G_s, G_{s20}, is expressed as:

$$G_{s20} = G_s K. \qquad (3.2)$$

[1] Don't forget to visit www.wiley.com/college/kalinski to view the lab demo!

Table 3.1—Temperature correction factor, K, for reporting G_{s20}.

Temperature (°C)	**Correction Factor *K***
17	1.0006
18	1.0004
19	1.0002
20	1.0000
21	0.9998
22	0.9996
23	0.9993
24	0.9991

The procedure for performing the specific gravity measurement is as follows:

1) Weigh approximately 60 g of dry soil to obtain M_o.
2) Fill the flask to the etch line with distilled or demineralized water to obtain M_a.
3) Pour half of the water out of the flask and place the soil in the flask with a funnel.
4) Wash the soil down the inside neck of the flask.
5) Connect the flask to the vacuum source with the hose and stopper and apply vacuum for 30 minutes, occasionally agitating the mixture.
6) Fill the flask to the etch line with distilled water and weigh it to obtain M_b.
7) Record the water temperature in the flask and use Table 3.1 to obtain *K*.

3.6 EXPECTED RESULTS

Specific gravity of soil solids is controlled by soil mineralogy. In coarse-grained soils such as sands and gravels, where the mineralogy is dominated by quartz and feldspar, G_s is typically around 2.65. In fine-grained soils, G_s is more variable due to the presence of clay minerals, and may range from 2.70-2.85.

3.7. LIKELY SOURCES OF ERROR

When measuring the specific gravity, the most likely source of error is inadequate de-airing of the soil mixture, which leads to an underestimate for G_s. According to ASTM D854, oven-dried clay specimens may require 2-4 hours of applied vacuum for adequate de-airing. However, for the purposes of demonstration in this lab, and to accommodate the typical three-hour laboratory class time, a de-airing time of 30 minutes is recommended. It is also recommended that a coarse-grained soil be used to improve the accuracy of the measurement given the short de-airing period.

3.8. ADDITIONAL CONSIDERATIONS

In the absence of laboratory testing, G_s is often assumed based on the predominant mineralogy of the soil. However, certain types of soils, including organic soils, gypsum, and fly ash, possess values of G_s that are significantly less than the range of 2.65-2.85 often assumed by practicing engineers. Therefore, it is particularly important when dealing with such soils to measure G_s rather than assuming a value.

Finally, ASTM D854 includes criteria for assessing the acceptability of test results using this method. Assuming that all of the tests are performed by the same laboratory technician, G_s for two separate tests of the same material should be within 0.06 of each other to be considered acceptable.

3.9. SUGGESTED EXERCISES

1) Measure the specific gravity of the dry soil specimen supplied by the laboratory instructor using the Specific Gravity of Soil Solids Laboratory Data Sheet at the end of the chapter (additional data sheets can be found on the CD-ROM that accompanies this manual).

2) If you did not adequately de-air your specific gravity specimen such that bubbles remained, would you overestimate or underestimate specific gravity? Why?

3) If you were not able to perform a specific gravity test and had to estimate specific gravity for a sand and a clay, what values would you use?

SPECIFIC GRAVITY OF SOIL SOLIDS (ASTM D854)
LABORATORY DATA SHEET

I. GENERAL INFORMATION

Tested by:	Date tested:
Lab partners/organization:	
Client:	Project:
Boring no.:	Recovery depth:
Recovery date:	Recovery method:
Soil description:	

II. TEST DETAILS

Vacuum level:	Duration vacuum applied:
Flask volume:	
Scale type/precision/serial no.:	
Notes, observations, and deviations from ASTM D854 test standard:	

III. MEASUREMENTS AND CALCULATIONS

Test ID			
Mass of flask filled with water (M_a)			
Mass of flask filled with soil and water (M_b)			
Mass of dry soil (M_o)			
Specific gravity of soil solids (G_s)			
Water temperature			
Correction factor (K)			
Specific gravity of soil solids at 20°C (G_{s20})			

IV. EQUATION AND CALCULATION SPACE

$$G_s = \frac{M_o}{M_o + (M_a - M_b)}$$

$$G_{s20} = G_s K$$

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4. LIQUID AND PLASTIC LIMIT TESTING

4.1. APPLICABLE ASTM STANDARD

- ASTM D4318: Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils

4.2. PURPOSE OF MEASUREMENT

The liquid limit and plastic limit tests provide information regarding the effect of water content (w) on the mechanical properties of soil. Specifically, the effects of water content on volume change and soil consistency are addressed. The results of this test are used to classify soil in accordance with ASTM D2487, and to estimate the swell potential of soil.

4.3. DEFINITIONS AND THEORY

The liquid and plastic limit are water contents at which the mechanical properties of soil changes. They are applicable to fine-grained soils, and are performed on soil fractions that pass the #40 (0.425-mm) sieve. Plastic limit (*PL*) and liquid limit (*LL*) are depicted in Fig. 4.1. The difference between the *PL* and the *LL* is defined as the plasticity index (*PI*):

$$PI = LL - PL. \tag{4.1}$$

In Fig. 4.1, the volume of fine-grained soil increases with increasing w. This indicates that *PI* is an indicator of the swell potential of a cohesive soil. Certain clay minerals, including bentonite, montmorillonite, and smectite, have a high cation exchange capacity, so their ability to hold water molecules and electrically bind them to their surface is greater. Therefore, they can exist in a plastic state over a relatively wide range of w and soil volume, and have a high swell potential.

A third value called the shrinkage limit (*SL*) is also depicted in Fig. 4.1. Shrinkage limit is the water content at which the volume of soil begins to change as a result of a change in w. The three parameters (*SL*, *PL*, and *LL*) are collectively referred to as the Atterberg limits. Shrinkage limit is measured using a separate standard, ASTM D427. However, shrinkage limit is not commonly specified in earthwork construction, and laboratory shrinkage limit testing includes the handling of mercury, which is not desirable for health and safety purposes. Therefore, the scope of this laboratory includes only plastic limit and liquid limit testing.

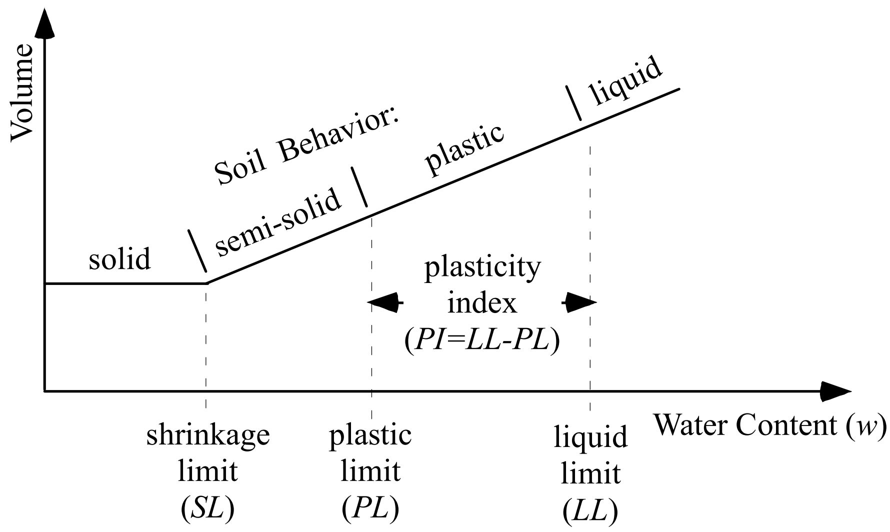

Fig. 4.1—Relationship between volume and water content in fine-grained soil.

4.4. EQUIPMENT AND MATERIALS

4.4.1. <u>Liquid Limit Test</u>

The following equipment and materials are required for liquid limit testing:

- Fine-grained soil;
- #40 sieve (0.425-mm opening);
- distilled or demineralized water;
- scale capable of measuring to the nearest 0.01 g;
- ceramic soil mixing bowl;
- soil drying oven set at $110^{o} \pm 5\,^{o}$ C;
- frosting knife;
- liquid limit device;
- grooving tool;
- 3 soil moisture containers; and
- permanent marker for labeling soil moisture containers.

4.4.2. <u>Plastic Limit Test</u>

The following equipment and materials required for plastic limit testing:

- Fine-grained soil;
- #40 sieve (0.425-mm opening);
- distilled or demineralized water;
- scale capable of measuring to the nearest 0.01 g;
- ceramic soil mixing bowl;
- soil drying oven set at $110^{o} \pm 5\,^{o}$ C;
- 0.125-in. diameter metal rod;
- frosted glass plate;

- 3 soil moisture containers; and
- permanent marker for labeling soil moisture containers;

4.5. PROCEDURE[1]

4.5.1 Liquid Limit Testing

The liquid limit is defined as the water content at which the soil starts to act as a liquid. To derive liquid limit, the following procedure, described as the Multipoint Method (Method A) in ASTM D4318, is described:

1) Pass the soil through a #40 sieve and use the fraction that passes the sieve.

2) Add distilled water to approximately 50 g of soil until it has the consistency of peanut butter or frosting.

3) Check that the drop height of the cup in the liquid limit device is 1.0 cm (Fig. 4.2), and adjust the apparatus as necessary. Most grooving tools have a tab with a dimension of exactly 1.0 cm that you can use.

Fig. 4.2—Checking the drop height of the cup using the calibration tab on the grooving tool.

4) Spread a flat layer of soil in the cup with the frosting knife (Fig. 4.3).

[1] Don't forget to visit www.wiley.com/college/kalinski to view the lab demo!