Field Materials Manual Series:

Aggregate Base & Subbase

Design Sampling & Compaction

Edited and adapted by: Donald Parnell, PE

& Dr Jeelan Moghraby, PhD, MBA

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

Aggregate base and subbase typically provide the first layer of the structural pavement section. These are manufactured aggregate products that may be produced from mining or quarrying naturally occurring rock deposits or as a by-product of other manufacturing processes such as slag.

This course covers the selection, testing, sampling, and placement of aggregate base and subbase layers (the structural foundation of the pavement). It will examine how to assess aggregate quality at the source, design sampling procedures for different production scenarios, and verify field compaction. 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:

- Evaluate aggregate quality using standard test methods (LA Abrasion, Soundness, Durability)
- Design proper sampling procedures for aggregate from stockpiles, flowing streams, and conveyor belts
- Understand base stabilization techniques (cement, lime, fly ash, asphalt)
- Verify compaction of aggregate base and recognize deficiencies in the field
- Accept or reject aggregate base materials based on test results and contract requirements

Intended Audience

This course is intended for highway engineers, asphalt and materials engineers, as well as construction managers, field inspectors, and quality assurance personnel responsible for aggregate base materials 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 & Role of Aggregate Base

1.1 Introduction

Aggregate base and subbase layers are the structural foundation of highway pavements. These layers, typically 4 to 12 inches thick, provide support and load distribution directly beneath asphalt or concrete pavement. The performance of the entire roadway, its resistance to rutting, fatigue, and environmental damage, depends heavily on the quality of the aggregate base.

This course covers the selection, testing, sampling, and field verification of aggregate base materials. Engineers will learn how to evaluate aggregate quality at the source (quarry or recycled source), specify gradation and material properties, perform field compaction verification, and make acceptance decisions based on test results. The content draws from the Federal Lands Highway Field Materials Manual and reflects standard practices used across US highway construction

1.2 Summary and Description

Aggregate base and subbase typically provide the first layer of the structural pavement section. These are manufactured aggregate products that may be produced from mining or quarrying naturally occurring rock deposits or as a by-product of other manufacturing processes such as slag. Base aggregates may be combined with a binding agent to form a stronger stabilized base. Cement, lime, fly ash, emulsified asphalts, and other materials have been used to provide additional strength and stability to the aggregate base layer.

Testing of the aggregate for use as base is designed to provide information on the inherent quality properties of the rock to be used. Among these are hardness, soundness, stability, resistance to abrasion and other forms of mechanical breakdown, and resistance to weathering. Once the quality properties of the aggregate are established to meet the intended use, the aggregate will need to be crushed and processed to meet requirements of the finished product. During construction of the base layer, proper compaction is required to provide the proper support as required by the structural pavement design.

Other materials are also used as part of the construction of aggregate base construction. These include aggregate-topsoil courses and dust palliatives. These products serve a unique purpose and are used for specific applications. In general, these uses are limited compared with the more common use of aggregate base.

Tests in Tables 1, 3 and 6, and Figure 1 function to either evaluate the quality of aggregate, quality of the finished product, or verify proper construction. Base aggregate tests vary throughout the United States. When contract specifications permit options, the selection of one test over another is often a matter of local engineering judgment. Consideration needs to be given to local knowledge and past performance of aggregate bases to determine what testing is appropriate and applicable. The Project Engineer should consult the contract to determine what aggregate tests have been specifically included in the project.

1.3 Aggregate Base in the Construction Process

Aggregate base materials originate from two sources: natural rock deposits (quarried and crushed) or industrial byproducts (such as slag from steel mills). The selected material undergoes laboratory testing at the source to verify quality properties—hardness, soundness, resistance to weathering and abrasion. If the source material meets specifications, it is crushed, processed, and stockpiled.

During construction, aggregate base is delivered to the project site, sampled, and tested to confirm its properties remain within specification. The material is then spread and compacted to a specified density and moisture content. Field density testing verifies compaction; results determine whether the material is accepted, rejected, or accepted at a reduced price.

Throughout this process, both contractor and Government personnel perform testing and verification. The acceptance methods described in the Federal Lands Highway manual—visual inspection, certification, measured/tested conformance, and statistical evaluation—guide these decisions. Understanding which method applies and how to interpret results is critical to project success.

Chapter 2

Aggregate Source Quality & Testing

2.1 Aggregate Quality Properties

Quality of the aggregate material can be determined by testing samples obtained from the source. These samples should be obtained from various locations throughout the source. Sampling techniques used to obtain rock for testing including core samples, rock face grab samples, or crushed processed aggregate stockpiles to name a few. Regardless, the rock or aggregate that is sampled should be representative of the aggregate to be used in the production of the aggregate base. The tests listed in Table 1 provide a listing of test methods typically used to determine aggregate quality. The Project Engineer should also review the contract to determine if other quality aggregate tests have been specified based on project location, local conditions, or other engineering judgment.

Resistance of an aggregate to abrasion, impact, and grinding is determined using the Los Angeles Abrasion test. The test measures the degree to which a graded aggregate is reduced in size when subjected to the rolling and pounding of steel spheres inside a rotating steel drum. This is also a measure of aggregate toughness or hardness.

Resistance of an aggregate to breakdown by freezing and thawing is determined using the Soundness test. With the Soundness test, weak porous aggregates often disintegrate from the pressure of the salt that crystallizes in the pores during the performance of the test. This pressure simulates the effect that ice crystals would have in the aggregate when subjected to severe multiple freeze thaw cycles.

The Aggregate Durability test measures resistance of an aggregate to mechanical methods of degradation. In this method, a sample of aggregate is agitated in the presence of water. The amount of fines generated during the test determines the durability index.

The Fractured Faces test is used when aggregate is obtained from a gravel or pit source. In order to provide for aggregate interlock, the round character of the rock needs to be altered by crushing. This test determines the percentage of aggregates that have mechanically fractured faces.

Table 1: Aggregate Quality Test Methods.

Aggregate Test	Test Method	Aggregate Performance Characteristic
L.A. Abrasion	AASHTO T 96	Hardness
Sodium Sulfate Soundness	AASHTO T 104	Freeze / Thaw Resistance
Aggregate Durability	AASHTO T 210	Mechanical Abrasion
Fractured Faces	ASTM D5821	Aggregate Interlock

A minimum 200-pound (90 kg) representative sample should be obtained in order to perform all of the quality tests listed in Table 1. In the event that the contract includes additional quality tests, consult the FLH Division Materials Engineer for additional guidance.

2.2 Interpreting Aggregate Quality Test Results

The tests listed in Table 1, Los Angeles Abrasion, Soundness, and Durability, measure different aspects of aggregate durability and strength. Each provides information about how the aggregate will perform under traffic loading and environmental conditions.

The Los Angeles Abrasion test simulates mechanical breakdown under traffic. Aggregates with high LA values (excessive loss) are soft or weak; they will break down under truck traffic, accelerating pavement deterioration. Typical specifications require LA values of 40 or less.

The Soundness test simulates freeze-thaw weathering by using salt solutions. Weak, porous aggregates disintegrate; sound aggregates resist degradation. This test is critical in cold climates.

The Durability test measures resistance to general environmental degradation. Results guide decisions about aggregate suitability and expected pavement life. Low durability ratings may indicate the need for improved drainage or pavement design modifications.

Source testing occurs during the project development phase. If an aggregate source fails these tests, it is rejected; the engineer seeks an alternative source.

Source approval ensures baseline quality before material reaches the construction site.

2.2 Processed Aggregate Properties

Once the quality of the aggregate has been determined to meet the contract requirements, processed aggregate properties will be determined. For any aggregate layer, the gradation of the material and moisture density relationship will be determined. In addition, other properties may be included depending on the use and particular specifications of the project. Certain aggregate base requirements may include a liquid limit or sand equivalent requirement to ensure that the fine portion of the aggregate mixture is granular in nature. A plasticity index requirement may be included when surface course aggregate is used to ensure that the fines exhibit a binding characteristic that would provide a higher quality driving surface. The contract may also include a minimum strength requirement, such as CBR or R-Value, for aggregates.

Gradation or particle size is the one characteristic subject to control by conventional field processing. Gradation is not an inherent geological property of the rock, although to some extent the type of rock does influence the amount and character of coarse and fine materials produced by crushing.

Gradation of the aggregate is determined by means of a sieve analysis, which is the separation of the aggregates into several designated sizes by passing the material through a series of sieves arranged from coarse to fine. The aggregate gradation is determined according to AASHTO T 11 and T 27. Generally, aggregates for highways and structures are divided into two gradation classifications. See Table 2.

Table 2: Gradation Classification.

Type of Aggregate	Aggregate Size
Coarse aggregate	Material retained on the #4 (4.75 mm) sieve
Fine aggregate	Material passing the #4 (4.75 mm) sieve

When the #200 (75 µm) sieve is specified as part of the gradation requirements, washing the sample in accordance with AASHTO T 11 is required in conjunction with the sieving process.

The character and relative quality of the fine aggregate can be determined using the liquid limit, plastic index, and sand equivalent test methods. If certain binding characteristics of an aggregate are required, this can be determined using the liquid limit and plasticity index tests. Aggregate material should be prepared using the dry preparation method as stated in AASHTO R 58. The presence and amount of potentially detrimental clay-like fines in the aggregate can be determined using the sand equivalent test method. These tests may or may not be included in the contract depending on the purpose and function of the aggregate base layer being placed.

Table 3: Supplemental Aggregate Base Tests.

Fine Aggregate Tests	Test Method	Aggregate Characteristic
Liquid Limit	AASHTO T 89	Liquid state of fine aggregate
Plastic Limit	AASHTO T 90	Plastic state of fine aggregate
Sand Equivalent	AASHTO T 176	Proportion of clay in aggregate

Moisture Density Relationship

The moisture density relationship of an aggregate will be determined through laboratory testing. This testing will establish a reference density that will be used during the construction of the base layer to verify appropriate field compaction has been achieved. The test method most commonly used to establish the moisture density standard is AASHTO T 180 although there are other tests that may also be used. The contract documents will specify the method to be used to establish the target density and moisture content. Aggregates often contain oversized material, particles larger than 0.75 inch (19 mm). The maximum dry density and optimum moisture content of the aggregates containing more than 5 percent of oversized material should be corrected according to AASHTO T 99 or T 180.

During construction, field density tests are taken and compared to the established standard to verify that the material has been properly compacted. Results of any field density test cannot be properly evaluated until compared to the appropriate reference density and moisture content. There are several acceptable methods that may be used to determine the field density and moisture content of the aggregate. The method most common is AASHTO T 310. This method utilizes a nuclear gage to determine the moisture content and density of the aggregate. Other methods such as the sand-cone method (AASHTO T 191) and the oven-drying moisture method (AASHTO T 265) may still be used however they are becoming less common.

Chapter 3

Acceptance Methods for Aggregate Base

3.1 Acceptance

Aggregate base materials undergo acceptance testing similar to other highway materials. The material 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 Federal Highway Projects (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.

3.1.1 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. Engineers can visually accept aggregate base if the stockpile appears clean, well-graded (mix of coarse and fine particles), and free of contamination (mud, clay coating, foreign materials). However, visual inspection alone is insufficient for formal acceptance; test results must confirm that gradation, strength, and durability meet specification.

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.

3.1.2 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 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.

3.1.3 Measured or Tested Conformance

The most common acceptance method of acceptance is based on measuring or testing material for conformance to the specifications stated in the contract. Contractor and Government personnel sample the aggregate during stockpiling or placement. Samples are tested for gradation, quality properties (LA Abrasion, Soundness), and moisture-density relationships. Results are compared to contract specifications; material is accepted if results comply, or rejected if non-conforming.

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.

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

For large volumes of aggregate base (extended placement seasons, multiple sources), the contract may specify statistical acceptance. This 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.

3.2 Verification Processes

3.2.1 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.

3.2.2 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.

3.2.3 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.

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

For this type of material acceptance, the contract specifies the sampling frequency and the Project Engineer determines the random location of all the samples. All samples intended for use in the acceptance decision must be obtained by the contractor in the presence of the Project Engineer. The sample location should not be revealed to the contractor until moments before the sample is to be obtained. The Project Engineer should take immediate possession of the sample after it is obtained and split. All comparisons of results should be made in QL-PAY.

Chapter 4

Sampling Procedures for Aggregate

4.1 Sampling Aggregate Materials: Challenges and Best Practices

Sampling aggregate base correctly is challenging. Unlike homogeneous materials, aggregate stockpiles and flowing streams exhibit natural segregation; coarse particles accumulate on the outside and in low areas, while fine particles settle in the center. A grab sample taken from an unrepresentative location will bias results, leading to incorrect acceptance or rejection decisions.

The Federal Lands Highway manual provides detailed diagrams and procedures for four sampling scenarios: from stockpiles, flowing streams, conveyor belts, and windrows. Each scenario has specific techniques designed to obtain representative samples despite segregation challenges.

Random sampling, selecting locations using random numbers, not visual judgment, is essential for valid statistical analysis. The sampling procedures that follow specify equipment (cutting devices, shovels, sample splitters), witness requirements (Project Engineer must be present), and chain-of-custody protocols (maintaining sample integrity from collection to laboratory testing).

Mastering these procedures ensures reliable test results and defensible acceptance decisions.

4.2 Aggregate Sampling and Splitting

The importance of obtaining a proper sample of aggregate cannot be overemphasized. When obtaining a sample of aggregate, proper methods and technique need to be used to ensure a representative sample has been obtained. A proper sample is vital in order to provide correct information for evaluation purposes. If a proper sample is not obtained, any testing performed on that sample may be of little value.

AASHTO provides a standard practice for sampling of aggregates in AASHTO R 90. This practice provides guidance on obtaining samples from various locations such as stockpiles, flowing aggregate stream, conveyor belts, transportation units, and roadways. Guidance is also provided for the sampling of aggregate for the exploration of potential aggregate sources. The following paragraphs will provide some additional guidance on proper sampling technique.

4.2.1 Sampling from Stockpiles

As a general rule, sampling from stockpiles should be avoided whenever possible. Because of the potential for segregation to occur during the construction of the stockpile, obtaining a representative sample must be undertaken with great care.

When taking a sample of coarse or mixed coarse and fine aggregate, exercise caution to ensure that only the material from the sampling area is incorporated into the sample. A barrier, such as a wooden board or metal sheet, should be used to restrict the flow of the material down the pile so that the sample may be obtained from the specified area. Power equipment, if available, could also be used to obtain material from various locations in the main pile. These increments would then be combined to compose one field sample. Samples should be made by obtaining material from at least three increments taken from the upper, middle, and lower third of the pile. See Figure 1 and Figure 2.

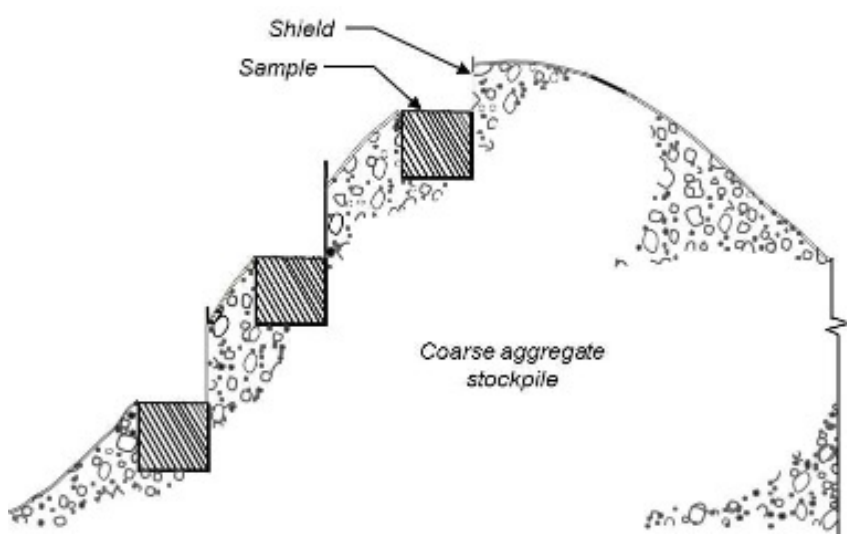

Figure 1: Proper Sampling of Coarse Aggregate.

NOTE: Sample the stockpile near its base, middle, and top as shown. Combine and mix the material obtained to form one sample and then reduce the size of the combined sample by splitting to the required testing size.

Figure 2: Proper Use of Shield for Sampling.

A sampling tube may be used to sample stockpiles of fine aggregate. The sampling tube should be inserted into the pile at random locations to extract material. As is the case with coarse or mixed coarse and fine stockpiles, multiple locations throughout the pile should be selected to obtain one composite sample. See Figure 3.

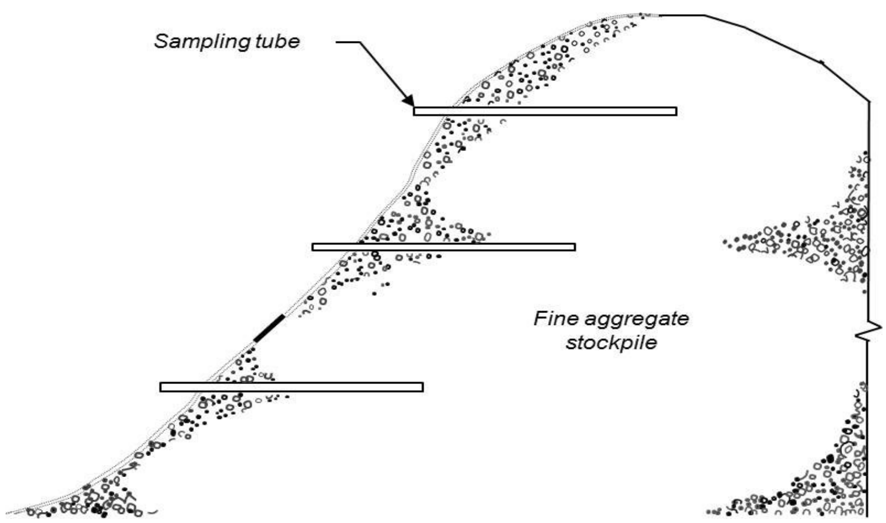

Figure 3: Proper Sampling of Fine Aggregate Stockpile.

NOTE: Insert the sampling tube horizontally near the base, middle, and top of the stockpile as shown. Combine and mix the material obtained to form one sample and then reduce the size of the combined sample by splitting to the required testing size.

4.2.2 Sampling from Flowing Aggregate Stream

It is recommended to obtain a sample from a flowing aggregate stream by cutting the entire cross section of material as it is being discharged. Another practice is to cut across the flowing material. In either case, special sampling devices are typically fabricated to obtain the sample. Figure 4 is an example of a fabricated sampling device.

Figure 4: Sampling Device Cutting Across Flowing Stream.

4.2.3 Sampling from Conveyor Belt

In sampling from a conveyor belt, the belt must be stopped in order to obtain the sample. A template should be manufactured that conforms to the shape of the belt. Insert two templates in the aggregate stream and space them appropriately to obtain the recommended amount for the sample. The sample should be obtained for the full width of the belt. Exercise care to ensure that all of the fines are swept off the belt and into the sample container. Figure 5 and 6 show proper sampling technique and devices typically used when obtaining a sample from a conveyor belt. Figure 7 provides a schematic drawing of a device typically used to obtain conveyor belt samples.

Figure 5: Sampling from Conveyor Belt.

Figure 6: Proper Device for Belt Sampling.

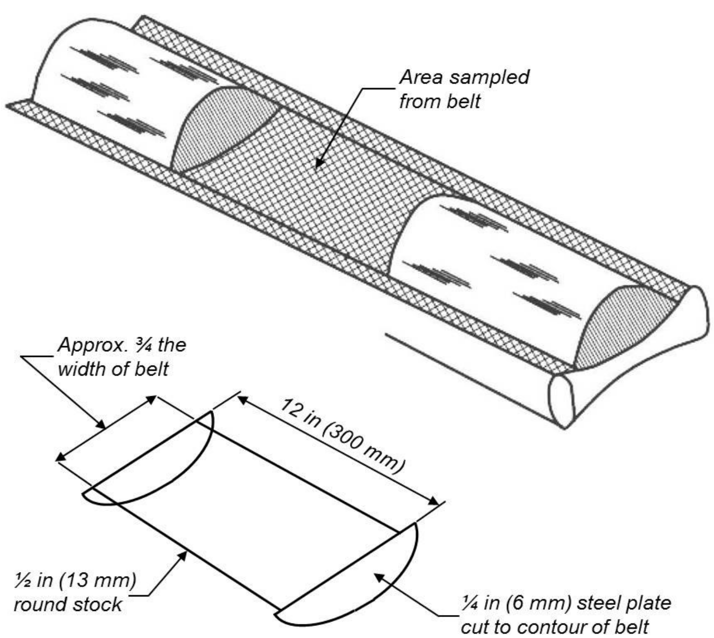

Figure 7: Schematic of Belt Sampling Device.

4.2.4 Sampling from Roadbed or Windrow

Roadbed and windrow sampling is generally used in the acceptance process for aggregate base materials. The sample should be obtained from the windrow or the roadbed after the aggregate has been processed. The typical method of sampling a windrow is to strike off the top of the windrow and sample a minimum of three random locations and combine the material into one sample. Figure 8 shows a schematic of this type of sampling.

When sampling from the roadbed, all of the material for the sample should be obtained full depth. Care should be exercised when obtaining this sample to ensure that none of the underlying materials are included in this sample. If this does occur, the sample would be considered contaminated and a new sample should be obtained.

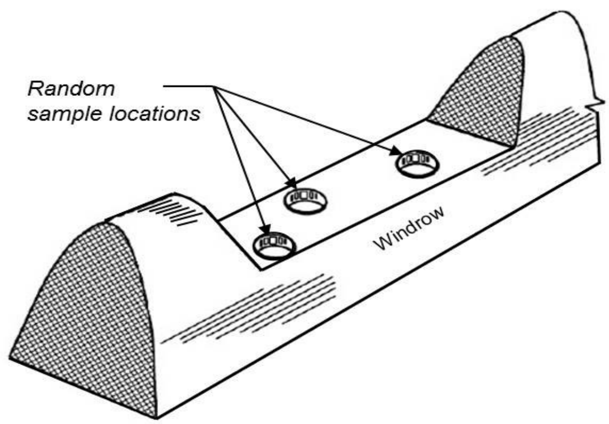

Figure 8: Schematic of Sampling from a Windrow.

> NOTE: Flatten the windrow to approximately 12 inches (300 mm) in width. Sample material from at least 3 random locations as shown. Combine and mix the material obtained to form one sample and then reduce the size of the combined sample by splitting to the required testing size.

The Project Engineer should review the contract documents and identify sample locations or any special sampling or testing requirement that may be specified. The contract will also indicate the point of sampling and sampling frequency for various aggregate products that are included in the contract.

4.2.5 Splitting Samples

Once a field sample has been obtained, it will need to be reduced in size to the proper testing size. AASHTO R 90 provides guidance on the minimum sample sizes of aggregate that constitute an appropriate field sample. From this original field sample, a smaller representative testing sample can be obtained. AASHTO R 76, Reducing Samples of Aggregate to Testing Size, is the method for reducing large field samples to appropriate sizes for testing. Samples are reduced by the use of a quartering blanket or a mechanical splitter. It is important to comply with both the minimum field sample size requirements and the minimum testing size requirements found in the specific test method to have valid test results.

Minimum split sample sizes for general aggregate testing are provided in Table 4. If multiple tests are to be performed on a single field sample, consult the FLH Division Materials Engineer for specific guidance on field sample sizes.

Table 4: Guidance for Sample Sizes for Transmitting to FLH Laboratory.

Material	Minimum Split Size for Transmitting to FLH Laboratory	Purpose	Test Method or Specification
Subbase, Aggregate Base, and Aggregate Surfacing	50 lbs (23 kg)*	Gradation Atterberg Limits Moisture – Density Sand Equivalent	AASHTO T 11 & T 27 AASHTO T 89 & T 90 AASHTO T 180 AASHTO T 176
Subbase, Aggregate Base, and Aggregate Surfacing	200 lbs (90 kg)	Aggregate Quality Test	AASHTO T 96 AASHTO T 104 AASHTO T 210 ASTM D5821

*100 lbs (50 kg) if CBR or R-value testing is required.

4.3 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.

4.3.1 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.

4.3.2 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.

4.3.3 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.

4.3.4 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. Sufficiently identify all samples to facilitate reporting, logging, and tracking of sample information. Table 1 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 5: 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

4.3.5 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.

4.4 Aggregate-Specific Sampling Challenges

Several factors complicate aggregate sampling:

- **Segregation:** Coarse and fine particles separate during handling and stockpiling. Improper sampling (grabbing from accessible spots) biases results toward fine or coarse fractions, giving a false picture of actual material quality.
- **Shield Use:** When sampling from stockpiles or streams, a shield prevents fine particles from bouncing away or being carried by air currents. Proper technique with the shield ensures the sample represents all size fractions.
- **Contamination:** Dust, dirt, and moisture can contaminate samples if containers are not clean. Canvas sacks should be new or well-cleaned; plastic buckets must be dry and clean.
- **Documentation:** Labels must be clear, legible, and permanent. Samples can be tracked for weeks; faded labels lead to confusion and lost chains of custody.

Attention to these details underpins valid testing and reliable acceptance decisions.

Chapter 5

Aggregate Base Treatments & Stabilization

5.1 Typical Aggregate Base Treatments

Aggregate bases and subbases can be treated with various additives to improve the strength and performance characteristic as compared to water-bound (untreated) bases. Laboratory tests are used to determine the amount of additive required to provide the specified mixture requirements. Typically these tests are used to determine the amount of additive required to meet the mixture requirements. Aggregates can be treated as part of the construction of a new aggregate course or in-place aggregates can be stabilized to strengthen an existing base layer.

The additives most commonly used to improve the structural capacity of a base layer are hydraulic cement, lime, or fly ash. It is critical during construction that the proportioning of the components be accurate in order to achieve the desired material properties. Using additional additive will produce a mixture with a higher strength but may also cause undesired side effects such as excessive shrinkage cracking.

The process for determining the proportioning of a treated base is typically established in the contract documents. In general, the contract will specify the requirements for the treated base and the contractor will design a treated aggregate mixture that meets those requirements. As part of the mix design submittal, samples of aggregate and additive may also be obtained for the Government to perform verification testing. Consult your FLH materials staff or the contract for additional guidance.

In some instances, additives may be used to improve handling or alter material characteristics without providing a substantial increase in strength. Emulsified asphalt treated bases are an example of this type of treatment. The additive is used primarily to assist in the binding of the aggregate to provide a water-tight platform for paving and reduce dust generated by traffic.

5.2 Other Associated Aggregate Products

5.2.1 Minor Crushed Aggregate

Minor crushed aggregate is a product that is typically specified on projects that have small quantities. The material requirements for this product are for crushed aggregate material normally used and available near the project location. The furnished aggregate should conform to the gradation and quality requirements used by local agencies in the construction of highway projects.

5.2.2 Recycled Aggregate Base and Road Reconditioning

Recycled aggregates and road reconditioning are methods that use existing roadway aggregate as the material for construction. The existing base material is processed on the roadway in the same manner as virgin material. Any organic or deleterious materials are removed during the processing and the material is shaped to provide a uniform surface. The material is compacted according to the methods specified in the contract. Typically for small quantities a method-type specification is used to monitor compaction; whereas for larger quantities compaction is monitored by obtaining a specified percentage of the maximum density determined by a proctor test such as AASHTO T 180.

5.2.3 Aggregate-Topsoil

As the name suggests, aggregate-topsoil is a blended material of crushed aggregate and topsoil that is mixed together. The proportioning is roughly 50/50 by volume and is designed to provide some structural support within a medium that promotes vegetation. This material is typically placed and compacted as a shoulder finishing material. To complete the construction sequence, the completed surface is seeded.

5.2.4 Dust Palliatives and Stabilization Admixtures

There are several reasons to use dust palliatives or stabilizing agents to enhance the performance of aggregate surfacing. Using various additives can improve strength, waterproof, or control dust. The primary purpose of these additives is to provide a bound cohesive material and prevent the loss of fine particulates. If this is accomplished, the aggregate surfacing will provide improved service and prevent unwanted side effects. Aggregate surface roads will experience some loss of surfacing due to surface abrasion. Use of dust palliatives and stabilization admixtures will help to minimize the loss.

Dust palliatives are utilized to reduce airborne dust particulates and aid in maintaining an aggregate surface. The dust palliatives are applied on a properly constructed prepared surface or are mixed with the aggregate prior to final placement and compaction. The FP lists specific products for use as dust palliatives. Traditionally three categories of dust suppressants have been used in FLH. These categories are as follows:

- **Salts.** The primary salts used as dust suppressants are calcium chloride and magnesium chloride. These materials can be incorporated into the aggregate in two forms, dry flakes or as a brine solution. In either case, the material should be mixed into the top few inches of the aggregate to provide maximum benefit. The problems associated with using salts as dust palliatives include leaching during wet weather, vehicle corrosion potential, and ineffectiveness in dry climates. Multiple applications within a single year may be necessary depending on the local weather and climate conditions. Application rates and construction requirements should be included in the contract if these materials are used.

- **Lignosulfonates.** Lignosulfonates are a waste product of the paper pulp industry and are refined and used as dust palliatives. They provide a cementing reaction with the coarse and fine aggregate to provide the dust suppressing action. This material is provided as a liquid and is sprayed on the road surface and allowed to penetrate. Similarly to the salts, lignosulfonates can leach out of the surfacing material during rainy weather and thus may have to be reapplied to provide adequate benefits. However, a distinct benefit of this material is its use in more variable climate conditions.
- **Emulsified Asphalts.** Asphalt and other petroleum-based products have been used as prime coats to provide a temporary driving surface. The use of emulsified asphalts as dust palliatives is very similar. When sprayed on the aggregate surface, the emulsified asphalt cements particles together and in doing so, reduces the airborne particulates. The aggregate surfacing must be low in fines content (typically less than 10% passing the #200 (75 µm) sieve) for the application to be successful. The use of this material may also require covering with blotter material to prevent traffic from picking up the newly constructed dust palliative surface.

Other non-traditional stabilizing agents are currently available. These include enzymes, synthetic polymers, and organic non-petroleum derivatives. These products vary in material requirements and use and may be considered on a case-by-case basis. The FP does not currently provide specifications for these types of stabilizing agents.

5.2 Field Testing Requirements

When field-testing soil-aggregate and aggregate materials, Table 6 provides test procedures to be used as appropriate and as specified in the contract.

Table 6: AASHTO, ASTM and FLH Aggregate Test Procedures.

Test Number	Test Title
AASHTO R 58	Dry Preparation of Disturbed Soil and Soil Aggregate Samples for Test
AASHTO R 76	Reducing Samples of Aggregate to Testing Size
AASHTO R 90	Sampling of Aggregates
AASHTO T 11	Materials Finer Than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing
AASHTO T 27	Sieve Analysis of Fine and Coarse Aggregates
AASHTO T 89	Determining the Liquid Limit of Soils
AASHTO T 90	Determining the Plastic Limit and Plasticity Index of Soils
AASHTO T 96	Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
AASHTO T 104	Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate
AASHTO T 176	Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test
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 210	Aggregate Durability Index
AASHTO T 255	Total Evaporable Moisture Content of Aggregate by Drying
AASHTO T 265	Laboratory Determination of Moisture Content of Soils
AASHTO T 310	In-Place Density and Moisture Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)
ASTM D5821	Determining the Percentage of Fractured Particles in Coarse Aggregate

5.3 Field Testing and Compaction Verification

While laboratory testing of samples provides information about material properties, field testing verifies that the aggregate has been properly placed and compacted. The two processes complement each other.

Laboratory tests (gradation, moisture-density, quality tests) confirm the material meets specification. Field tests (density testing, visual inspection) confirm the material has been compacted to the specified density and moisture content in the field.

Table 6 lists the field testing methods and their purposes. Density testing, performed with nuclear gauges, sand cones, or other methods, is the primary field verification. Results are compared to the standard Proctor density established in the laboratory. If field density equals or exceeds 95–100% of standard Proctor (as specified), compaction is accepted. If field density is below specification, the contractor may continue compaction efforts, or the engineer may reject or reduce payment for the deficient work.

Chapter 6

Recycling & Reclamation Techniques

6.1 Cold Recycling

A cold recycled asphalt base course can be accomplished through two different techniques; in place recycled or central plant mixed. Both of these methods consist of processing recycled asphalt pavement, recycling agents, emulsified asphalt, and lime into a homogenous material that is placed as a layer. In some instances and usually at central mixing plant operations, reclaimed aggregate or virgin aggregates can be added. Generally speaking, in-place recycling incorporates only recycled asphalt pavement and does not include aggregates as part of the newly mixed material.

A mix design is usually performed to ensure proper proportioning of the ingredients of the cold recycled materials regardless of the technique used to mix and place the final product. Contract requirements will specify the amount of material to be submitted to the FLH division laboratory for testing to be completed. Unlike the verification process for hot asphalt concrete mix design, the FLH division laboratory will perform the mix design and provide the initial application rates for emulsified asphalt, recycling agent, lime or other additives for the mixture. Typically 21 days are allowed to complete the mix design process prior to beginning recycling operations; however consult the specific contract to verify time requirements for the submittals.

The quality of the emulsified asphalt used in the recycling operations is typically the only parameter that is verified through sampling and testing. Contract specifications will provide sampling and testing requirements for this material. Testing is performed by the FLH division laboratory.

6.2 Full Depth Reclamation (FDR) Techniques

Full depth reclamation (FDR) is a technique in which the asphalt pavement and underlying materials are pulverized and blended into a homogenous base layer. The underlying material may include base, subbase and subgrade depending on the design. Additional base aggregate can also be incorporated when necessary to improve the existing grade or cross-slope. This technique differs from cold recycling in that the reclamation depth is much greater and is intended to incorporate various layers of the existing pavement structure into the final product.

A broad range of stabilizing additives can be used including cement, lime, emulsified asphalt, hot asphalt binder plus various proprietary products. FDR processes often have different names depending on the additive used. These include:

- Foamed asphalt stabilization
- Bituminous base stabilization
- Cement base stabilization
- Pulverized pavement
- Recycled aggregate base

Because the FDR method and additive can vary, it is important to review the contract documents to determine what specific material testing is required. In most instances, some type of mix design will be required prior to beginning production. The Project Engineer needs to review the contract for the submittal, sampling and testing requirements.

6.3 Recycling and Reclamation: Sustainability and Performance

Cold recycling and full-depth reclamation (FDR) techniques preserve existing roadway materials, reducing the need for new aggregate and virgin materials. These methods support sustainability goals and often reduce costs.

However, recycled materials introduce variables not present in virgin aggregate: variability in previous pavement composition, potential contamination, and unknown aging effects on binder properties (if asphalt is recycled). Additional testing and verification are often required to ensure recycled materials perform as intended.

When recycled materials are specified, engineers should expect more intensive field monitoring and testing during construction. Certifications and test records become especially important to establish baseline properties before incorporation into the roadway.

Chapter 7

Verification & Acceptance of Aggregate Base

7.1 Verification and Acceptance in the Field

Once aggregate base has been tested and compacted, acceptance decisions must be made. Is the material acceptable, or does it require corrective action?

Acceptance depends on comparing test results (from sampling during and after placement) to contract specifications. Laboratory test results for gradation, quality properties, and moisture-density characteristics are the primary basis for acceptance. Field density test results confirm compaction adequacy.

If all results meet specification, the material is accepted. If results show minor non-conformance, negotiation may occur. The contractor may propose reduced payment, or corrective action (additional compaction, blending). If results show significant non-conformance, rejection and replacement may be required.

The procedures that follow detail how to evaluate test results and determine appropriate acceptance decisions.

7.2 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.

7.3 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.

7.4 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.

7.5 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:

- 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).
- Review test data to determine the significance of non-compliance.
- 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.
- 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 8

Roles, Responsibilities & Documentation

8.1 Contractor's Responsibilities

The contractor is responsible for constructing the aggregate base layers 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.

Construction of the aggregate base layers and the placing of the aggregate materials require that the material provided meet the specification and that it be in a suitable condition for compaction. Specific requirements for the aggregate will be specified in the contract. The contractor will establish a process to verify that the material and construction requirements are met through a quality control plan. In general, the sampling and testing responsibilities of the contractor include:

- Sampling material to be tested according to proper sampling methods.
- Providing split samples to the Government when required or requested.
- Monitor the production of aggregate to ensure compliance with the specifications.
- Testing material for conformance to material requirements. (i.e., aggregate quality, gradation, Atterberg Limits, etc.)
- Providing appropriate moisture density curves for the aggregate base material.
- Testing density of placed aggregate to ensure proper compaction.
- Providing appropriate certifications for material.

- Submitting a mix design meeting the design parameters as specified in the contract for treated base 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 4 provides guidance on sample sizes required for given testing.

8.2 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 the material will be made in accordance with Subsection 106.01.

The Project Engineer or designated representative will also be present to witness all required split samples taken for the Government. Upon completion of splitting, the samples will be secured and immediately placed in Government control. 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 contract requirements. In regard to aggregate base materials, the testing should verify the appropriate material characteristic as listed in the contract requirements. Testing verifies that the material is suitable for use in the work and may be constructed according to the contract documents.

8.3 Material Certifications

Table 7 provides guidance for some of the certifications that may be required. Certifications need to be in conformance with the contract requirements as provided in Subsection 106.03.

Table 7: Materials Certifications.

Section	Description	Material	Frequency	
			Certification	Sample
302	Minor crushed aggregate	Crushed aggregate	1 per source	Upon request
304	Full depth reclamation	Crushed aggregate	1 per source	Upon request
305	Full depth reclamation with cement	Hydraulic cement Crushed aggregate	1 per shipment 1 per source	Upon request
306	Full depth reclamation with asphalt	Asphalt binder Emulsified asphalt Fly ash Portland cement Crushed aggregate	1 per shipment " " 1 per source	Upon request
309	Emulsified asphalt treated base	Emulsified asphalt	1 per shipment	Upon request
310	Cold in-place recycled asphalt base course	Emulsified asphalt Lime	1 per shipment	Upon request
311	Stabilized aggregate surface course	Calcium chloride	1 per shipment	Upon request
312	Dust palliative	Dust palliative material	1 per source per manufacturer	Upon request

Appendix A: Form References

Form references for use in the testing of aggregate base materials.

- Form FHWA 1600C – Request for Laboratory Tests (CFL)
- Form FHWA 1600E – Request for Laboratory Tests (EFL)
- Form FHWA 1600W – Request 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 1626 – Sand Equivalent worksheet
- 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 and Record-Keeping

Comprehensive documentation, including source certifications, laboratory test reports, field density records, sampling locations and dates, digital photographs, and Project Engineer observations, creates a complete project record. This record supports acceptance decisions and provides evidence of compliance if disputes arise. All records should be retained per Federal contract requirements, typically through final project acceptance and beyond.

Appendix B: FLH Test Methods and Addendums

FLH Test Methods

T 521	Determining Riprap Gradation by Wolman Count
T 522	Determination of Optimum Emulsified or Foamed Asphalt Content of Full Depth Reclamation Mixtures
T 523	Discontinued
T 524	Determination of Optimum Emulsified Asphalt Content of Cold In-Place Recycled Mixtures
	FLH Addendums
T 308	Addendum to AASHTO T 308 – Correction Factors for Hot Mix Asphalt (HMA) Containing Recycled Asphalt Pavement (RAP) by the Ignition Method

T 522

Standard Practice for

Determination of Optimum Emulsified or Foamed Asphalt Content of Full Depth Reclamation Mixtures

FLH Designation: T 522

1. SCOPE

1.1 This procedure is used to determine the percent of emulsified or foamed asphalt and other needed additives for recycling asphalt concrete and aggregate base materials using Full Depth Reclamation (FDR).

2. REFERENCED DOCUMENTS

2.1 *AASHTO Standards:*

- T 11, Materials Finer Than No. 200 (75 µm) Sieve in mineral Aggregates by Washing
- T 27, Sieve Analysis of Fine and Coarse Aggregates
- T 30, Mechanical Analysis of Extracted Aggregate
- T 209, Theoretical Maximum Specific Gravity (G_{mm}) and Density of Hot Mix Asphalt (HMA)
- T 269, Percent Air Voids in Compacted Dense and Open Asphalt Mixtures
- T 283, Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage
- T 312, Preparing and Determining the Density of Asphalt Mixture Specimens by Means of the Superpave Gyratory Compactor
- T 331, Bulk Specific Gravity (G_{mb}) and Density of Compacted Hot Mix Asphalt (HMA) Using Automatic Vacuum Sealing Method

ASTM Standards:

- D6857, Maximum Specific Gravity and Density of Bituminous Paving Mixtures Using Automatic Vacuum Sealing Method

3. SAMPLING MATERIALS

3.1 *Sampling Existing Pavement Materials*

3.1.1 Obtain pavement cores, auger borings, or test pit samples from the areas to be recycled. Depending upon project length and existing pavement thickness, develop a sampling plan that will provide at least 350 lbs. of RAP and aggregate base for each mix design.

In all cases, the material provided must be representative of the material to be recycled. Where visual differences in the pavement surface are noted, additional cores may be required to evaluate the differences. If these additional samples show significant material differences, a separate mix design should be performed for each identified pavement segment.

3.1.2 Cores are to be cut for the full depth of the asphalt pavement. Sample aggregate base to the depth specified for the full depth reclamation project.

3.1.3 Crush cores and sieve to obtain materials that meet the gradation shown in Table 1.

Table 1—RAP Gradation Requirements

Sieve Size	Percent Passing
1.5 in. (38 mm)	100
1 in. (25 mm)	85-95
¾ in. (19 mm)	75-85
No. 4 (4.75 mm)	30-40
No. 30 (0.600 mm)	1-5

3.1.4 Milled RAP from the areas and depth to be recycled or other approved means of obtaining RAP samples can be used as an alternative to cores.

3.1.5 Sieve the milled pavement or crushed cores according to AASHTO T 27 with the exception that drying the RAP to constant mass shall be performed at 104 ± 4°F (40 ± 2°C). The washed sieve analysis of AASHTO T 11 is not required.

RAP material will be recombined to meet the gradation requirements shown in Table 1 for additional testing as described in this method.

3.1.6 For the aggregate base material obtained, perform a washed sieve analysis in accordance with AASHTO T 11 and AASHTO T 27 and report the obtained gradation.

3.2 *Sampling of Emulsified Asphalt Binder or Asphalt Binder*

3.2.1 Obtain 3 gallons of the emulsified asphalt or 2 gallons of asphalt binder that will be used to produce the recycled mix. Include the name and location of the supplier in the mix design report. Include the grade and properties of the asphalt product used in the mix design report.

3.3 *Sampling of Other Additives*

3.3.1 Obtain 10 lbs. of cement, lime, or other mineral filler if these additives will be used as a part of the mix design.

3.3.2 Obtain a sufficient amount of other additives that will be used to complete the mix design. List the name and source of all additives in the mix design report.

4. DETERMINING FOAMED ASPHALT CHARACTERISTICS

4.1 For FDR mixtures using foamed asphalt, determine the asphalt expansion ratio and half-life of the asphalt binder to be used.

4.2 Using a laboratory asphalt foaming device designed for the purpose of evaluating asphalt foaming characteristics, determine the asphalt expansion ratio and the half-life of the foamed expansion for asphalt binder temperatures of 320, 338, and 356°F (160, 170, and 180°C) and a range of water contents from 1.5% to 3.5% in increments of 0.5%.

The asphalt expansion ratio is defined as the ratio between the maximum volume achieved in the foamed state and the volume of binder once the foam has completely subsided.

The half-life of the foamed expansion is the time for the foamed asphalt to reduce to half of the maximum volume attained during the foaming process.

4.3 Discharge foamed asphalt into a sufficiently sized container with the capability of measuring the volume of the foam asphalt at various time intervals.

4.4 Measure the maximum volume of the foamed asphalt after being initially discharged into the container.

4.5 Measure the time, in seconds, for the foam to dissipate to half of the maximum volume. Record this time as the half-life of the foamed asphalt.

4.6 Allow the foamed asphalt to completely dissipate. Calculate the expansion ratio by dividing the maximum foamed asphalt volume by the volume of binder after the foam has been dissipated.

4.7 Plot the percent water added versus asphalt expansion ratio and half-life of foamed expansion for each asphalt binder temperature.

5. COMBINING RAP AND AGGREGATE BASE MATERIALS

5.1 *Combined Materials*

5.1.1 Combine RAP prepared to the gradation in Table 1 with aggregate base of the gradation determined in 3.1.6 to the planned percentages as determined from the depth of the respective layers. Calculate the combined gradation of RAP and aggregate base.

5.1.2 Batch material to the combined gradation determined in Subsection 5.1.1.

5.1.3 Perform a Modified Proctor test on the combined material in accordance with AASHTO T 180, Method D, to determine optimum moisture content (OMC) at peak dry density of the combined RAP and base material. Materials shall be mixed with the selected amount of water, sealed, and allowed to hydrate for a minimum of 3 hours prior to compaction. The OMC shall be defined by a best-fit curve.

6. DETERMINATION OF INDIRECT TENSILE STRENGTH AND TENSILE STRENGTH RATIO

6.1 *Specimen Size*

6.1.1 Determine the amount of RAP and aggregate base, before the addition of water, required to produce a 95 ± 5 mm tall specimen when compacting 150 mm diameter specimens with the gyratory compactor at 35 gyrations for testing.

6.1.2 Batch the RAP and aggregate base material according to the proportions established in Subsection 5.1.1 and 5.1.2.

6.1 Select a minimum of three emulsified or foamed asphalt contents in either 0.5% or 1.0% increments covering a range typically between 2.0% and 4.0% by dry weight of batched material. Six specimens will be compacted and tested for each emulsified or foamed asphalt content selected. As an option, additional specimens may be batched, compacted, and tested that have varying percentages of other additives such as cement, lime or mineral filler.

In addition, batch two samples for use in determining the theoretical maximum specific gravity value according to AASHTO T 209. Determine the theoretical maximum specific gravity according to Section 7.

6.2 *Mechanical Mixing*

6.2.1 Place the batched RAP and aggregate in a mixing bowl. Add sufficient water so that the total moisture content of water plus added emulsified asphalt or foamed asphalt will be equal to the OMC as determined in Subsection 5.1.3.

6.2.2 Mix samples for testing using a mechanical bucket mixer or laboratory sized pugmill or a combination of the two. Mix specimens with the required amount of water before addition of emulsified or foamed asphalt. If any additives (such as lime) are in the mixture, introduce the additives in a similar manner that they will be added during field production.

6.2.3 Mix specimens thoroughly with water first, or water and additives as appropriate, then add the emulsified asphalt or foamed asphalt. Thoroughly mix the material to provide uniform coating. One specimen will be mixed at a time. Mixing time should not exceed 60 seconds.

6.2.4 Transfer mixture to a sealed container and cure at 77 ± 4°F (25 ± 2°C) for 30 ± 3 minutes.

6.3 *Compacting*

6.3.1 Compact the mixture immediately after the curing specified in 6.2.3.

6.3.2 Compact the specimens using 35 gyrations according to AASHTO T 312 compaction procedures with the exception that the materials and the molds are not heated.

6.3.3 Compact six specimens at each asphalt content selected for tensile strength testing; three for unconditioned (dry) tensile strength on cured samples and three for conditioned tensile strength on cured samples for moisture conditioning.

6.3.4 If paper disks are used, place paper disks on the top and bottom of the specimen before compaction and remove paper disks from specimens immediately after compaction.

6.4 *Curing*

6.4.1 Extrude the specimens from the molds after compaction. Handle specimens carefully as to not disturb or damage. Carefully remove the paper disks from the top and bottom of the specimens.

6.4.2 Place specimens in 140 ± 2°F (60 ± 1°C) forced draft oven with ventilation on sides and top. Place each specimen in a small container to account for material loss from the specimens. Cure compacted specimens at 140 ± 2°F (60 ± 1°C) to constant mass but do not heat for more than 48 hours and not less than 16 hours. Constant mass is defined as 0.05% change in mass in 2 hours. After curing, cool specimens at ambient temperature a minimum of 12 hours and a maximum of 24 hours.

6.5 *Sample Conditioning and Testing*

6.5.1 After curing of specimens, determine the bulk specific gravity of each compacted, cured and cooled specimen according to AASHTO T 331.

6.5.2 Determine specimen heights according to AASHTO T 245. Alternatively, the height can be obtained from the SGC readout.

6.5.3 Determine air void contents of the compacted and oven-cured samples at each asphalt content according to AASHTO T 269 using the theoretical maximum specific gravity as determined in Section 7.

6.5.4 For each asphalt content tested, separate the specimens into two subsets of three specimens each so the average air void contents of the two subsets are approximately equal.

6.5.5 Perform moisture conditioning on three compacted samples at each asphalt content by applying a vacuum of 13 to 67 kPa absolute pressures (10 to 26 in. of Hg partial pressure) for a time duration required to vacuum saturate samples to 55 to 75 percent. Saturation calculation shall be in accordance with AASHTO T 283. Soak moisture conditioned samples in a 77 ± 2°F (25 ± 1°C) water bath for 24 ± 1 hours.

6.5.6 Determine tensile strength ratio by AASHTO T 283. Dry or unconditioned samples are tested after a minimum of 45 minutes temperature conditioning by immersing in a 77 ± 2°F (25 ± 1°C) water bath. Place dry specimens in a leak proof bag to prevent samples from coming in contact with water. This testing is performed at the same time that moisture-conditioned specimens are tested.

6.5.7 Report the dry indirect tensile strength and the tensile strength ratio according to AASHTO T 283.

7. DETERMING THE THEORECTRICAL MAXIMUM SPECIFIC GRAVITY

7.1 Batch samples according to Subsection 6.1

7.2 Mix samples according to Subsection 6.2.

7.3 Two specimens are required for determination of theoretical maximum specific gravity. Follow AASHTO T 209 with the exception that loose mixtures are cured in a forced draft oven at 140 ± 2°F (60 ± 1°C) to constant mass. Cure for no more than 48 hours and no less than 16 hours. Constant mass is defined as 0.05% change in mass in 2 hours. Do not break any agglomerates that will not easily reduce with a flexible spatula. Test both specimens at the highest asphalt content in the design and back calculate for the lower asphalt contents. Use the dry-back procedure of AASHTO T 209 to account for uncoated particles. ASTM D6857 may be used as an alternative to AASHTO T 209.

8. EMULSIFIED ASPHALT OR FOAMED ASPHALT CONTENT SELECTION

8.1 Choose the design emulsified or foamed asphalt content that meets the requirements listed in the specification. For the foamed asphalt mixture, include the water content and asphalt binder temperature required for proper foaming.

9. REPORT

9.1 Report the following information:

9.1.1 Gradation of RAP;

9.1.2 Gradation of aggregate base;

9.1.3 Planned percentages of RAP and aggregate base;

9.1.4 Combined gradation of the blended RAP and aggregate base material;

9.1.5 Foamed asphalt expansion and half-life plots;

9.1.6 Density and OMC from Proctor compaction of the blended material;

9.1.7 Moisture content used in mix design;

9.1.8 Range of emulsified asphalt or foamed asphalt contents used for the mix design;

9.1.9 Density, Gmm, and air voids at each emulsified asphalt or foamed asphalt content (individual and average values) of AASHTO T 283 samples;

9.1.10 Indirect tensile strength at each emulsified asphalt or foamed asphalt content (individual and average values);

9.1.11 Level of saturation and conditioned indirect tensile strength at each emulsified asphalt or foamed asphalt content (individual and average values);

9.1.12 Tensile strength ratio;

9.1.13 Design emulsified or foamed asphalt content;

9.1.14 Design water content;

9.1.15 Emulsified asphalt or asphalt binder grade, supplier company name and location;

9.1.16 Additive type, company name and location;

9.1.17 Certificates of compliance for emulsified asphalt, asphalt binder, and any additives, as necessary.

T 524

Standard Practice for

Determination of Optimum Emulsified Asphalt Content of Cold In-Place Recycled Mixtures

FLH Designation: T 524

1. SCOPE

1.1. This standard practice is used to determine the percent of emulsified asphalt and other additives to use for recycling asphalt concrete when using Cold In-Place Recycling (CIR) of bituminous pavements.

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards:*

- T 27, Sieve Analysis of Fine and Coarse Aggregates
- T 30, Mechanical Analysis of Extracted Aggregate
- T 166, Bulk Specific Gravity (G_{mb}) of Compacted Hot Mix Asphalt (HMA) Using Saturated Surface-Dry Specimens
- T 209, Theoretical Maximum Specific Gravity (G_{mm}) and Density of Hot Mix Asphalt (HMA)
- T 245, Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus
- T 269, Percent Air Voids in Compacted Dense and Open Asphalt Mixtures
- T 283, Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage
- T 312, Preparing and Determining the Density of Asphalt Mixture Specimens by Means of the Superpave Gyratory Compactor
- T 331, Bulk Specific Gravity (G_{mb}) and Density of Compacted Hot Mix Asphalt (HMA) Using Automatic Vacuum Sealing Method

2.2. ASTM Standards:

- D6857, Maximum Specific Gravity and Density of Bituminous Paving Mixtures Using Automatic Vacuum Sealing Method
- D7196, Raveling Test of Cold Mixed Emulsified Asphalt Samples

3. OBTAINING AND PREPARATION OF MATERIALS

3.1. *Sampling and Processing of Recycled Asphalt Pavement (RAP) Materials*

3.1.1. Obtain cores from the areas to be recycled. Depending upon project length and existing pavement thickness, develop a coring plan that will provide at least 350 pounds of RAP for each mix design. Additional cores will need to be obtained for more specific asphalt content and gradation analysis if desired.

In all cases, the material provided must be representative of the material to be recycled. If the pavement is not being recycled full depth, cores should be cut to the specified milling depth with the bottom portion being discarded.

Where visual differences in the pavement surface are noted, additional cores may be required to evaluate the difference. If these additional cores show significant material differences, a separate mix design should be performed for each identified pavement segment.

3.1.2. Cut cores to the depth specified for the cold recycled layer.

3.1.3. Crush cores to obtain materials that meet the gradation shown in Table 1.

As an alternative to obtaining and crushing cores, RAP may be obtained by milling. Mill the pavement from areas to be recycled to the specified depth.

3.1.4. Sieve the milled pavement or crushed cores according to AASHTO T 27 with the exception that drying the RAP to constant mass shall be performed at 104 ± 4°F (40 ± 2°C). The washed sieve analysis of AASHTO T 11 is not required.

RAP material will be recombined to meet the gradation requirements shown in Table 1 for additional testing as described in this method.

Table 1— RAP Gradation Requirements

Sieve Size	Percent Passing
1.5 inch (37.5mm)	100
1 inch (25.0mm)	90-100
3/4 inch (19.0mm)	85-95
1/2 inch (12.5mm)	75-85
No. 4 (4.75mm)	35-50
No. 16 (1.18mm)	5-16
No. 200 (75µm)	0-7

4. MIX DESIGN BINDER AND ADDITIVES FOR MIX DESIGN

4.1. *Sample of Emulsified Asphalt Binder Agent*

4.1.1. Obtain 3 gallons of the emulsified asphalt that will be used to produce the cold recycled mix. Include the name and location of the supplier in the mix design report. Include the grade and properties of the emulsified asphalt in the mix design report.

4.2. *Sample of Other Additives*

4.2.1. Obtain 5 pounds of quicklime, if quicklime will be used as a part of the mix design.

4.2.2. Obtain a sufficient amount of other additives that will be used to complete the mix design. List the name and source of all additives in the mix design report.

5. DETERMINATION OF INDIRECT TENSILE STRENGTH AND TENSILE STRENGTH RATIO

5.1. *Batching RAP Material*

5.1.1. Select a minimum of three emulsified asphalt contents in either 0.5% or 1.0% increments covering a range typically between 1.0% and 4.0% by dry weight of RAP. Batch RAP material for each specimen conforming to the gradation selected for the mix design and meeting the gradation requirements shown in Table 1. Six specimens will be compacted and tested for each emulsified asphalt content selected. As an option, additional specimens may be batched, compacted, and tested that have varying percentages of other additives such as quicklime.

Determine the amount of RAP material required to produce a 150 mm diameter and 95 ± 5 mm tall specimen when compacted in the gyratory compactor at 35 gyrations.

In addition, batch two RAP material samples for use in determining the theoretical maximum specific gravity value according to AASHTO T 209. Determine the theoretical maximum specific gravity according to Section 6.

5.2. *Mechanical Mixing*

5.2.1. Mix samples for testing using a mechanical bucket mixer, laboratory sized pugmill or a combination of the two. Add moisture that is expected to be added at the milling head, typically 1.5 to 2.5 percent, and mix thoroughly. If any additives (such as lime) are in the mixture, introduce the additives in a similar manner that they will be added during field production.

5.2.2. Mix RAP thoroughly with water first or water and additives as appropriate, then mix with emulsified asphalt at room temperature, 77 ± 4°F (25 ± 2°C). One specimen will be mixed at a time. Mixing time should not exceed 60 seconds.

5.3. *Compacting*

5.3.1. Immediately after mixing, compact the specimens. Compact the specimens at 77 ± 4°F (25 ± 2°C).

5.3.2. Compact the specimens using 35 gyrations according to AASHTO T 312 compaction procedures with the exception that the materials and the molds are not heated.

5.3.3. Compact six specimens at each emulsified asphalt content for tensile strength testing; three for unconditioned (dry) tensile strength on cured samples and three for conditioned tensile strength on cured samples for moisture conditioning.

5.4. *Curing*

5.4.1. Extrude the specimens from the molds after compaction. Handle specimens carefully as to not disturb or damage. Carefully remove the paper disks from the top and bottom of the specimens.

5.4.2. Place specimens in 140 ± 2°F (60 ± 1°C) forced draft oven with ventilation on sides and top. Place each specimen in a small container to account for material loss from the specimens. Cure compacted specimens at 140 ± 2°F (60 ± 1°C) to constant mass but do not heat for more than 48 hours and not less than 16 hours. Constant mass is defined as 0.05% change in mass in 2 hours. After curing, cool specimens at ambient temperature a minimum of 12 hours and a maximum of 24 hours.

5.5. *Sample Conditioning and Testing*

5.5.1. After curing of specimens, determine the bulk specific gravity of each compacted, cured and cooled specimen according to AASHTO T 166 Method A or AASHTO T 331, if required.

5.5.2. Determine specimen heights according to AASHTO T 245. Alternatively, the height can be obtained from the SGC readout.

5.5.3. Determine air void contents of the compacted and oven-cured samples at each emulsified asphalt content according to AASHTO T 269 using the theoretical maximum specific gravity as determined in Section 6.

5.5.4. For each emulsified asphalt content tested, separate the specimens into two subsets of three specimens each so the average air void contents of the two subsets are approximately equal.

Perform moisture conditioning on three compacted samples at each emulsified asphalt content by applying a vacuum of 10 to 26 in. of Hg partial pressure (13 to 67 kPa absolute pressure) for a time duration required to vacuum saturate samples to 55 to 75 percent. Saturation calculation shall be in accordance with AASHTO T 283. Soak moisture conditioned samples in a 77 ± 2°F (25 ± 1°C) water bath for 24 ± 1 hours.

5.5.5. Determine tensile strength ratio by AASHTO T 283. Dry or unconditioned samples are tested after a minimum of 45 minutes temperature conditioning by immersing in a 77 ± 2°F (25 ± 1°C) water bath. Place dry specimens in a leak proof bag to prevent samples from coming in contact with water. This testing is performed at the same time that moisture-conditioned specimens are tested.

5.5.6. Report the dry indirect tensile strength and the tensile strength ratio according to AASHTO T 283.

6. DETERMINING THE THEORETICAL MAXIMUM SPECIFIC GRAVITY

6.1. Batch samples according to 5.1.

6.2. Mix samples according to 5.2.

6.3. Two specimens are required for determination of theoretical maximum specific gravity. Follow AASHTO T 209 with the exception that loose RAP mixtures are cured in a forced draft oven at 140 ± 2°F (60 ± 1°C) to constant mass. Cure for no more than 48 hours and no less than 16 hours. Constant mass is defined as 0.05% change in mass in 2 hours. Do not break any agglomerates that will not easily reduce with a flexible spatula. Test both specimens at the highest emulsified asphalt content in the design and back calculate for the lower emulsified asphalt contents. Use the dry-back procedure of AASHTO T 209 to account for uncoated particles. ASTM D6857 may be used as an alternative to AASHTO T 209.

7. RAVELING TEST

7.1. Mix specimens at the target optimum emulsified asphalt content established. Mix according to ASTM D7196 for lab blended mixtures.

7.2. Cure the specimens for 4 hours at 50°F and 50% relative humidity.

7.3. Abrade the specimens for 15 minutes according to ASTM D7196.

7.4. Record the percent mass loss according to ASTM D7196.

8. EMULSIFIED ASPHALT CONTENT SELECTION

8.1. Choose the design emulsified asphalt content that meets the cold mix requirements listed in the specification.

9. REPORT

9.1. *Report the following information:*

9.1.1. Gradation of RAP;

9.1.2. Recommended water content range as a percentage of dry RAP;

9.1.3. Amount of additive as a percentage of dry RAP;

9.1.4. Range of emulsified asphalt contents used for the mix design;

9.1.5. Theoretical maximum specific gravity of the mixture at selected emulsified asphalt content, Gmm

9.1.6. Air voids and bulk specific gravity at each emulsified asphalt content (individual and average values) of AASHTO T 283 samples;

9.1.7. Indirect tensile strength at each emulsified asphalt content (individual and average values);

9.1.8. Level of saturation and conditioned indirect tensile strength at each emulsified asphalt content (individual and average values);

9.1.9. Tensile strength ratio;

9.1.10. Theoretical maximum specific gravity, air void content, tensile strength, tensile strength ratio, and raveling at recommended moisture and emulsified asphalt contents;

9.1.11. Optimum emulsified asphalt content as a percentage of dry RAP;

9.1.12. Emulsified asphalt and additive designation, supplier company name and location;

9.1.13. Emulsified asphalt residue content;

9.1.14. Additive designation, company name and location;

9.1.15. Certificates of compliance for emulsified asphalt and additive.

Appendix C: Sample Quantities Guide

Division 300

	Material / Product	Characteristic	Sampling Method	Minimum Field Sample lbs (kg)	Minimum Split Size to FLH Lab lbs (kg)
Section 301	Aggregate source quality	LA abrasion, Sodium sulfate soundness, Durability index, Fractured faces	AASHTO R 90	300 (150)	200 (90)
	Subbase course (grading A & B)	Gradation, Liquid Limit	AASHTO R 90	165 (75)	33 (15)
		Moisture - Density	AASHTO R 90	110 (50)	50 (23)
	Base course (grading C, D, & E)	Gradation, Liquid Limit	AASHTO R 90	110 (50)	22 (10)
		Moisture - Density	AASHTO R 90	110 (50)	50 (23)
	Surface course aggregate	Gradation, Liquid Limit, Plasticity Index, Fractured faces	AASHTO R 90	110 (50)	22 (10)
		Moisture density (max. density)	AASHTO R 90	110 (50)	50 (23)
Section 302	Crushed aggregate	Moisture - Density	AASHTO R 90	110 (50)	50 (23)
Section 304	Pulverized material	Moisture - Density	AASHTO R 90	110 (50)	50 (23)
Section 309	Aggregate source quality	LA abrasion, Sodium sulfate soundness, Durability index, Fractured faces	AASHTO R 90	—	200 (90)
	Emulsified asphalt treated base	Gradation, Sand Equivalent	AASHTO R 90	110 (50)	22 (10)
	Emulsified asphalt treated base (submittal)	Quality (mixture properties)	AASHTO R 90	—	300 (150)
Section 310	Recycled base course, Type A (mix design)	Pavement samples		—	10 6-inch (150 mm) cores
		Emulsified asphalt	AASHTO R 66	—	2 1-quart samples (2 1-liter samples)
		Lime	AASHTO T 218	—	2 (1)
	Emulsified asphalt	Quality	AASHTO R 66	—	2 1-quart samples (2 1-liter samples)
Section 311	Aggregate source quality	LA abrasion, Sodium sulfate soundness, Durability index, Fractured faces	AASHTO R 90	300 (150)	200 (90)
	Surface course aggregate	Gradation, Liquid Limit/Plasticity Index	AASHTO R 90	110 (50)	22 (10)
		Moisture density (max. density)	AASHTO R 90	110 (50)	50 (23)

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