Field Materials Manual Series:

Earthwork Testing & Subgrade Specification

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Based on: Federal Lands Highway Field Materials Manual (March 2021), U.S. Department of Transportation, Federal Highway Administration in the public domain.

This course is adapted from the Federal Lands Highway Field Materials Manual (March 2021), a public domain document by the U.S. Department of Transportation's Federal Highway Administration.

This adaptation is a pedagogical reorganization of existing Federal Lands Highway practices and standards. All technical content remains consistent with the original manual. The organization of the course itself, including course sections, bridging text, and pedagogical structure is the work of the editors. No copyright is claimed on the technical content or original manual material.

The organizational adaptation is provided for educational purposes only.

Course Overview

Course Description

Typical highway construction involves the use of existing native materials to form the roadbed prior to the placement of the manufactured materials that compose the pavement structure. These native materials, if properly handled and compacted, can be used successfully to construct the roadbed. Soils are the most abundant material used in highway construction. Due to this importance, knowledge of soil properties, condition, and proper construction practice is of utmost importance."

This course covers the core testing and verification procedures for earthwork materials on highway projects. It examines how to classify soils, verify compaction through field density testing, and ensure imported materials meet specification. The course draws from the Federal Lands Highway Field Materials Manual by the FHWA U. S. Department of Transport (2021) and is part of a series on highway materials acceptance and testing.

Learning Objectives

Upon successful completion of this course, participants will be able to:

- Classify soil materials using AASHTO M 145 and field test methods
- Design and execute moisture-density testing for embankment compaction control
- Specify and verify imported subgrade, select borrow, and backfill materials
- Interpret field density test results and assess compliance
- Document material certifications for earthwork projects

Intended Audience

This course is intended for highway and civil engineers, construction managers, and project engineers responsible for subgrade construction, embankment inspection, and materials acceptance on highway projects.

Table of Contents

Acronym Reference Guide

This glossary lists the acronyms and abbreviations used in this course.

Acronym	Full Name	Context/Usage
AASHTO	American Association of State Highway and Transportation Officials	Sets test methods (T 11, T 99, etc.)
ASTM	ASTM International	Sets test standards
FHWA	Federal Highway Administration	U.S. Department of Transportation agency
FLH	Federal Lands Highway	Oversees highway projects on federal lands; issues the Field Materials Manual
FP	Federal Highway Projects	Projects funded and managed under Federal Highway Administration authority; subject to FLH Field Materials Manual requirements
NETTCP	Northeast Transportation Training and Certification Program	Nationally accepted certification for sampling and testing personnel; regional certification standard
NICET	National Institute for Certification in Engineering Technologies	Technician certifications (Level II)
QL-PAY	Quality Level/Payment Statistical Analysis Software	FLH software for comparing contractor vs. inspector test results and determining pay factors
WAQTC	Western Alliance for Quality Transportation Construction	Regional testing standards

Chapter 1

Introduction & Overview

1.1 Introduction

This course covers the testing, evaluation, and acceptance of soil materials used in highway construction. Soils form the foundation of every roadway. They support pavement, bridges, and earthwork structures. The quality of these materials, and how well they are compacted and verified in the field, directly affects how long the roadway will perform.

This course will examine how to classify soils using standardized test procedures, measure moisture and density to verify compaction, and sample and test imported materials such as borrow, backfill, and subgrade improvements. It will also help in the understanding of the responsibilities of contractors and inspectors, and how material test results drive acceptance decisions.

Throughout, the course will reference procedures from the Federal Lands Highway Field Materials Manual, a practical guide used by Project Engineers and Construction Managers on Federal Highway Projects (FP). While specific to Federal Lands projects, the testing methods and quality assurance principles apply broadly to highway and infrastructure construction.

1.2 Summary and Description

Typical highway construction involves the use of existing native materials to form the roadbed prior to the placement of the manufactured materials that compose the pavement structure. These native materials, if properly handled and compacted, can be used successfully to construct the roadbed.

Soils are the most abundant material used in highway construction. They form the foundation or supporting surface for roadways, bridges, and other highway structures. Work involved in preparing the foundation and using soils in the construction of a normal highway project can be a major cost of the project. Due to this importance, knowledge of soil properties, condition, and proper construction practice is of utmost importance.

Testing of soil is designed to provide information on the classification, engineering properties and address any unexpected conditions that may be encountered during construction. The project specifications will determine the required testing for the project, however in most cases earth embankment materials will need to be classified to determine proper handling and compaction.

Earthwork construction can also consist of excavating and embanking material, preparing the foundation, bedding, and backfilling for structures. In these instances, materials for construction may be specified. To ensure compliance with the contract, testing will be required to verify the quality of material used.

Imported subgrade materials will typically need to be tested and evaluated prior to use. These materials include unclassified borrow, select borrow, and topping. In addition, subgrade stabilization techniques, where lime, fly ash, or hydraulic cement is incorporated into the upper layer of the subgrade, will require additional testing to establish the appropriate proportioning for the desired design properties.

Tests listed in Tables 1, 2, and 5, as well as Figure 2, function to either evaluate or describe soils and control the manner in which they are to be used. Several different test procedures may be available to analyze the same material property. The tests accomplish the same evaluation but require different equipment or use a slightly different procedure. For instance, there are several tests for determining in-place density and for determining moisture content.

When contract specifications permit options, selection of one test over another is often a matter of personal preference. More often than not, a higher quality of test results is dependent on how carefully a test was performed rather than on the superiority of one piece of equipment or process over another.

1.3 How Materials are Accepted

Before diving into soil testing procedures, it is important to understand how test results lead to acceptance or rejection of materials. The Federal Lands Highway program uses four methods to accept materials:

- **Visual Inspection:** The Project Engineer observes the material and accepts it based on experience and judgment, without testing. For soil, this is rarely sufficient alone.
- **Certification:** The contractor provides documentation (e.g., mill test report, supplier certification) certifying that the material meets specifications. For some imported materials, this may be acceptable.
- **Measured or Tested Conformance:** The contractor and/or Government sample the material, test it, and accept or reject it based on results. This is the most common method for soil testing. The contractor samples under witness; the Inspector takes possession of a split sample and sends it to the laboratory.
- **Statistical Evaluation:** Random samples are obtained throughout construction, tested by both contractor and Government, and results are analyzed statistically to determine a "pay factor": a percentage of the contract price the contractor earns based on quality. This method is less common for earthwork but may apply to imported materials.

For soil materials on highway projects, certification and tested conformance methods are typical. As you read the sections on soil testing procedures, keep in mind that the goal is to obtain representative samples, have them tested properly, and use those results to make confident acceptance decisions.

Chapter 2

Soil Classification & Material Properties

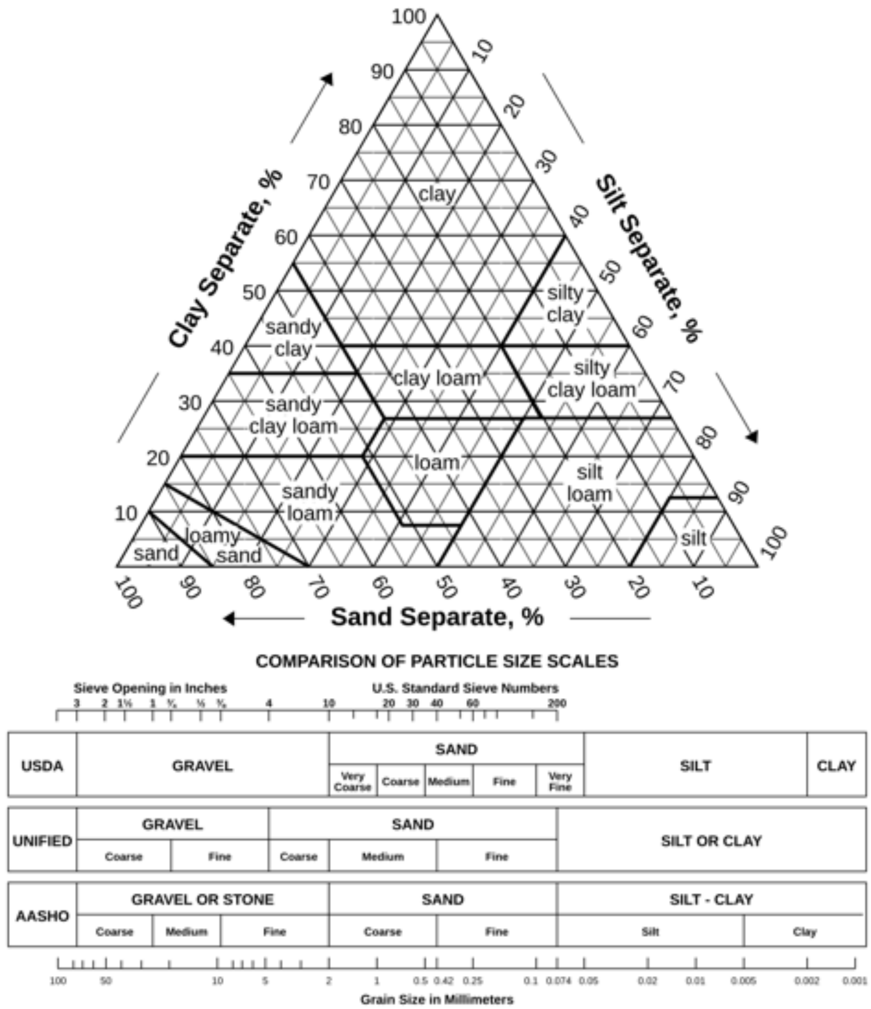

Figure 1: Soil Texture Triangle (USDA).

2.1 Material Properties and Test Methods

There are a number of tests to determine properties of soils used in highway construction. Data from tests on the soil will provide useful information to ensure that the desired materials and properties of those materials are incorporated into the construction of the roadbed. Typical soil testing includes tests shown in Table 1.

Table 1: Soil Test Methods.

Primary Categories	AASHTO Test Method
Grain size analysis	AASHTO T 11, T 27, & T 88
Moisture content determinations	AASHTO T 265 & T 310
Density standards and density determinations	AASHTO T 99, T 180, T 191, & T 310
Consistency and Plasticity (Atterberg Limits)	AASHTO T 89 & T 90

2.2 Classification

Classification of the soil material is an important factor in determining handling and placement characteristics (see Table 2). Classification results indicate if the soil is granular (A-1, A-2, A-3) or fine grained silt-clay (A-4, A-5, A-6, A-7). It can also be used to determine the various components of a mixture such as larger sized stone (boulders, cobbles, gravel), sand, silt, or clay. The standard specification system used by FLH and stated in the FP is AASHTO M 145. Two items are needed to classify soil material; particle size distribution and consistency properties (Atterberg limits) of silt-clay materials.

Figure 1 above shows USDA classification system for soil based on grain size, known as the soil texture triangle.

Table 2: Classification of Soil Material from AASHTO M 145.

Table 1—Classification of Soils and Soil-Aggregate Mixtures

General Classification	Granular Materials (35 Percent or Less Passing 75 µm)			Silt-Clay Materials (More Than 35 Percent Passing 75 µm)			
Group Classification	A-1	A-3[a]	A-2	A-4	A-5	A-6	A-7
Sieve analysis, percent passing:							
2.00 mm (No. 10)	—	—	—	—	—	—	—
0.425 mm (No. 40)	50 max	51 min	—	—	—	—	—
75 µm (No. 200)	25 max	10 max	35 max	36 min	36 min	36 min	36 min
Characteristics of fraction passing 0.425 mm (No. 40)							
Liquid limit	—			40 max	41 min	40 max	41 min
Plasticity index	6 max	NP	[b]	10 max	10 max	11 min	11 min
General rating as subgrade	Excellent to Good			Fair to Poor			

[a] The placing of A-3 before A-2 is necessary in the "left to right elimination process" and does not indicate superiority of A-3 over A-2.
[b] See Table 2 for values.

Table 2—Classification of Soils and Soil-Aggregate Mixtures

General Classification	Granular Materials (35 Percent or Less Passing 75 µm)							Silt-Clay Materials (More Than 35 Percent Passing 75 µm)			
Group Classification	A-1			A-2							A-7
	A-1-a	A-1-b	A-3	A-2-4	A-2-5	A-2-6	A-2-7	A-4	A-5	A-6	A-7-5, A-7-6
Sieve analysis, percent passing:											
2.00 mm (No. 10)	50 max	—	—	—	—	—	—	—	—	—	—
0.425 mm (No. 40)	30 max	50 max	51 min	—	—	—	—	—	—	—	—
75 µm (No. 200)	15 max	25 max	10 max	35 max	35 max	35 max	35 max	36 min	36 min	36 min	36 min
Characteristics of fraction passing 0.425 mm (No. 40)											
Liquid limit	—		—	40 max	41 min	40 max	41 min	40 max	41 min	40 max	41 min
Plasticity index	6 max		NP	10 max	10 max	11 min	11 min	10 max	10 max	11 min	11 min[a]
Usual types of significant constituent materials	Stone fragments, gravel and sand		Fine sand	Silty or clayey gravel and sand				Silty soils		Clayey soils	
General rating as subgrade	Excellent to Good							Fair to Poor			

[a] Plasticity index of A-7-5 subgroup is equal to or less than LL minus 30. Plasticity index of A-7-6 subgroup is greater than LL minus 30. (See Figure 2.)

Table 2 demonstrates how particle size distribution and consistency properties are used to determine the soil classification. Granular soils, those with higher percentages of rock and sand, are rated excellent to good for use in subgrade construction. As the amount of silt and clay increases, the rating of the material decreases to being either fair or poor. More detailed information and soil descriptions can be found in AASHTO M 145.

2.2.1 Particle Size Distribution

AASHTO T 88, Particle Size Analysis of Soils, is used to determine the particle size distribution of soils that consist primarily of sand, silt and clay. The test consists of a sieve analysis, primarily on the granular portion of the soil, and a hydrometer analysis for the fine-grained material. The hydrometer portion of the test is not needed for classification and is typically not performed as part of the quality assurance testing. AASHTO T 11, Materials Finer than No. 200 Sieve in Mineral Aggregates by Washing and AASHTO T 27, Sieve Analysis of Fine and Coarse Aggregates are used to determine the particle size distribution of granular soils that contain a significant portion of gravel size particles. Particle size ranges as defined in AASHTO M 145 are shown in Table 3.

Table 3: Particle Sizes.

Soil Constituent	Passing Sieve	Retained on Sieve

Gravel	3 inch (75 mm)	No. 10 (2.00 mm)
Coarse Sand	No. 10 (2.00 mm)	No. 40 (425 μm)
Fine Sand	No. 40 (425 μm)	No. 200 (75 μm)
Silt and Clay	No. 200 (75 μm)	—

Granular materials, as defined by AASHTO M 145, contain 35 percent or less material passing the No. 200 (75 μm) sieve and silt-clay materials contain more than 35 percent material passing the No. 200 (75 μm) sieve.

Decisions regarding subsequent tests are made based on information gained from the particle size analysis. Most other soil tests are performed on a specific range of particle sizes that require the soil be separated accordingly.

2.2.2 Consistency and Plasticity (Atterberg Limits)

Consistency of silt-clay materials varies in proportion to the water content. At higher water contents, silt-clay materials possess properties of a liquid whereas at lower water contents possess properties of a plastic, semisolid or even a solid. The moisture content of a soil at the division between the liquid and plastic phase is defined as the liquid limit. The moisture content of a soil at the division between the plastic and semisolid phase is defined at the plastic limit. The algebraic difference between these two defined limits is known at the plasticity index. The liquid limit is determined from AASHTO T 89 and the plastic limit and plasticity index are determined from AASHTO T 90. The consistency properties (Atterberg limits) and the plasticity index are used to classify soils. They also provide an indication of some engineering properties of the soil. Generally, high liquid limits and high plasticity indices are indicative of potentially troublesome soils. Figure 2 demonstrates the relationship of these properties.

AASHTO T 89 and T 90 provide for options in the preparation of the soil; the dry preparation method as stated in AASHTO R 58 or the wet preparation method as stated in AASHTO R 74. For the purposes of obtaining consistency and plasticity data for general highway construction, the material should be prepared using the dry preparation method, AASHTO R 58. The wet preparation method would be used only in unique circumstances and would be specifically designated in special contract requirements.

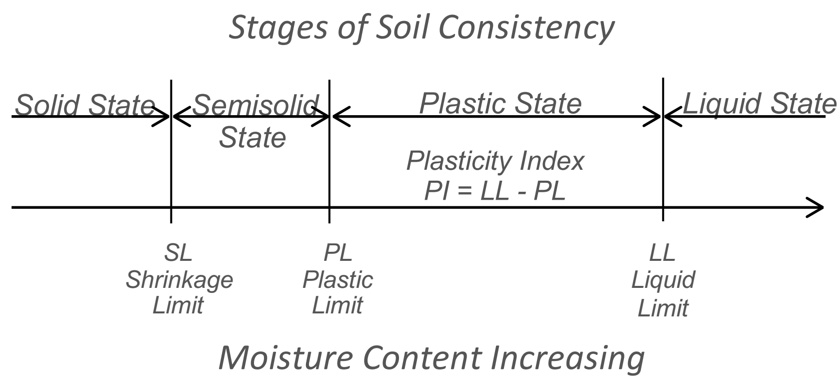

Figure 2: Relationship of Atterberg Limits.

2.3 Using Classification Results in Practice

Soils classified as A-1, A-2, or A-3 (granular materials with less than 35% passing the #200 sieve) are generally excellent to good for use as subgrade or embankment fill. These soils drain well, compact reliably, and provide stable support.

Soils classified as A-4, A-5, A-6, or A-7 (fine-grained, silt-clay materials with more than 35% passing the #200 sieve) are rated fair to poor. These soils are more difficult to compact, retain moisture, and can be problematic in wet conditions or freeze-thaw climates.

On the job site, materials will be classified from the borrow pit or imported source before approving their use. If classification results show the soil is unsuitable (high plasticity, high fines content, problematic components), there are several options: reject the material, request modifications (e.g., blending with coarser material), or apply stabilization (lime, cement, fly ash). The contract will specify which approach is acceptable. Classification results are the first line of defense against poor-quality materials entering the roadway.

2.4 Moisture: Density Relations

The relative density of the soil largely influences the behavior of material. The soil type, percentage of moisture, and the compactive effort will determine the density of the in-place material.

2.4.1 Moisture content

Water can greatly influence engineering properties of soil. Too much or too little water can render some otherwise desirable and stable material virtually useless. Knowledge of the in-place moisture content is necessary for making decisions regarding design and control of material. AASHTO T 265, Laboratory

Determination of Moisture Content of Soils, is the method recommended by FLH. In-place field moisture content may also be determined through the use of a nuclear density and moisture gage as provided in AASHTO T 310. The actual moisture content of the soil can be compared with the optimum moisture content to determine if the material is in a suitable condition for compaction. The optimum moisture content of a material will be determined through appropriate proctor testing (typically according to AASHTO T 99 or T 180 depending on the soil classification). A proper proctor test includes five moisture density points to adequately define the relationship. Figure 3 is an example of a proper proctor test result.

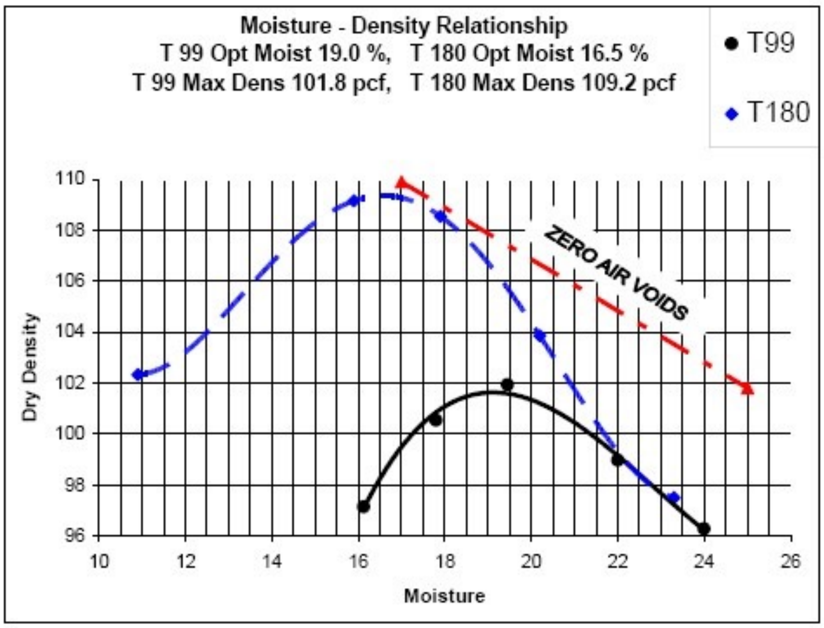

Figure 3: Five Point Moisture Density Curve.

Note that as the compactive effort increases (T 99 vs. T 180) the maximum dry density increases and the optimum moisture content decreases.

2.4.2 Density

Density determinations include both the determination of density in the field and the establishment, through standard tests, of reference or standard densities to which the field tests are compared. Results of a field density test cannot be properly evaluated until compared to an appropriate reference density. Tests used to establish density standards are those represented by AASHTO T 99 and T 180, Moisture-Density Relations of Soils. Four alternate methods are provided when using these test procedures. The specific method to be used will be indicated in the contract specifications.

Density determination, of the material placed on a project, using nuclear test methods AASHTO T 310 is the preferred method specified in the FP; however, the Sand-Cone Test AASHTO T 191 is also an approved method.

Field density tests are performed on the project site. Each type of density equipment and test procedure is unique. An operator performing a density test should be aware of all special precautions for the equipment and test procedures being used. For example, the sand cone test is extremely sensitive to vibration and nuclear instruments require very careful and uniform surface preparation. Operators must be familiar with the equipment features and test methods.

In working with subgrade material it is common to encounter particles larger than can be tested. When this situation occurs, recognition must be made of the oversize material and a density correction needs to be made. A procedure for making this correction is described in AASHTO T 99 and T 180. Oversized material is typically defined as particles larger than 0.75 inch (19 mm).

2.5 Soil Strength

Soil strength can be determined through various test methods. Most common are the Resistance R-value and the California Bearing Ratio, (CBR); however, other methods such as triaxial testing and resilient modulus have also been used. More specialized testing can also be performed to determine the shear strength, unconfined compressive strength, or cohesion of a soil. This testing would be performed during the development of a project, typically by the geotechnical engineer. Regardless of the method used, the purpose of the testing is to determine the support that can be provided by the soil. Results of the soil strength tests are used to determine the structural pavement design needed to accommodate traffic loading or the appropriate support needed for a structural member, such as a bridge or retaining wall.

During construction, it may become necessary to verify the subgrade soil strength value. This is often done to compare the strength of the soil that is being compacted during the construction phase of the project to the design values used during the geotechnical investigation and recommendation phase of the project. These verification and testing requirements are typically located in the contract documents. When a question exists regarding this type of testing or the results, consult the Division Materials Engineer for guidance.

Soil strength testing may also be performed as part of a stabilization technique. Based on initial project development sampling and testing, a stabilization technique may be selected. Techniques may include treatment with cement, lime, fly ash, asphalt, or possibly some other chemical treatment. During construction, it may become necessary to validate the original stabilization through the testing of the on-site materials. Again, the contract requirements will address any strength testing that will be needed to verify the original design work. Specific sampling and testing requirements will be included based on the treatment method.

Chapter 3

Acceptance Methods for Soil Materials

Material, in this case the soil stockpile, is to be inspected and/or tested by the Project Engineer before final acceptance of the work. There are four methods for accepting material each having varying degrees of involvement by the Project Engineer; visual inspection, certification, measured or tested for conformance, and statistical evaluation. The contract defines these methods for any particular item of work. The contract also defines the primary acceptance procedure applicable to each item of work in the Acceptance Subsection under each Section of work in the FP. Where there is a conflict between the contract and the Fields Materials Manual, the contract will control. A brief discussion of each method follows.

3.1 Visual Inspection

This is the simplest method of acceptance and allows material to be accepted without certification or test results. The Project Engineer accepts or rejects the material based solely on visual inspection of the material, for example appropriate color and texture. The Project Engineer relies on experience and engineering judgment to determine the acceptability of the material. When accepting material based on visual inspection the Project Engineer should ascertain if the material will perform as intended. Visual acceptance still requires documentation in writing. This can be as simple as a notation in the pay estimate, materials record book, or project files. See Subsection 106.02 of the FP.

Visual inspection is best used as a quick screening tool, combined with testing.

3.2 Certification

The next method of acceptance is based on the receipt of a certification. A certification should accompany the material to document that the material meets the specifications. The contractor shall provide a commercial certification for items requiring a certification, unless the acceptance subsection for the item specifically calls for a production certification.

A **commercial certification** is a manufacturer's or Contractor's representation that the material complies with all contract requirements. It typically consists of a supplier's certification indicating the material has been produced to a specific specification and is often accompanied by product catalog data. Commercial certifications are routinely required for products purchased off the shelf, such as paint, sign hardware, mortar, grout, fencing materials, etc. Only one commercial certification is required for all similar materials.

A **production certification** requires a supplier's certification that the material has been produced to a specific standard, accompanying test data and more. When production certification is required, a production certification is required for each separate shipment of material and must include the following:

- Date and place of manufacture
- Lot number or other means of cross-referencing to the manufacturer's inspection and testing system; and
- Substantiating evidence that the material conforms to the contract quality requirements of the Federal Acquisition Regulation FAR 46.105(a)(4). Such evidence includes:
    - Test results on material from the same lot and documentation of the inspection and testing system
    - A statement from the manufacturer that the material complies with all contract requirements; and
    - Manufacturer's signature or other means of demonstrating accountability for the certification.

A production certification covers materials that are specifically manufactured or fabricated for a specific project. Examples might include culvert pipes, structural elements, bridge hand rails, asphalt binder, etc. The Project Engineer should check the certification prior to allowing the material to be incorporated into the work, although this may not always be possible. The certification should identify the project and reference the appropriate specification requirements (e.g., AASHTO or ASTM standard).

The certification generally must specify that it conforms to "FLH specifications" or specific AASHTO, ASTM or other recognized testing standards. The applicable standards will be stated in the contract.

Sometimes certifications are provided that give test results for individual parameters and do not reference the applicable specification. These are acceptable; however, the Project Engineer needs to verify that the values and individual parameters are those listed in the project specification and that the values are all within acceptable limits. The Project Engineer should discuss the content of certifications with the contractor or supplier ahead of time. Early discussions can help avoid delay in receiving certifications.

Material accepted by certification may be sampled and tested at any time to verify the quality of the materials being supplied. If such material is found not to be in conformance with the contract, it should be rejected whether in place or not.

Certifications should be kept as part of the final documentation for the project and should be included in the project files. See Subsection 106.03 of the FP.

3.3 Measured or Tested Conformance

A third method of acceptance is based on measuring or testing material for conformance to the specifications stated in the contract. The contractor may perform tests on the material and provide the results to the Project Engineer to demonstrate that the product meets the contract requirements. In the event of small quantities, testing may be performed ahead of the actual delivery of the product; however, the contractor may elect to provide these results at the time the material is delivered and/or placed (e.g., structural steel, prefabricated concrete units).

The Project Engineer may accept the results provided by the contractor or arrange for sampling and testing once the material has arrived on-site. Sampling should normally be performed by the contractor and witnessed by Government personnel. Upon the completion of the sampling, the Project Engineer should take possession of the sampled material and arrange for testing. Testing will usually be performed by the FLH Laboratory; however, with concurrence of the FLH Division Materials Engineer, arrangements may be made for testing by a third-party laboratory. The third-party laboratory should not be under contract to or otherwise affiliated with the contractor.

If the test results indicate that the material meets the contract requirements, the material will be accepted. If the test results indicate that the material does not conform to the contract specifications, the material should be removed and replaced with conforming material at no cost to the Government. As an alternative to removal and replacement, the contractor may request acceptance at a reduced price or be given permission to correct any deficiencies. A decision to accept material at a reduced price will be made by the Contracting Officer generally after review by the Division Materials Engineer.

Material used in highway construction projects may be fabricated or manufactured at plants or locations off site. Materials fabricated off-site (such as prestressed concrete girders, steel bridge girders, etc.) require inspection, sampling, and testing arrangements. This off-site inspection and testing must be arranged for at least 30 days before fabrication begins. Contact the Division Materials Engineer for coordination of inspection and testing requirements. See Subsection 106.04 of the FP.

3.4 Statistical Evaluation of Work and Determination of Pay Factor (Value of Work)

The fourth and final method of acceptance is based on making an evaluation of the value of the work and is often called "Statistical Acceptance". The Project Engineer determines the random sampling locations using QL-PAY. Typically, the contractor will be sampling and testing the materials and will have a portable testing laboratory on site. The random sampling locations should not be divulged to the contractor until moments before a sample is to be taken. The Project Engineer must witness the actual sampling and splitting of each sample. Once the material is sampled and split, the Project Engineer must take immediate possession of the Government's portion (split).

After obtaining the sample, the Project Engineer will test the material. This means sending the material to the FLH Laboratory. Upon receiving test results, the Project Engineer should immediately enter all the test results (those tested by the contractor as well as those tested by the Government) into QL-PAY to determine the value of the work. QL-PAY files should be transmitted to the Division Materials Engineer at least weekly. If no additional test results are added during the next 7-day reporting period, the current QL-PAY files do not need to be resubmitted.

Where contractor testing is part of the contract, in addition to determining the value of the work, it is necessary to verify the validity of the contractor's results. This is also done within QL-PAY. Only after the contractor's test results are validated may they be used to determine the amount of pay due the contractor. See Subsection 106.05 of the FP.

This method is less common for earthwork than for asphalt or concrete but provides robust assurance of consistent quality.

Chapter 4

Sampling Procedures & Material Handling

4.1 Sampling Soil Materials: Why It Matters

The quality of soil testing depends entirely on the quality of the sample obtained. A poor sample, one that is not representative of the material, or that is contaminated or improperly handled, will produce unreliable test results, leading to wrong acceptance decisions.

Sampling must follow strict procedures: selecting random locations (not just "easy" spots), using proper equipment, protecting the sample from contamination, and maintaining custody (keeping the sample secure and accounted for from collection to testing). The responsibility of the inspector is to witness the sampling; they must be present when the contractor takes the sample, observe that procedures are followed correctly, and immediately take possession of the Government's portion of the sample (called a "split").

The next sections detail sampling responsibilities, equipment, procedures, and documentation. Pay close attention to the sampling methodology subsections; these describe the difference between random sampling (required for statistical and acceptance decisions) and selective sampling (a quick check, but not suitable for formal acceptance).

4.2 Personnel

Individuals performing sampling and testing of materials to be used in the construction of FLH projects must be knowledgeable in the sampling and testing procedures and requirements of the contract. In addition to sampling and testing requirements testing personnel must also be familiar with proper use and calibration of equipment required for the testing of materials.

In general, contractor personnel assigned to perform sampling, testing, or inspection functions should have 1 year or more of recent job experience in the type of sampling, testing or inspection required by the contract. Qualifications can also be demonstrated through other certifications or participation in proficiency testing. Examples of these types of qualifications include:

- NICET Level II certification in highway materials, or State Highway Agency (SHA) or industry certification-related sampling and testing equivalent to their contract responsibilities.
- Nationally accepted certification for intended sampling and testing responsibilities, i.e. WAQTC, ACI, NETTCP.
- Current or previous employment by an AASHTO accredited laboratory performing sampling and testing equivalent to their intended responsibilities.
- Demonstrated proficiency or successful testing of one or more proficiency samples (may be substituted for basic qualifications pending verification of test results).

4.2.1 Qualification Documentation

Before the start of the work, the Project Engineer should obtain documentation supporting personnel qualifications. Documentation requirements are listed in the contract.

4.2.2 Subcontracted Sampling and Testing

If sampling, testing or inspection is to be performed by a subcontractor, the Project Engineer should request from the prime contractor detailed information about how the sampling, testing and inspection by the subcontractor will interface with the prime contractor's work and other subcontractors performing work required by the contract.

The contractor is required to have a quality control system that includes the appropriate process control of material. The Project Engineer is responsible to ensure that material being incorporated into the work conforms to the contract requirements as supported by the appropriate inspections, sampling, and testing.

4.3 Equipment and Testing Laboratories

Testing of materials used in highway construction projects requires specialized materials testing equipment. Laboratories are essential to assure quality materials are incorporated in the project. Laboratories must be adequately staffed and properly equipped to conduct materials tests required by the contract quality control provisions.

The Project Engineer is responsible for inspecting, verifying, and documenting that field laboratories are properly equipped and staffed prior to the start of the work that requires sampling and testing.

4.3.1 Contractor-furnished Laboratories

The contractor may use a commercial laboratory or an on-site contractor furnished laboratory. The commercial or on-site contractor furnished laboratory must be equipped with all the testing equipment and accessories to meet contract sampling and testing requirements.

Laboratory facilities should be kept clean and equipment maintained in proper working condition. Subject to the terms of the contract, the Project Engineer has unrestricted access to the laboratory for inspection and review.

4.3.2 Government-furnished Laboratories

A government-furnished field laboratory trailer may be available for rent. If this is the case, the government will offer to the contractor a furnished field laboratory with testing equipment. Field laboratory availability and a listing of the testing equipment included in each field laboratory may be obtained by contacting the CO. Due to the wide-range of construction complexity for FLH projects, the laboratory facility may not be equipped with all of the necessary testing equipment required for the project. It is the responsibility of the contractor to review the basic equipment list and provide any specialty or missing testing equipment needed for use on the project.

In general, the laboratory includes testing equipment to conduct process control and project acceptance testing for embankments, crushed aggregate base, asphalt paving materials, and plastic concrete. Other equipment, such as equipment for breaking and curing concrete cylinders, may be included on a specific contract basis. The Sampling and Testing tables located at the end of each Section in the contract will provide references to test methods and procedures that include the equipment requirements.

The laboratory facility should be kept clean and equipment maintained in proper working condition. Subject to the terms of the contract, the Project Engineer has unrestricted access to the laboratory for inspection and review.

Laboratory Cost

Field laboratory trailer and testing equipment are offered to the contractor at a cost specified in the contract. The contractor shall replace at their cost or be responsible for the replacement cost of all missing or damaged equipment (other than through reasonable wear and tear).

Laboratory Equipment

The contractor shall determine if the laboratory testing equipment is adequate to perform all testing required by the contract.

In addition, the following apply:

- The equipment has been checked and calibrated to applicable specifications. It is the contractor's responsibility to ensure the equipment is maintained in proper operating condition.
- No nuclear devices will be furnished.
- The contractor is responsible for providing the laboratory trailer with a water supply and adequate 240-volt, 60-cycle, 200 amp single-phase current for all laboratory electrical needs. A minimum of 60 kilowatts of power at the entrance box is required for effective use of electrical equipment. Equip the power supply with a regulator that will limit the voltage of the power furnished to not more than 240 volts and not less than 220 volts.
- The contractor shall accept responsibility for the trailer and equipment upon receipt.
- All equipment provided by the Government and replaced by the contractor shall become the property of the Government.
- The rental rate specified in the contract is in effect for the duration of the contract, excluding periods of seasonal or other work shut downs.
- The laboratory shall be used only for testing materials for a specific contract.

Upon completion of the work, the contractor should clean the equipment and trailer. All equipment should be properly stored and secured for the transport of the trailer to the FLH office. Any damage that occurs prior to the trailer being received at the FLH office will be handled according to the contract.

4.3.3 Equipment Calibration

Use only equipment that has been calibrated or verified for the specific test and meets the applicable testing requirements of the contract. Equipment will be calibrated or standardized in accordance with national, FLH Standards, State

Highway Agency (SHA), industry standard, or Standard Accreditation Programs.

Prior to the beginning of sampling and testing on a project, the Project Engineer should inspect and document the acceptability of the sampling and testing equipment that will be used on the project.

All necessary equipment should be marked with a tag indicating the date of last inspection, inspector, and calibration number. Checking and monitoring of the equipment during the life of the project should be performed and documented by the contractor to ensure equipment is performing properly.

4.3.4 Equipment Calibration Documentation

The Project Engineer should obtain the following documentation supporting the calibration or verification of all necessary equipment prior to actual sampling and testing. The documentation should be on file.

- Description of the equipment calibrated or verified, including model number, serial number, or other acceptable identification.
- Identification of the individual performing the calibration or verification.
- Identification of the calibration or verification procedure used.
- Current calibration or verification date and the next due date.
- Detailed report of calibration results of the work performed, i.e. dimension, mass, force, frequency, temperature, time etc.

The Project Engineer may check equipment to verify condition and calibration. If at any time, it is suspected that the test equipment is not functioning properly or is not calibrated within specification limits the Project Engineer should contact the FLH materials staff to determine what corrective action should be taken.

Under no circumstances should test results obtained using faulty equipment be accepted.

4.4 Sampling

The control of material is an important part of any construction project. It can only be accomplished when the material being incorporated into the work is acceptably inspected, properly sampled, and accurately tested. The importance of obtaining a good representative sample cannot be overstated.

Samples obtained or used on construction projects have different purposes. Samples can be obtained to verify proper testing is being performed, to control production processes, or to verify product quality. Here are the general sample types and purposes that are typically used on FLH construction projects:

- **Quality Control (also called process control) Samples**. These samples are obtained by the contractor for the purpose of assessing and making adjustments to a production or construction process. Samples, taken during production, assist the contractor in making appropriate corrections for producing a quality product. Information obtained by testing these samples is used by the contractor to control the level of quality of the furnished end product. The contractor may take a quality control sample at any time. However, when the quality control sample test results are to be utilized in the material acceptance decision, the Government will randomly identify the material to be sampled and tested.

  The Government will witness the sampling and splitting procedures and will immediately take possession of the Government's split portion of the sample. The Government must maintain control and custody of the sample at all times to ensure the integrity of the testing and verification process.

- **Acceptance Samples**. These samples are tested by the government to determine conformance to contract requirements.

- **Verification Samples**. These samples are obtained by the contractor; witnessed and tested by the government or its designated laboratory for the purpose of verifying the results of contractor tested quality control samples. The results are used in a statistical evaluation for the purpose of acceptance and payment. In the event that the contractor's test results are not verified, the Government's test results will be used for acceptance and payment for the material.

- **Independent Assurance Samples**. Any qualified person from a qualified laboratory, as defined in the contract, which are not associated with the contractor or the FLH project inspection staff, can take an Independent Assurance (IA) sample. This sample can be taken at any location and at any time within the project. The purpose of this sample is to provide an unbiased and independent evaluation of the sampling and testing procedures used in the acceptance decision. IA samples evaluate the sampling and testing personnel and their associated equipment. The sample cannot be used in the acceptance decision for the material since it is a biased non-random sample used to evaluate testing personnel and equipment. The Division Materials Engineer evaluates the results to determine if any discrepancies exist in the sampling and testing.

- **Proficiency Samples**. These samples are manufactured by the FLH central laboratory and used as a tool to evaluate the quality of the testing being performed for a project. The results are used in the same manner as the independent assurance samples. The Division Materials Engineer evaluates the results to determine if any discrepancies exist in the testing.

In all cases, it is critical to obtain a representative portion of the manufactured product that will be tested to verify that the material used or the work done conforms to the requirements of the contract. The use of proper sampling procedures and techniques is a vital piece of the verification process for quality highway construction.

4.4.1 Sampling Responsibilities

Generally speaking, the contractor is responsible for obtaining all of the samples on a construction project. The sampling process takes place under the supervision or witness of the Project Engineer or government representative. In addition to acquiring the sample, the contractor is also responsible for splitting the sample, if appropriate, and providing a split portion of the sample to the government. When results of the contractor testing are to be considered in the acceptance decision, the contractor needs to ensure that a government representative is present during the sampling and splitting process. Once this has been accomplished, the government will take immediate control of the sample. This sample may then be tested and the results used as part of the verification process. It is vitally important for the integrity of the acceptance process that the sampling is witnessed and that the chain of custody for the government portion of the sample has not been compromised.

The contractor is responsible for following proper sampling and testing methods in accordance with the submitted quality control plan and the contract specifications. This includes monitoring, certifying, or verifying the quality of products manufactured off-site and delivered to the project meet contract specifications. At a minimum, the contractor is required to perform all sampling and testing listed in the sampling and testing tables provided in the contract.

The Project Engineer is responsible for verifying that the required sampling is accomplished according to standard procedures and that the material used and work performed on the project, whether produced on the project or manufactured off-site and delivered to the project from an outside source, comply with contract specifications. In addition, the Project Engineer will ensure that all samples used to evaluate work for acceptance are retained until final acceptance.

4.4.2 Sampling Procedures

Established sampling methods provide specific guidance regarding the amount of material required for the sample. This amount should not be confused with the amount of material needed to perform the proper testing. The sample obtained needs to be taken in accordance with the appropriate referenced method. Subsequent testing is usually performed on a smaller representative portion of that sample. These smaller testing amounts will be specifically stated in the appropriate test method for the given material.

Project personnel should be knowledgeable in the following sampling criteria that are required by the contract.

- **Minimum required sample size.** The sampling methods, typically cited as AASHTO or ASTM methods, identify the size sample required for the particular material.
- **Sampling frequency.** Sufficient samples must be taken to represent the material that is delivered to the project for assurance that it complies with specification requirements. A non-uniform product can require more samples than the minimum specified in the contract for acceptance of its quality. For acceptance purposes, the contract will specify the minimum sampling frequency.
- **Sampling methods.** Different materials require different sampling methods. The appropriate test methods should be used to ensure a proper sample has been obtained. These methods will be referenced in the contract documents and also in this manual.
- **Sample location.** Where practicable, samples to be tested for acceptance shall be obtained from the finished product. The contract specifications identify where samples are to be taken for acceptance and at what minimum frequency.

4.4.3 Sampling Methodologies

Samples may be obtained at any time and at any location. Specific contract language in subsection 106.01 states that the government may inspect, sample, or test all work at any time before final acceptance of the project. In general, there are two sampling methodologies.

- **Selective sampling.** This is a biased non-random procedure in which a sample of material is obtained from a specific location determined by observation. The information obtained from the testing of this sample can be used to determine compliance with the contract but cannot be included in any statistical evaluation. This methodology may be used at any time.
- **Random sampling.** This is an unbiased sampling procedure in which a sample of material is chosen in such a manner that any incremental amount of material placed has an equal probability of being selected. For the statistical concepts and comparisons to function properly, the sample

used for statistical acceptance must be selected on a random basis. Random sampling locations are selected in advance of the production and placement of the material to be sampled. These locations should be selected using random numbers generated by use of random number tables, the random number function on a calculator, or the random number function in computer software. QL-PAY has a random number generator developed specifically for use with highway construction materials.

4.4.4 Sample Handling

Samples need to be stored and handled appropriately to ensure that the integrity of the material has not been compromised. The samples need to be properly labeled and identified so that all information regarding the sample location and test results can be correlated. If the samples are to be transported, use proper containers to maintain the integrity of the sample throughout the shipping process. Include a Request for Laboratory Tests form, FHWA 1600, for all samples shipped to the central laboratory.

Sample storage and retention

Once the government takes possession of the sample, it should be handled and stored in an appropriate manner. Care should be taken to avoid damage to the sample container, disturbance of the sample, or contamination. The Project Engineer will store, handle, label and date samples in a manner that will preserve the character of the material. Most samples should be stored in a dry environment and kept free from contamination until final acceptance of the project. It is important that all samples be cared for in this manner in the event that complete testing of verification or acceptance samples becomes necessary.

Sample labeling

When obtaining the sample, the contractor will need to label the sample container with the appropriate project information. As a minimum, the following information should be included on any sample. Additional information may be required depending on the specific location and/or purpose for the sample.

- Project name
- Project number
- Pay item number
- Pay item description
- Sample number

- Lot number
- Sublot number
- Date
- Location of sample

Sample transport and shipment

Ship samples in a container of sufficient strength to prevent the loss, contamination or damage of the contents during shipment. For earthwork materials, use clean tight woven canvas sacks or 5-gallon plastic buckets. Sufficiently identify all samples to facilitate reporting, logging, and tracking of sample information. Table 4 provides a brief summary list of containers to be used for common highway materials. If additional guidance is needed for a particular material, contact the Division Materials Engineer.

Table 4: Common Sample Containers.

Material	Appropriate Sample Container
Soil and Aggregate	Clean tight woven canvas sacks 5-gallon plastic buckets with tight lids
Cement, Lime, Fly ash	1-gallon watertight containers
Asphalt binder and cutback asphalts	1-quart cans
Emulsified asphalt	1-gallon large mouth plastic jugs with screw top lids
Asphalt mixture – uncompacted	6” x 12” cylinders 5-gallon plastic or metal buckets Cardboard box of sufficient size
Asphalt mixture – cores	Cushioned container 4” x 8” or 6” x 12” plastic concrete cylinder molds with appropriate packing
Concrete cylinders	Appropriate sized concrete cylinder molds shipped in a sturdy box with insulation and padding

4.4.5 Request for laboratory testing

All samples shipped to the FLH division laboratory must have a Request for Laboratory Tests form, form FHWA 1600, to provide instruction as to the testing to be performed. The form should be completed by the Project Engineer and attached to the outside of the sample container in a manner that will protect it during shipment. A duplicate copy should be placed inside the shipping container. The form can also be faxed or electronically sent in advance of shipment to alert the lab personnel that a sample will be arriving.

Table 5 provides guidance on minimum sample sizes required for given testing.

Table 5: Guidance for Sample Sizes for Transmitting to FLH Laboratory.

Material	Minimum Split Size for Transmitted to FLH Laboratory	Purpose	Test Method or Specification
Subgrade soil	50 lbs (23 kg)	Classification Moisture - Density	AASHTO M 145 AASHTO T 99 OR T 180
Unclassified Borrow	50 lbs (23 kg)	Classification Moisture - Density	AASHTO M 145 AASHTO T 99 OR T 180
Select Borrow	50 lbs (23 kg)	Gradation Atterberg Limits Moisture - Density	AASHTO T 11 & T 27 AASHTO T 89 & T 90 AASHTO T 99 OR T 180
Topping	50 lbs (23 kg)	Classification Moisture - Density	AASHTO M 145 AASHTO T 99 OR T 180
Foundation fill	50 lbs (23 kg)	Gradation Atterberg Limits Moisture - Density	AASHTO T 11 & T 27 AASHTO T 89 & T 90 AASHTO T 99 OR T 180
Bedding material	50 lbs (23 kg)	Gradation Moisture - Density	AASHTO T 11 & T 27 AASHTO T 99 OR T 180
Backfill material	50 lbs (23 kg)	Classification Moisture - Density	AASHTO M 145 AASHTO T 99 OR T 180
Structural backfill	50 lbs (23 kg)	Gradation Atterberg Limits Moisture - Density	AASHTO T 11 & T 27 AASHTO T 89 & T 90 AASHTO T 99 OR T 180

4.5 Soil-Specific Sampling Notes

When sampling earthwork materials, the following soil-specific considerations should be kept in mind:

- **Oversized Particles:** Soils often contain rock fragments larger than the equipment can test. If particles larger than 0.75 inch (19 mm) are present, the engineer must account for them in density calculations (see AASHTO T 99/T 180 procedures).
- **Cohesive Soils:** Fine-grained soils (clay, silt) are "sticky" and can clump or separate during sampling and transport. Handle carefully to maintain representativeness.
- **Variability:** In-situ soils may vary significantly over short distances (different deposits, layers, weathering). The number of samples needed may be higher than the contract minimum to capture this natural variability.

These complexities are why proper sampling and qualified personnel are so important.

Chapter 5

Imported Subgrade & Backfill Materials

5.1 Imported Materials: When & Why They Are Used

Not all soil used in highway construction comes from the site itself. When on-site materials are unsuitable (poor gradation, high plasticity, contamination, or insufficient quantity), engineers specify imported materials:

- **Unclassified Borrow:** General-purpose fill for deep embankments
- **Select Borrow:** High-quality granular material, typically for frost-resistant layers
- **Topping:** Clean, well-graded material for the uppermost embankment layer
- **Foundation Fill, Bedding, Backfill, Structural Backfill:** Materials for structures (culverts, retaining walls, bridges)

Unlike in-situ soils, imported materials must be explicitly approved and certified before use. The sections that follow describe the testing and certification procedures for each material type.

5.2 Imported Subgrade and Backfill Materials

For some projects, it may become necessary to import materials for the completion of embankments. These materials include:

- **Unclassified borrow:** granular material that has a maximum size of 24 inches (600 mm) and used in deep embankment construction
- **Select borrow:** granular material with specific gradation requirements and typically used in areas as resistance to frost heave
- **Topping:** granular material that has a maximum size of 3 inches (75 mm)

Typically a bid item for the specific material will be listed in the contract documents for the project. Unlike in-situ soils, these materials will need to meet specific requirements as defined in the contract. These materials are described as granular in nature and will be tested for character and quality to ensure compliance with contract requirements. These tests include sieve analysis, Atterberg Limits, and soil classification. Requirements for unclassified borrow are often modified in the special contract requirements for projects in areas where granular materials are not readily available.

Backfill material for structures is also a product that is typically imported for use. These materials include:

- **Foundation fill:** typically used to replace unsuitable or unstable material for the construction of footings or other structural components
- **Bedding material:** typically used under culvert pipe
- **Backfill material:** typically used as backfill material for pipes
- **Structural backfill:** typically used to provide uniform material for backfill behind structures

These materials are often considered subsidiary to the installation of the structure. Like imported subgrade materials, backfill materials are granular and have specific requirements as indicated in the contract. Testing of these materials is important to ensure compliance with the contract. Sampling and testing requirements that are applicable to the contract may be found in the "Sampling and Testing Requirements" table located at the end of each section in the FP or in the special contract requirements.

Electrochemical requirements may also be included if the backfill will be used in connection with metallic construction elements. These elements include items such as reinforcement for mechanically stabilized earth walls, rock bolts, anchor bolts, gabion mattress material, or pipe elements. The primary use of this testing is to determine the corrosion potential of the soil on metal elements. Soil resistivity measurements supplemented by the soil pH value are used to identify conditions under which the corrosion of the metals in the soil may be sharply accentuated. Sulfate and chloride content are also used in determining the corrosive nature of soil. These tests measure the water-soluble ion content in the soil that would be detrimental to buried metal components.

The quality of the backfill material used is critical to the service life of the constructed retaining structure. If the corrosion potential is a concern, the contract will include sampling and testing requirements to verify the quality of the backfill material. Any questions regarding the specific testing or sampling requirements may be directed to the Division Materials Engineer.

Table 6 provides guidance on minimum sample sizes required for given testing.

Table 6: Guidance for Sample Sizes for Transmitting to FLH Laboratory.

Material	Minimum Split Size for Transmitted to FLH Laboratory	Purpose	Test Method or Specification
Subgrade soil	50 lbs (23 kg)	Classification Moisture - Density	AASHTO M 145 AASHTO T 99 OR T 180
Unclassified Borrow	50 lbs (23 kg)	Classification Moisture - Density	AASHTO M 145 AASHTO T 99 OR T 180
Select Borrow	50 lbs (23 kg)	Gradation Atterberg Limits Moisture - Density	AASHTO T 11 & T 27 AASHTO T 89 & T 90 AASHTO T 99 OR T 180
Topping	50 lbs (23 kg)	Classification Moisture - Density	AASHTO M 145 AASHTO T 99 OR T 180
Foundation fill	50 lbs (23 kg)	Gradation Atterberg Limits Moisture - Density	AASHTO T 11 & T 27 AASHTO T 89 & T 90 AASHTO T 99 OR T 180
Bedding material	50 lbs (23 kg)	Gradation Moisture - Density	AASHTO T 11 & T 27 AASHTO T 99 OR T 180
Backfill material	50 lbs (23 kg)	Classification Moisture - Density	AASHTO M 145 AASHTO T 99 OR T 180
Structural backfill	50 lbs (23 kg)	Gradation Atterberg Limits Moisture - Density	AASHTO T 11 & T 27 AASHTO T 89 & T 90 AASHTO T 99 OR T 180

When field-testing soils, Table 7 provides some of the test procedures to be used as appropriate and as specified in the contract. And Table 8 in Chapter 7 provides guidance for certifications that may be required.

Table 7: AASHTO Soil Test Procedures.

Test Number	Test Title
AASHTO R 58	Dry Preparation of Disturbed Soil and Soil Aggregate Samples for Test
AASHTO T 89	Determining the Liquid Limit of Soils
AASHTO T 90	Determining the Plastic Limit and Plasticity Index of Soils
AASHTO T 99	Moisture-Density Relations of Soils Using a 2.5-kg (5.5-lb) Rammer and a 305-mm (12-in.) Drop
AASHTO T 180	Moisture-Density Relations of Soils Using a 4.54-kg (10-lb) Rammer and a 457-mm (18-in.) Drop
AASHTO T 190	Resistance R-Value and Expansion Pressure of Compacted Soils
AASHTO T 191	Density of Soil In-Place by the Sand-Cone Method
AASHTO T 193	The California Bearing Ratio
AASHTO T 255	Total Evaporable Moisture Content of Aggregate by Drying
AASHTO T 265	Laboratory Determination of Moisture Content of Soils
AASHTO T 272	One Point Method for Determining Maximum Dry Density and Optimum Moisture
AASHTO T 310	In-Place Density and Moisture Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)

Chapter 6

Verification & Acceptance Decisions

6.1 Verification & Acceptance of Test Results

Once soil samples are tested in the laboratory, the engineer makes the decision to verify or accept the results.

If results show the material meets all specification requirements, classification are within limits, moisture-density as designed, and strength adequate, the material is accepted. It can be incorporated into the roadway.

If results show non-conformance, then there are three options: reject and remove the material, accept at a reduced price (with approval), or allow corrective action (e.g., further compaction, stabilization). These decisions follow specific procedures outlined in the acceptance framework. The next sections detail how to verify test results are valid and how to apply acceptance decisions in practice.

6.2 Verification Processes

6.2.1 Verification of Material Quality

Regardless of which acceptance method is used, it is always necessary to verify the quality of materials incorporated into the work. The responsibility for final acceptance of all materials rests with the Contracting Officer. Therefore, the Project Engineer must be confident that the results obtained on which the acceptance decision is based are valid. Using qualified laboratories and qualified technicians facilitates achieving a quality project and having reliable test results on which to base acceptance decisions.

Whenever there are at least three samples tested by both the contractor and the Government, comparison of the results should be performed by entering them into QL-PAY. QL-PAY uses statistical procedures to analyze the data and determine if there are significant differences between the contractor’s and Government’s results or if the results are within what would be considered normal limits of variability. If the results are within normal variability limits, the contractor’s results would be considered valid. If the results are not within normal variability limits, QL-PAY will issue an alert. It is essential that the Division Materials Engineer be contacted immediately and review the data before any action is taken. A final determination as to the validity of the contractor’s results must be made by an individual having a background in both statistical analysis and materials in order to avoid making an incorrect decision.

When there are fewer than three samples tested by either party, the comparison cannot be done in QL-PAY. In those instances, the results of samples should be compared using the multi-laboratory precision limit specified in the applicable test method. This provides an acceptable range for two results obtained from different laboratories by different operators. If the results are within the multi-laboratory precision limit, the contractor’s results would be considered valid.

6.2.2 Visual Inspection and Certification

Acceptance verification of material quality may be by visually inspecting the material and verifying the certification. If the Project Engineer has any doubts regarding material quality, he has the right to obtain a sample and have it tested and should do so. Normally, if a sample is desired, it should be obtained by the contractor in the presence of the Project Engineer with the Project Engineer determining the location of the sample. The Project Engineer should take immediate possession of the sample after it is obtained (and split if desired). The sample is usually obtained by using random numbers; however, the Project Engineer may elect to test in a specific location to verify the quality of the material.

6.2.3 Measured or Tested for Conformance

The Project Engineer should normally obtain and test a minimum of three random samples; however, for small quantities fewer samples may be appropriate. In the case where the Project Engineer has suspicions concerning the quality of the material, the Project Engineer may direct the contractor to obtain one or more samples from the suspect area rather than use random samples. The Project Engineer should take immediate possession of the sample after it is obtained (and split if desired) by the contractor.

6.3 Acceptance of Work and Value Determination

Acceptable work conforming to the contract should be paid for at the contract unit bid price. When material or work fails to meet the established specification, the material or work shall be removed and replaced unless in the public interest the Government consents to accept the work with an appropriate adjustment in price or corrective action. If the contractor requests to have the work accepted at a reduced price or requests permission to perform corrective measures, the request will be evaluated based on the public interest. It is the contractor's responsibility to submit a proposal outlining any action that will be taken in lieu of removal and replacement. The contractor may submit a written request to:

1. Have the work accepted at a reduced price; or
2. Be given permission to perform corrective measures to bring the work into conformity.

A written request must contain supporting rationale and documentation. This would include references or data justifying the proposal based on an evaluation of test results, effect on service life, value of material or work, quality, aesthetics, and other tangible engineering basis.

If the contractor submits a written request, the following process outline provides guidance for addressing the request to accept work at a reduced price:

1. Meet to discuss the non-compliance material or workmanship. The meeting should include the Project Engineer, Construction Operations Engineer, and Technical Services Branch representative with expertise in or responsibility for the area of concern (i.e., bridge, hydraulics, materials).
2. Review test data to determine the significance of non-compliance.
3. Evaluate the degree of deviation from contract requirements. Such evaluation is a subjective process and must take into account the criticality of the material or work, the risk associated with any deviation from the contract requirements, and the degree of deviation from contract requirements.
4. Reduce the contract unit price for the item in question depending on the significance of the noncompliance. The percent reduction in the unit price are based on the following guidelines:

   0 to 5% Material substantially meets the contract requirements with minor deviations from the specifications.

6 to 15% Material fails to meet contract requirements and results in the use of an inferior product. Generally, this material will result in a reduction in the usable life of the item in question.

16 to 75% Material fails to meet contract requirements by a significant amount and is clearly and inferior product. Use of this material may meet the intended purpose; however, the quality is well below that specified. The criticality of this material may be low and does not warrant removal or other corrective action.

Likewise, corrective actions need to be evaluated to determine the level of effectiveness. The remedial/corrective work must provide results that are more desirable than reducing item pay amounts. In certain instances, corrective actions may be used in combination with a contract bid price reduction.

When it is determined that the material or work does not meet the intended purpose or results in substantial quality or safety deficiencies, it shall be removed and replaced.

Chapter 7

Roles, Responsibilities & Documentation

7.1 Contractor's Responsibilities

The contractor is responsible for excavation and constructing the subgrade and embankments according to the requirements provided in the contract. As part of these requirements, the contractor is to control the quality of the materials provided and also monitor the construction process to ensure compliance. The construction of embankments and the placing of backfill materials require that the material provided meet the specification and be in a suitable condition for compaction. The specific requirements will be established in the contractor quality control plan and contract specifications. In general, the sampling and testing responsibilities of the contractor include:

- Providing subgrade stabilization mix design submittals.
- Sampling material to be tested according to proper sampling methods.
- Providing split samples to the Government when required or requested.
- Testing material for conformance to material requirements. (i.e., classification, gradation, Atterberg Limits, etc.)
- Providing appropriate moisture density curves for a specific material type.
- Testing density of placed material to ensure proper compaction.
- Monitoring the production of any imported material to ensure compliance with the specifications.
- Providing appropriate certifications for material.

The contractor needs to provide information and test results according to the timeframe specified in the contract. Distribution of the test reports and certifications should be according to the contract documents and the quality control plan.

Table 6 provides guidance on minimum sample sizes required for given testing.

7.2 Government's Responsibilities

The Project Engineer or designated representative will review the test results and certifications for contract compliance. A decision regarding the acceptance of materials and work will be made in accordance with Subsection 106.01.

The Project Engineer or designated representative will also be present to witness all samples taken for the Government and split, when required. Upon completion of splitting, the samples will be secured and should immediately be in the control of the government. The Project Engineer needs to be aware of the contractor's operations and be available to witness the sampling and splitting activities.

The Project Engineer should review the testing protocols and equipment to ensure compliance with the contract requirements. In regard to subgrade materials, the testing should verify the appropriate material characteristic as listed in the contract requirements. The testing should also verify that the material is suitable for use in the work and may be constructed according to the contract documents.

Visual observations are an important part of the Project Engineer's responsibilities with regard to earthwork operations. Because soils are not a manufactured product, there can be significant variations in the materials being used, especially in areas with many different soil deposits. The Project Engineer should review the Geotechnical and Pavement Design Reports to become familiar with the subsurface conditions and what to expect with on-site materials. It is important to view the contractor's operations to ensure that proper materials are properly placed. The quality control tests should be used by the Project Engineer to confirm field observations. For instance, if tests indicate passing density results but the material is pumping under the weight of construction equipment, an investigation should be conducted to resolve the conflict in test results and field observations. By visually observing earthwork operations, problems can often be identified and addressed early in the construction process and future problems can be eliminated when placing final surfacing.

7.3 Material Certifications

Many of the materials specified and used on a project are manufactured off-site and acceptance is based on materials certification.

Certifications need to be in conformance with the contract requirements as provided in Subsection 106.03.

FP specifications reference two types of materials certifications, production and commercial. The Project Engineer needs to determine the appropriate certification for the type of material being provided and obtain the appropriate documentation in accordance with the certification being provided.

Table 8 provides guidance for certifications that may be required.

Table 8: Materials Certification.

Section	Description	Material	Frequency	
			Certification	Sample
207	Earthwork geotextiles	Geotextile	1 per shipment	First shipment
213	Subgrade stabilization	Chemical admixtures Fly ash Hydraulic cement	1 per shipment “ “	Upon request “ “
251	Grout for riprap	Material for grout	1 per mix	–
253	Gabions and revet mattresses	Material for gabion structures	1 per source	–
255	MSE walls	Material for MSE walls	1 per shipment	–
256	Ground anchors	Material for ground anchors	1 per shipment	–
258	Reinforced concrete retaining walls	As specified	1 per shipment	–
259	Soil nail retaining walls	As specified	1 per shipment	–
260	Rock bolts and Rock dowels	As specified	1 per shipment	–

7.4 Government’s Responsibilities

The Project Engineer or designated representative will review the test results and certifications for contract compliance. A decision regarding the acceptance of materials and work will be made in accordance with Subsection 106.01.

The Project Engineer or designated representative will also be present to witness all samples taken for the Government and split, when required. Upon completion of splitting, the samples will be secured and should immediately be in the control of the government. The Project Engineer needs to be aware of the contractor's operations and be available to witness the sampling and splitting activities.

Appendix A: Form References

Form references for use in the testing of soils and subgrade materials.

- Form FHWA 1600C – Request for Laboratory Tests (CFL)
- Form FHWA 1600E – Requests for Laboratory Tests (EFL)
- Form FHWA 1600W – Requests for Laboratory Tests (WFL)
- Form FHWA 1616 – Moisture content by microwave method
- Form FHWA 1618 – In-place nuclear moisture/density worksheet
- Form FHWA 1621 – Coarse and fine aggregate gradation worksheet
- Form FHWA 1624 – Liquid Limit and Plastic Limit worksheet
- Form FHWA 1625 – Moisture density worksheet (T 99/T 180)
- Form FHWA 1627 – Sieve analysis for fine and coarse aggregate worksheet
- Form FHWA 1636 – Correction for coarse particles in soil compaction worksheet

FHWA Forms

The most current version of FHWA forms are found at the following website:

https://flh.fhwa.dot.gov/resources/materials/

Documentation & Record-Keeping

Maintain detailed records of all sampling, testing, and acceptance decisions. Keep certifications, test reports, request forms (FHWA 1600), and split samples organized by location and date. These records protect both the contractor and the Government in case questions arise later about material quality or compliance.

Appendix B: Sample Quantities Guide

APPENDIX : SAMPLE QUANTITIES GUIDE

Division 200

	Material / Product	Characteristic	Sampling Method	Minimum Field Sample lbs (kg)	Minimum Split Size to FLH Lab lbs (kg)
Section 204	Topping	Classification	AASHTO R 90		
		2"		220 (100)	44 (20)
		1"		110 (50)	22 (10)
		Moisture - Density	AASHTO R 90	330 (150)	50 (23)
	Unclassified Borrow	Classification	AASHTO R 90		
		2"	AASHTO R 90	220 (100)	44 (20)
		1"	AASHTO R 90	110 (50)	22 (10)
		Moisture-density	AASHTO R 90	330 (150)	50 (23)
	Select Borrow	Classification	AASHTO R 90		
		2"		220 (100)	44 (20)
		1"		110 (50)	22 (10)
		Gradation	AASHTO R 90		
		2"		220 (100)	44 (20)
		1"		110 (50)	22 (10)
		Liquid Limit/Plasticity Index	AASHTO R 90	12 (5)	12 (5)
		Moisture-density	AASHTO R 90	330 (150)	50 (23)
	Earth Embankment	Classification	AASHTO R 90		
		2"		220 (100)	44 (20)
		1"		110 (50)	22 (10)
		3/4"		55 (25)	11 (5)
		1/2"		35 (15)	4 (2)
		Moisture-density	AASHTO R 90	330 (150)	50 (23)
Section 208	Foundation Fill	Classification	AASHTO R 90		
		2"		220 (100)	44 (20)
		1"		110 (50)	22 (10)
		Gradation	AASHTO R 90		
		2"		220 (100)	44 (20)
		1"		110 (50)	22 (10)
		Liquid Limit/Plasticity Index	AASHTO R 90	12 (5)	12 (5)
		Moisture-density	AASHTO R 90	220 (100)	50 (23)
	Structural Backfill	Gradation	AASHTO R 90	330 (150)	130 (60)
		Liquid Limit/Plasticity Index	AASHTO R 90	12 (5)	12 (5)
		Moisture-density	AASHTO R 90	330 (150)	50 (23)
Section 209	Backfill Material	Gradation	AASHTO R 90		
		3"		330 (150)	130 (60)
		2"		220 (100)	44 (20)
		1"		110 (50)	22 (10)
		Liquid limit	AASHTO R 90	12 (5)	12 (5)
		Moisture-density	AASHTO R 90	330 (150)	50 (23)
	Bedding Material	Moisture-density	AASHTO R 90	35 (15)	50 (23)
	Foundation Fill	Moisture-density	AASHTO R 90	220 (100)	50(23)
	Unclassified Borrow	Classification	AASHTO R 90		
		3"		330 (150)	130 (60)
		2"		220 (100)	44 (20)
		1"		110 (50)	22 (10)

Division 200 (continued)					
	Material / Product	**Characteristic**	**Sampling Method**	**Minimum Field Sample lbs (kg)**	**Minimum Split Size to FLH Lab lbs (kg)**
Section 213	Subgrade Stabilization	Mix Design			
		Soil	AASHTO R 90	—	200 (90)
		Fly Ash	ASTM C311	—	50 (25)
		Lime	AASHTO T 218	—	25 (10)
		Hydraulic Cement	AASHTO R 71	—	25 (10)
Section 251	Riprap Quality Requirements	Apparent specific gravity & absorption, Sodium Sulfate Soundness, LA Abrasion	AASHTO R 90	—	200 (90)
Section 252	Rock for Buttresses Quality Requirements	Apparent specific gravity & absorption, Durability	AASHTO R 90	—	200 (90)
	Rock for Rockeries Quality Requirements	Apparent specific gravity & absorption, Durability, LA Abrasion, Sodium Sulfate Soundness	AASHTO R 90	—	200 (90)
Section 255	Select Granular Backfill Quality Requirements	Gradation, Angle of internal friction, Soundness, Plasticity Index, LA Abrasion, Electrochemical	AASHTO R 90		
		3"		330 (150)	130 (60)
		2"		220 (100)	44 (20)
		1"		110 (50)	22 (10)
		Moisture - Density	AASHTO R 90	330 (150)	50 (23)

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