Soil Mechanics Series - Laboratory Testing

An Online Continuing Education Course for Engineers

Course Number: G-6001

Credit: 6 Hours / 6 PDH / 6 CPD

Soil Mechanics Series: Laboratory Testing

Laboratory testing of soils and rocks is a fundamental element of geotechnical engineering. The complexity of testing required for a particular project may range from a simple moisture content determination to sophisticated tri-axial strength testing. A laboratory test program should be well-planned to optimize the test data for design and construction. The geotechnical specialist, therefore, should recognize the project=s issues ahead of time so as to optimize the testing program, particularly strength and consolidation testing.

Laboratory testing of samples recovered during subsurface investigations is the most common technique to obtain values of the engineering properties necessary for design. A laboratory-testing program consists of "index tests" to obtain general information on categorizing materials, and "performance tests" to measure specific properties that characterize soil behavior for design and constructability assessments (e.g., shear strength, compressibility, hydraulic conductivity, etc.). This course provides information on common laboratory test methods for soils and rocks including testing equipment, general procedures related to each test, and parameters measured by the tests.

1. QUALITY ASSURANCE FOR LABORATORY TESTING

Laboratory testing will be required for most projects. Therefore, it is necessary to select the appropriate types and quantities of laboratory tests to be performed. A careful review of all data obtained during the field investigation and a thorough understanding of the preliminary design of geotechnical, structural and hydraulic features of the project are essential to develop an appropriately scoped laboratory testing program. In some cases owners may hire external testing laboratories to perform select tests. It is necessary that testing requests be clear and sufficiently detailed. Unless specialized testing is required, the owner should require that all testing be performed in accordance with the appropriate specifications for laboratory testing such as those codified in AASHTO and/or ASTM. Several tables are presented in this course that summarize various common tests for soils and rocks per AASHTO and ASTM standards. In order to assure that the results of laboratory testing are representative, several precautions must be taken before the tests themselves are performed. These precautions include: sample tracking, sample storage, sample handling to prevent sample disturbance, and sample selection. Discussion of each of these precautions follows.

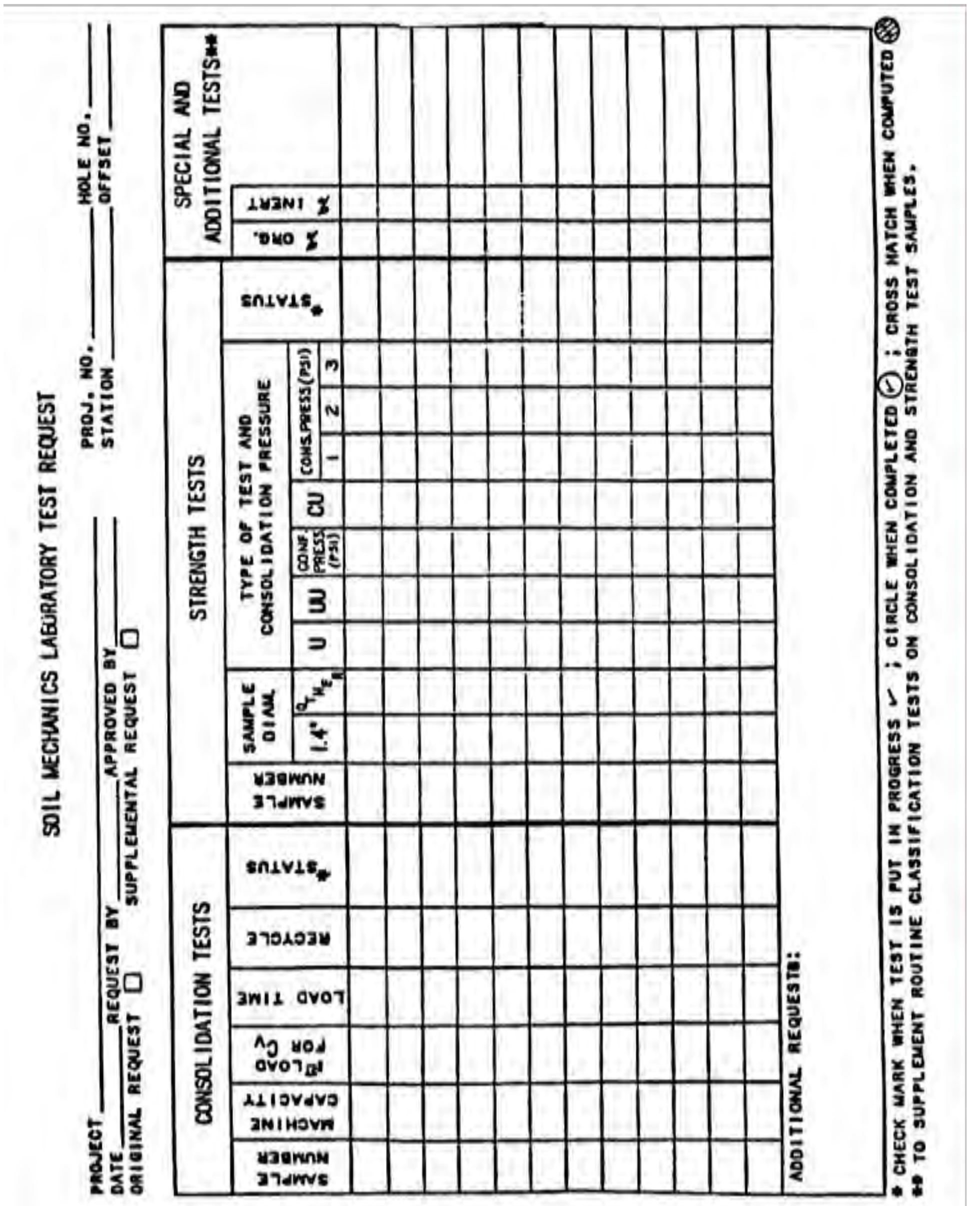
1.1 Sample Tracking

Whether the laboratory testing is performed in-house or is subcontracted, samples will likely be assigned a laboratory identification number that differs from the identification number assigned in the field. A list should be prepared to match the laboratory identification number with the field identification number. This list can also be used to provide tracking information to ensure that each sample arrived at the lab. When laboratory testing is requested, both the field identification number and the laboratory identification number should be used on the request form. An example request form is shown in Figure 1. A spreadsheet or database program is useful to manage sample identification data.

1.2 Sample Storage

Undisturbed soil samples should be transported and stored so that that the moisture content is maintained as close as possible to the natural conditions (AASHTO T 207, ASTM D 4220 and D 5079). Samples should not be placed, even temporarily, in direct sunlight. Shelby tubes should be stored in an upright position with the top side of the sample up in a humid room with relative humidity above 90%.

Long-term storage of soil samples in Shelby tubes is not recommended. As storage time increases, moisture will migrate within the tube. Potential for disturbance and moisture migration within the sample will increase with time, and samples tested 30 days after their retrieval should be noted on the laboratory data sheet. Excessive storage time can lead to additional sample disturbance that will affect strength and compressibility properties. Additionally, stress relaxation, temperature changes, and storage in a room with humidity below 90 percent may have detrimental effects on the samples. Long-term storage of soil samples should be in temperature- and humidity-controlled environments. The temperature control requirements may vary from sub freezing to ambient and above, depending on the environment of the parent formation. The relative humidity for soil storage normally should be maintained at 90 percent or higher to prevent moisture evaporation from the samples.



SOIL MECHANICS LABORATORY TEST REQUEST

PROJECT ______ REQUEST BY ______ APPROVED BY ______ PROJ. NO. ______ HOLE NO. ______

DATE ______ ORIGINAL REQUEST ☐ SUPPLEMENTAL REQUEST ☐ STATION ______ OFFSET ______

CONSOLIDATION TESTS						STRENGTH TESTS											SPECIAL AND ADDITIONAL TESTS**		
SAMPLE NUMBER	MACHINE CAPACITY	LOAD FOR Cv	LOAD TIME	RECYCLE	STATUS*	SAMPLE NUMBER	SAMPLE DIAM.		TYPE OF TEST AND CONSOLIDATION PRESSURE							STATUS*	% ORG.	% INERT	
							1.4"		U	UU	CONF. PRESS (PSI)	CU	CONS. PRESS (PSI) 1	2	3				

ADDITIONAL REQUESTS:

* CHECK MARK WHEN TEST IS PUT IN PROGRESS ✓ ; CIRCLE WHEN COMPLETED ✓ ; CROSS HATCH WHEN COMPUTED ⊗
** TO SUPPLEMENT ROUTINE CLASSIFICATION TESTS ON CONSOLIDATION AND STRENGTH TEST SAMPLES.

Figure 1. Sample laboratory test request form
(Note: only some tests are included in this sample form).

Long-term storage of soil samples in Shelby tubes is not recommended for another reason. During long term storage the sample tubes may corrode. Corrosion accompanied by adhesion of the soil to the tube may result in the development of such a large sidewall resistance that some soils may experience internal failures during extrusion. Often these failures cannot be seen by the naked eye; x-ray radiography (ASTM D 4452) will likely be necessary to confirm the presence of such conditions. If these samples are tested as “undisturbed” specimens, the results may be misleading.

1.3 Sample Handling

Careless handling of nominally undisturbed soil samples after they have been retrieved may cause major disturbances that could influence test results and lead to serious design and construction consequences. Samples should always be handled by experienced personnel in a manner that ensures that the sample maintains structural integrity and its natural moisture condition. Saws and knives used to prepare soil specimens should be clean and sharp. Preparation time should be kept to a minimum, especially where the maintenance of the moisture content is critical. Specimens should not be exposed to direct sun, freezing, or precipitation.

1.4 Effects of Sample Disturbance

As a soil sample is removed from the ground during a conventional soil investigation, its in- situ effective stress condition is being changed. In addition, nominally undisturbed specimens taken from samples obtained from drilled boreholes will become disturbed as a result of the drilling itself, sampling, sample extrusion, and sample trimming to form a specimen for testing. These processes will also change the effective stress condition in the soil sample, i.e., the effective stress in the soil at the time after a sample is trimmed and prepared for testing is different from that of the same soil in the ground. Therefore the utmost care should be taken to minimize the effect of these processes in order for the results of laboratory tests to represent the in-situ soil behavior accurately.

1.5 Specimen Selection

The selection of representative specimens for testing is one of the most important aspects of sampling and testing procedures. Selected specimens must be representative of the formation or deposit being investigated. The geotechnical specialist should study the boring logs, understand the geology of the site, and visually examine the samples before selecting the test specimens. Samples should be selected on the basis of their color, physical appearance, structural features and an understanding of the disturbance of the samples. Specimens should be selected to represent all types of materials present at the site, not just the worst or the best.

Samples with discontinuities and intrusions may fail prematurely in the laboratory. The first inclination would be to test these samples. However, if these features are small and randomly located, they may not necessarily cause such failures in the field. Therefore samples having such local features should be noted, but not necessarily selected for testing since such samples may not be representative of the stratum in terms of its response to applied loads.

Certain considerations regarding laboratory testing, such as when, how much, and what type, can be decided only by an experienced geotechnical specialist. The following minimal criteria should be considered when the scope of the laboratory testing program is being determined:

- Project type (bridge, embankment, building, reconstruction or new construction, etc.)
- Size of the project (geographic extent).

- Loads to be imposed on the foundation soils (geometry, type, direction and magnitude).
- Performance requirements for the project (e.g., settlement and lateral deformation limitations).
- Vertical and horizontal variations in the subsurface profile as determined from boring logs and visual identification of subsurface material types in the laboratory.
- Known or suspected peculiarities of subsurface strata at the project location (e.g., swelling soils, collapsible soils, organics, etc.)
- Presence of visually observed intrusions, slickensides, fissures, concretions, etc.

The selection of tests should be considered prelimin... echnical specialist is satisfied that the test results are suffi... ce profiles and provide the parameters needed f...

2. LABORATORY

Table 1 provides a lis... Tables 2 and 3 provide a summary of typical s... itional information on these tests is provided

Table 1
Commonly performed

Test Category		Test Designation AASHTO	ASTM
Visual Identification	Practice for Desc...	-	D 2488
	Practice for Desc...	-	D 4083
Index Properties	Test Method for I...	T 265	D 2216
	Test Method for S...	T 100	D 854; D 5550
	Method for Particl...	T 88	D 422
	Test Method for C...	M 145	D 2487; D 3282
	Test Method for A...		D 1140
	Test Method for L...	T 89; T 90	D 4318
Compaction	Test Method for La... (12,375 ft lbs/ft^3)	T 99	D 698
	Test Method for La... Modified Effort (56,250 ft lbs/ft^3)	T 180	D 1557
Strength Properties	Test Method for Un... of Cohesive Soil	T 208	D 2166
	Test Method for Unco..., Undrained Compressive Strength of Cohesive Soils in Triaxial Compression	T 296	D 2850
	Test Method for Consolidated, Undrained Compressive Strength of Cohesive Soils in Triaxial Compression	T 297	D 4767
	Method for Direct Shear Test of Soils under Consolidated Drained Conditions	T 236	D 3080
	Test Methods for Modulus and Damping of Soils by the Resonant-Column Method	-	D 4015
	Test Method for Laboratory Miniature Vane Shear Test for Saturated Fine-Grained Clayey Soil	-	D 4648
	Test Method for CBR (California Bearing Ratio) of Laboratory-Compacted Soils	-	D 1883
	Test Method for Resilient Modulus of Soils	T 294	-
	Test Method for Resistance R-Value and Expansion Pressure of Compacted Soils	T 190	D 2844
Consolidation, Swelling, Collapse Properties	Test Method for One-Dimensional Consolidation Properties of Soils	T 216	D 2435
	Test Method for One-Dimensional Consolidation Properties of Soils Using Controlled-Strain Loading	-	D 4186
	Test Methods for One-Dimensional Swell or Settlement Potential of Cohesive Soils	T 258	D 4546
	Test Method for Measurement of Collapse Potential of Soils	-	D 5333
Permeability	Test Method for Permeability of Granular Soils (Constant Head)	T 215	D 2434
	Test Method for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter	-	D 5084
Corrosivity (Electro-chemical)	Test Method for pH for Peat Materials	-	D 2976
	Test Method for pH of Soils	-	D 4972
	Test Method for pH of Soil for Use in Corrosion Testing	T 289	G 51
	Test Method for Sulfate Content	T 290	D 4230
	Test Method for Resistivity	T 288	D 1125; G57
	Test Method for Chloride Content	T 291	D 512
Organic Content	Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils	T 194	D 2974