Development of Digital Instructional Modules for Transportation Engineers Overviewing the Fundamentals of How to Obtain Soil Properties in Practice

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Contents

Abstract

The work completed in this project created a series of online lab modules that transportation professionals could use as a reference to learn how to conduct, how to interpret, and the applications of geotechnical lab tests used in practice to determine engineering soil properties. These instructional modules were produced and distributed through the Virginia Transportation Training Academy for use by highway design professionals throughout the state of Virginia. Additionally, the Transportation Training Academy made these videos available through their website for use by other MAUTC universities or State DOTs that wish to offer these instructional video modules as reference tools within their own highway design communities.

1 Introduction

Geotechnical Engineering and the determination of a soil's engineering properties is an integral component within Transportation Engineering design. Unfortunately, it is not uncommon for engineers and scientist designing and building highway projects to be unfamiliar with how to evaluate and exploit the engineering properties of soil. Of these professionals working within the transportation industry, many do not have a classical civil engineering background, while others were not required to take a geotechnical engineering/soils course while in school. Knowledge in interpretation of soil properties is fundamental within transportation construction design. Highway construction involves various types of earthwork, highway pavements themselves are typically built on grade, and, if built in areas of varying elevation, highway embankments will be built from soil, or walls must be engineered to hold soil back. Soil is a heterogeneous anisotropic material with the potential to be the primary cause of failures within highway infrastructure. Therefore, it is imperative that all engineers working within highway design be able to adequately assess soil conditions at a sight.

The work completed in this project created a series of online lab modules that transportation professionals can use as a reference to learn how to conduct, how to interpret, and the applications of geotechnical lab tests used in practice to determine engineering soil properties. These instructional modules were produced and distributed through the Virginia Transportation Training Academy for use by highway design professionals throughout the state of Virginia. Additionally, the Transportation Training Academy made these videos available through their website for use by other MAUTC universities or State DOTs that wish to offer these instructional video modules as reference tools within their own highway design communities.

Digital lab modules were created for the following geotechnical lab tests commonly used to obtain soil properties in highway design:

1.) Specific Gravity
2.) Grain Size Distribution: Coarse-Grained and Fine-Grained
3.) Atterberg Limits Test
4.) Compaction (Standard and Modified Proctor)
5.) Permeability (Constant and Falling Head)
6.) Consolidation
7.) Direct Shear
8.) Unconfined Compression Triaxial Test
9.) Consolidated Undrained Triaxial

2 Literature Review

To complete the digital lab modules developed for this project, an extensive review of the current lab procedure literature was conducted for each of the nine geotechnical lab tests.

A brief description of each test and the applicable literature is examined in the subsequent sections.

2.1. Specific Gravity

The specific gravity of a soil is an important parameter that is commonly used in calculating a soil's weight / volume relationship. To determine the specific gravity of a soil, the following standard is used [1]: ASTM D-854 – Specific Gravity of Soil Solids by Water Pycnometer.

2.2. Grain Size Distribution: Coarse and Fine

Classification of a soil for engineering purposes requires knowledge of the grain-size distribution within a sample. Grain size distribution is determined using ASTM D-422 – Particle Size Analysis of Soils [2]. This standard describes the procedure for determining distributions for particles larger than 75 micrometers (coarse-grained – sieve analysis) as well as for particles smaller than 75 micrometers (fine-grained – hydrometer analysis).

2.3. Atterberg Limits

Depending on the amount of moisture within the sample, a fine-grained soil may exhibit liquid, plastic, or semisolid behavior. The determination as to which type of behavior is most prominent can be determined using Atterberg limits testing. The standard for these tests, which include the determination of the liquid and plastic limits, is given in: ASTM D4318 – Liquid Limit, Plastic Limit, and Plasticity Index of Soils [3].

2.4. Compaction

Compaction of a soil is quite common when constructing roadways, since compaction is a means to improve the overall strength of the soil. The extent to which a particular soil may be compacted to can be found in laboratory testing. Two standard methods exist; the first method is used for a standard compaction effort, and the second is modified for a higher compaction effort. The respective standards used are:

Standard [4]: ASTM D-698 – Standard Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort [12,400 ft·lb/ft^3 (600 kN·m/m^3)]

Modified [5]: ASTM D-1557 – Standard Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort [56,000 ft·lb/ft^3 (2700 kN·m/m^3)]

2.5. Permeability Testing

The rate of flow of water through a soil specimen is determined through permeability testing. Two tests are used depending on the type of soil. A constant head test is used only for coarse-grained soils, and a falling head test may be used for coarse or fine-grained soils. Applicable standards for each are:

Constant Head [6]: ASTM D-2434 – Standard Test for Permeability of Granular Soils

Falling Head [7]: ASTM D-5084 – Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter

2.6. Consolidation

Consolidation is the process of time-dependent settlement of saturated clayey soils when subjected to increased loading. The standard method for determining the extent of settle for a soil under loading is ASTM D-2435 – Standard Test Method for One-Dimensional Consolidation Properties of Soils Using Incremental Loading [8].

2.7. Direct Shear

Direct shear testing is used to determine the internal angle of friction of a soil that has been compacted to a certain relative density. The internal angle of friction is an important property to consider when building retaining walls and earthen embankments. The standard used to determine this property is: ASTM D-3080 – Standard Test Method of Direct Shear Test of Soil Under Consolidated Drained Condition [9].

2.8. Unconfined Compression Testing

Unconfined compression testing is used to determine the unconfined compression strength of a soil. The test is quick to perform and obtains strength parameters for sites where soils will not have adequate time to drain as loading is increased. The procedure used to complete this type of test can be found in: ASTM D-2166 – Standard Test Method for Unconfined Compression Strength of Cohesive Soil [10].

2.9. Consolidated Undrained Triaxial Testing

Much like unconfined compression testing, consolidated undrained triaxial testing is used to obtain strength parameters in soils. However, in consolidated undrained (CU) testing, porewater pressures can be measured. The standard used to test samples in this manner is: ASTM D-4767 – Standard Method for Triaxial Test on Cohesive Soils [11].

3 Conclusions and Recommendations

Completed lab module videos were uploaded to the UVA Transportation Training Academy's YouTube page (wwwyoutube.com/user/virginiatta). Links to the videos may be accessed through the link to the YouTube page through the UVA TTA website, and are also searchable through YouTube itself. If these videos receive lots of "views", then the geotechnical lab module series could be expanded to include explanations of more specialized geotechnical tests used specifically in highway construction such as California Bearing Ratio testing, Plate Bearing testing, Resilient Modulus testing, or an explanation of how to determine AASHTO and USCS soil classifications.

References

[1] ASTM D-854. Specific Gravity of Soil Solids by Water Pycnometer. ASTM International, West Conshohocken, PA, 2013.

[2] ASTM D-422. Particle Size Analysis of Soils. ASTM International, West Conshohocken, PA, 2013.

[3] ASTM D4318. Liquid Limit, Plastic Limit, and Plasticity Index of Soils. ASTM International, West Conshohocken, PA, 2013.

[4] ASTM D-698. Standard Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort [12,400 ft·lb/ft^3 (600 kN·m/m^3)] ASTM International, West Conshohocken, PA, 2013.

[5] ASTM D-1557. Standard Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort [56,000 ft·lb/ft^3 (2700 kN·m/m^3)] ASTM International, West Conshohocken, PA, 2013.

[6] ASTM D-2434. Standard Test for Permeability of Granular Soils. ASTM International, West Conshohocken, PA, 2013.

[7] ASTM D-5084. Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter. ASTM International, West Conshohocken, PA, 2013.

[8] ASTM D-2435. Standard Test Method for One-Dimensional Consolidation Properties of Soils Using Incremental Loading. ASTM International, West Conshohocken, PA, 2013.

[9] ASTM D-3080. Standard Test Method of Direct Shear Test of Soil Under Consolidated Drained Condition. ASTM International, West Conshohocken, PA, 2013.

[10] ASTM D-2166. Standard Test Method for Unconfined Compression Strength of Cohesive Soil. ASTM International, West Conshohocken, PA, 2013.

[11] ASTM D-4767. Standard Method for Triaxial Test on Cohesive Soils. ASTM International, West Conshohocken, PA, 2013.