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.

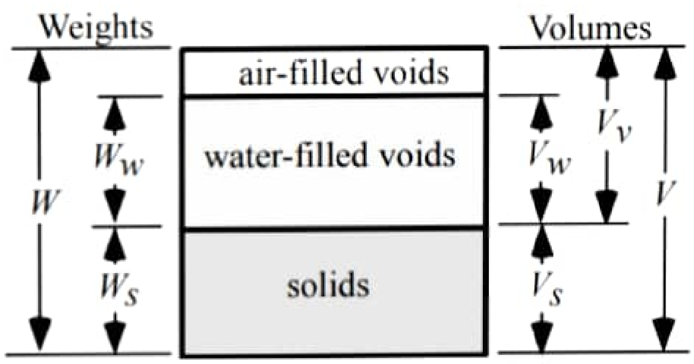

Fig. 1.1—Definitions of parameters used for weight-volume calculations in soil.

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	$w = \frac{W_w}{W_s}\ x\ 100\%$	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	$n = \frac{V_v}{V}\ x\ 100\%$	25-60%
Degree of Saturation	$S = \frac{V_w}{V_v}\ x\ 100\%$	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.

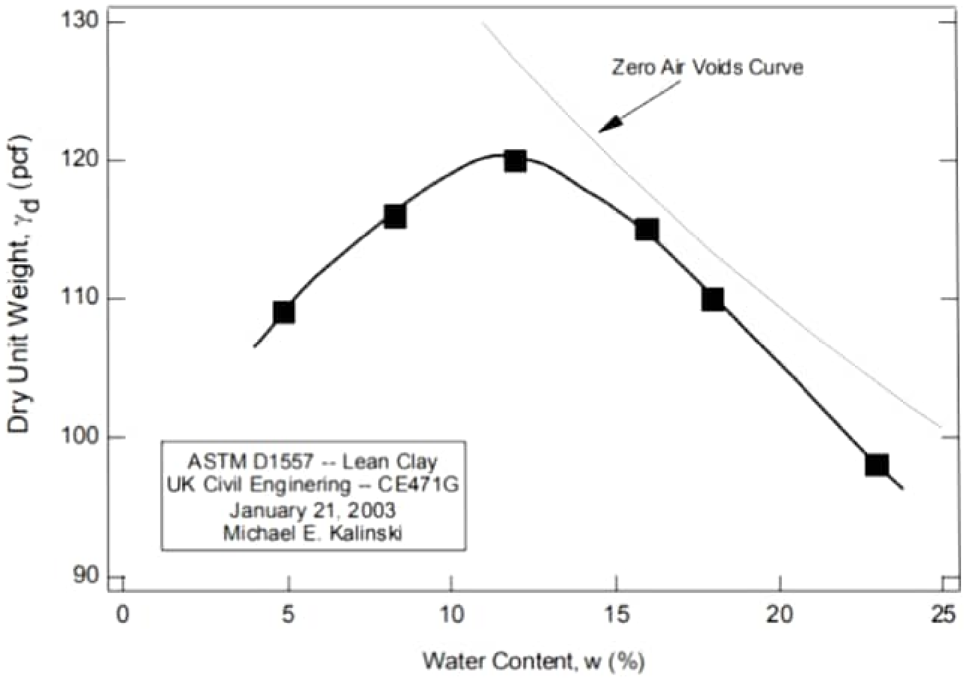

Fig. 1.2—Example of an acceptable graph.

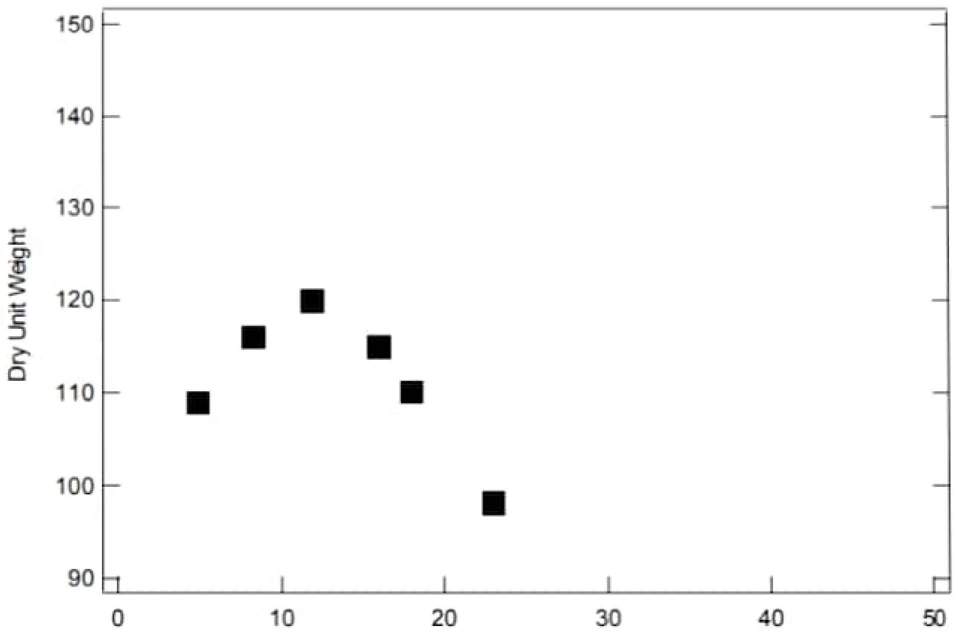

Fig. 1.3—Example of an unacceptable graph (axis label missing, units missing, graph title missing, and data do not fill the graph space).

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.