Transportation Technician Qualification Program

ASPHALT II

Participant

Workbook

WESTERN ALLIANCE FOR QUALITY

WAQTC

TRANSPORTATION CONSTRUCTION

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PREFACE

This module is one of a set developed for the Western Alliance for Quality Transportation Construction (WAQTC). WAQTC is an alliance supported by the western state Transportation Departments, along with the Federal Highway Administration (FHWA) and the Western Federal Lands Highway Division (WFLHD) of FHWA. WAQTC's charter includes the following mission.

MISSION

Provide continuously improving quality in transportation construction.

Through our partnership, we will:

- Promote an atmosphere of trust, cooperation, and communication between government agencies and with the private sector.
- Assure personnel are qualified.
- Respond to the requirements of identified needs and new technologies that impact the products that we provide.

BACKGROUND

There are two significant driving forces behind the development of the WAQTC qualification program. One, there is a trend to the use of quality control/quality assurance (QC/QA) specifications. QC/QA specifications include qualification requirements for a contractor's QC personnel and will be requiring WAQTC qualified technicians. Two, Federal regulation on materials sampling and testing (23 CFR 637, *Quality Assurance Procedures for Construction*, published in June 1995) mandates that by June 29, 2000 all testing technicians whose results are used as part of the acceptance decision shall be qualified. In addition, the regulation allows the use of contractor test results to be used as part of the acceptance decision.

OBJECTIVES

WAQTC's objectives for its Transportation Technician Qualification Program include the following:

- To provide highly skilled, knowledgeable materials sampling and testing technicians.
- To promote uniformity and consistency in testing.
- To provide reciprocity for qualified testing technicians between states.
- To create a harmonious working atmosphere between public and private employees based upon trust, open communication, and equality of qualifications.

Training and qualification of transportation technicians is required for several reasons. It will increase the knowledge of laboratory, production, and field technicians — both industry and agency personnel — and increase the number of available, qualified testers. It will reduce problems associated with test result differences. Regional qualification eliminates the issue of reciprocity between states and allows qualified QC technicians to cross state lines without having the concern or need to be requalified by a different program.

The WAQTC Executive Board

FOREWORD

This module is one of six developed to satisfy the training requirements prescribed by Western Alliance for Quality Transportation Construction (WAQTC) for technicians involved in transportation projects. The six modules cover:

- Aggregate
- Concrete
- Asphalt I
- Asphalt II
- Embankment and Base
- In-place Density

The modules are based upon AASHTO test methods along with procedures developed by WAQTC. They are narrative in style, illustrated, and include step-by-step instruction. There are review questions at the end of each test procedure, which are intended to reinforce the participants' understanding and help participants prepare for the final written and performance exams. Performance exam check lists are also included. The appendices include the corresponding AASHTO and WAQTC test methods.

It is the technician's responsibility to stay current as changes are made to this living document.

The comments and suggestions of every participant are essential to the continued success and high standards of the Transportation Technician Qualification Program. Please take the time to fill out the Course Evaluation Form as the course progresses and hand it in on the last day of class. If you need additional room to fully convey your thoughts, please use the back of the form.

The WAQTC Executive Board

GUIDANCE FOR COURSE EVALUATION FORM

The Course Evaluation Form on the following page is very important to the continuing improvement and success of this course. The form is included in each Participant Workbook. During the course introduction, the Instructor will call the participants' attention to the form, its content, and the importance of its thoughtful completion at the end of the course. Participants will be encouraged to keep notes, or write down comments as the class progresses, in order to provide the best possible evaluation. The Instructor will direct participants to write down comments at the end of each day and to make use of the back of the form if more room is needed for comments.

On the last day of the course, just before the written examination, the Instructor will again refer to the form and instruct participants that completion of the form after their last examination is a requirement before leaving. Should the course have more than one Instructor, participants should be directed to list them as A, B, etc., with the Instructor's name beside the letter, and direct their answers in the Instructor Evaluation portion of the form accordingly.

WESTERN ALLIANCE FOR QUALITY TRANSPORTATION CONSTRUCTION COURSE EVALUATION FORM

The WAQTC Transportation Technician Qualification Program would appreciate your thoughtful completion of all items on this evaluation form. Your comments and constructive suggestions will be an asset in our continuing efforts to improve our course content and presentations.

Course Title: _____

Location: _____

Dates: _____

Your Name (Optional): _____

Employer: _____

Instructor(s) _____

COURSE CONTENT

Will the course help you perform your job better and with more understanding? Yes Maybe No

Explain: _____

_____

Was there an adequate balance between theory, instruction, and hands-on application? Yes Maybe No

Explain: _____

_____

Did the course prepare you to confidently complete both examinations? Yes Maybe No

Explain: _____

_____

What was the most beneficial aspect of the course? _____

_____

What was the least beneficial aspect of the course? _____

_____

GENERAL COMMENTS

General comments on the course, content, materials, presentation method, facility, registration process, etc. Include suggestions for additional Tips!

_____

_____

_____

_____

_____

_____

_____

INSTRUCTOR EVALUATION

Were the objectives of the course, and the instructional and exam approach, clearly explained? Yes Maybe No

Explain: _____

_____

Was the information presented in a clear, understandable manner? Yes Maybe No

Explain: _____

_____

Did the instructors demonstrate a good knowledge of the subject? Yes Maybe No

Explain: _____

_____

Did the instructors create an atmosphere in which to ask questions and hold open discussion? Yes Maybe No

Explain: _____

_____

COURSE OBJECTIVES AND SCHEDULE

Learning Objectives

Instructional objectives for this course include:

- Being familiar with Quality Assurance (QA) concepts
- Developing a background in measurements and calculations
- Being knowledgeable in highway materials terminology
- Respecting safety issues
- Acquiring knowledge of random sampling techniques
- Understanding the basics of asphalt
- Becoming proficient in the following quality control test procedures:

  FOP for AASHTO T 168
  Sampling Bituminous Paving Mixtures

  FOP for AASHTO R 47
  Reducing Samples of Asphalt Mixtures to Testing Size

  FOP for AASHTO T 329
  Moisture Content of Asphalt Mixtures by Oven Method

  FOP for AASHTO T 308
  Determining the Asphalt Binder Content of Hot Mix Asphalt (HMA) by the Ignition Method

  FOP for AASHTO T 209
  Theoretical Maximum Specific Gravity (G_{mm}) and Density of Hot Mix Asphalt Paving Mixtures

  FOP for AASHTO T 166
  Bulk Specific Gravity (G_{mb}) of Compacted Hot Mix Asphalt Mixtures Using Saturated Surface-Dry Specimens

  FOP for AASHTO R 66
  Sampling Asphalt Materials

  FOP for AASHTO T 30
  Mechanical Analysis of Extracted Aggregate

  FOP for AASHTO T 312
  Asphalt Mixture Specimens by Means of the Superpave Gyratory Compactor

  FOP for WAQTC TM 13
  Hot Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor

The overall goals of this asphalt course are to understand the basics of asphalt and to be competent with specific quality control test procedures identified for the Transportation Technician Qualification Program of the Western Alliance for Quality Transportation Construction (WAQTC). Additional studies beyond this course will be required for those desiring greater in-depth knowledge of the theory behind the test procedures included herein.

Course Outline and Suggested Schedule

Day One

0800	Welcome Introduction of Instructors Introduction and Expectations of Participants
0815	WAQTC Mission and TTQP Objectives Instructional Objectives for the Course Overview of the Course Course Evaluation Form
0830	Review of Quality Assurance Concepts
0845	Background in Measurements and Calculations
0945	Break
1000	Random Sampling
1030	Basics of Asphalt
1045	Sampling Bituminous Paving Mixtures FOP for AASHTO T 168
1115	Reducing Samples of Asphalt Mixtures to Testing Size FOP for AASHTO R 47
1130	Review Questions Questions and Answers
1200	Lunch
1315	Moisture Content of Asphalt Mixtures by Oven Method FOP for AASHTO T 329
1415	Laboratory Practice Sampling Reducing

Moisture Content

1645 Evaluation
End of Day

Day Two

0800 Questions from the Previous Day

0815 Determining Asphalt Binder Content of Hot Mix Asphalt (HMA) by the Ignition Method
FOP for AASHTO T 308

0945 Break

1000 Sampling Asphalt Materials
FOP for AASHTO R 66

1030 Mechanical Analysis of Extracted Aggregate
FOP for AASHTO T 30

1200 Lunch

1315 Laboratory Practice
Asphalt Content – Ignition Oven
Gradation

1645 Evaluation
End of Day

Day Three

0800 Questions from Previous Day

0815 Theoretical Maximum Specific Gravity (G_{mm}) and Density of Hot Mix Asphalt
Paving Mixtures
FOP for AASHTO T 209

0930 Break

0945 Bulk Specific Gravity (G_{mb}) of Compacted Hot Mix Asphalt Mixtures Using Saturated Surface-Dry Specimens
FOP for AASHTO T 166

1200 Lunch

1315 Review Questions
Questions and Answers

1400 Laboratory Practice
Maximum Specific Gravity (G_{mm})
Bulk Specific Gravity (G_{mb})

1645 Evaluation
End of day

Day Four

0800 Questions from Previous Day

0815 Asphalt Mixture Specimens by Means of the Superpave Gyratory Compactor
FOP for AASHTO T 312

0930 Break

0945 Volumetric Properties of Hot Mix Asphalt (HMA)
FOP for WAQTC TM 13

1200 Lunch

1315 Review Questions
Questions and Answers

1400 Laboratory Practice
HMA Specimens
Volumetrics

1645 Evaluation
End of day

Day Five

0800 Questions from the Previous Day

0915 Review Questions
Questions and Answers

0945 Break

1100 Laboratory Practice

Open Lab to Practice Any Procedure

1200 Lunch

1415 Start of Exams

Participants will break into groups so that written and performance exams may be given concurrently.

Day Five

0800 Continuation of Exams

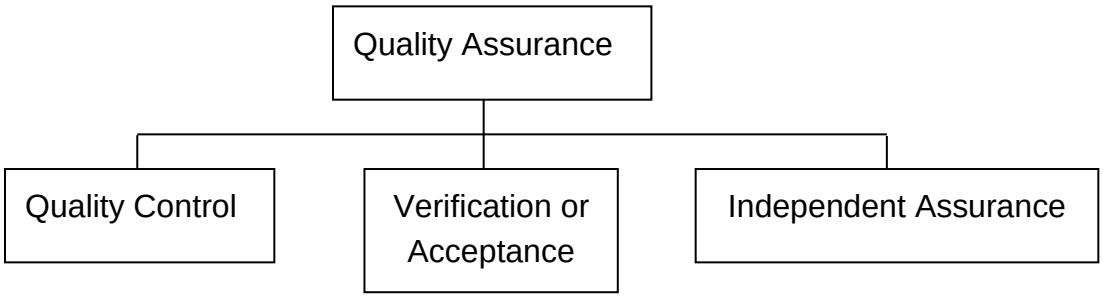
Participants will break into groups so that written and practical exams may be given concurrently.

Evaluation

QUALITY ASSURANCE CONCEPTS

The Federal Highway Administration (FHWA) has established requirements that each State Transportation Department (STD) must develop a Quality Assurance (QA) Program that is approved by the FHWA for projects on the National Highway System (NHS). In addition to complying with this requirement, implementing QA specifications in a construction program includes the benefit of improvement of overall quality of highway and bridge construction. 01 02

A QA Program may include three separate and distinct parts as illustrated below. 03



Quality Assurance (QA) are those planned and systematic actions necessary to provide confidence that a product or service will satisfy given requirements for quality. 04

Quality Control (QC) are those operational, process control techniques or activities that are performed or conducted to fulfill contract requirements for material and equipment quality. In some states, the constructor is responsible for providing QC sampling and testing, while in other states the STD handles QC. Where the constructor is responsible for QC tests, the results may be used for acceptance only if verified or accepted by additional tests performed by an independent group. 05

Verification/Acceptance consists of the sampling and testing performed to validate QC sampling and testing and, thus, the quality of the product. Verification/Acceptance samples are obtained and tests are performed independently from those involved with QC. Samples taken for QC tests may not be used for Verification/Acceptance testing. 06

Independent Assurance (IA) are those activities that are an unbiased and independent evaluation of all the sampling and testing procedures used in QC and Verification/Acceptance. IA may use a combination of laboratory certification, technician qualification or certification, proficiency samples, or split samples to assure that QC and Verification/Acceptance activities are valid. Agencies may qualify or certify laboratories and technicians, depending on the state in which the work is done. 07

BACKGROUND ON MEASUREMENTS AND CALCULATIONS

01

Introduction

This section provides a background in the mathematical rules and procedures used in making measurements and performing calculations. Topics include:

- Units: Metric vs. English
- Mass vs. Weight
- Balances and Scales
- Rounding
- Significant Figures
- Accuracy and Precision
- Tolerance

Also included is discussion of real-world applications in which the mathematical rules and procedures may not be followed.

02

Units: Metric vs. English

03

The bulk of this document uses dual units. Metric units are followed by Imperial, more commonly known as English, units in parentheses. For example: 25 mm (1 in.). Exams are presented in metric or english.

04

Basic units in SI include:

Length:	meter, m
Mass:	kilogram, kg
Time:	second, s

Derived units in SI include:

Force:	Newton, N

SI units

Depending on the situation, some conversions are exact, and some are approximate. One inch is exactly 25.4 mm. If a procedure calls for measuring to the closest 1/4 in., however, 5 mm is close enough. We do not have to say 6.35 mm. That is because 1/4 in. is half way between 1/8 in. and 3/8 in. – or half way between 3.2 and 9.5 mm. Additionally, the tape measure or rule used may have 5 mm marks, but may not have 1 mm marks and certainly will not be graduated in 6 mm increments.

Metric	English
25 mm	1 in.
1 kg	2.2 lb
1000 kg/m^3	62.4 lb/ft^3
25 MPa	3600 lb/in.^{2}

Some <u>approximate</u> conversions

In SI (Le Systeme International d'Unites), the basic unit of mass is the kilogram (kg) and the basic unit of force, which includes weight, is the Newton (N). Mass in this document is given in grams (g) or kg.

See the section below on "Mass vs. Weight" for further discussion of this topic.

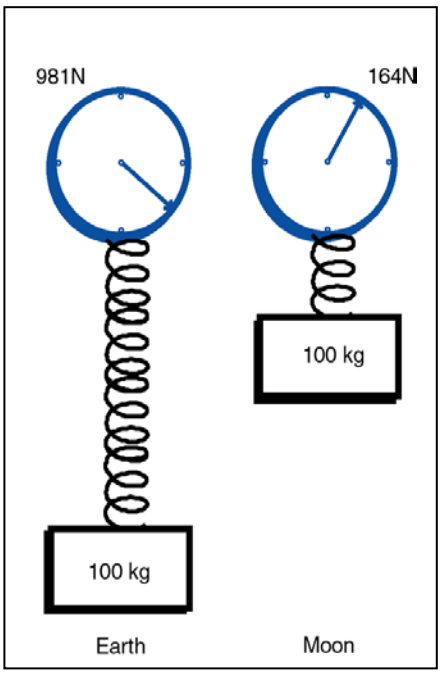
Mass vs. Weight

05 The terms mass, force, and weight are often confused. Mass, m, is a measure of an object's material makeup, and has no direction. Force, F, is a measure of a push or pull, and has the direction of
06 the push or pull. Force is equal to mass times acceleration, a.

$$F = ma$$

Weight, W, is a special kind of force, caused by gravitational acceleration. It is the force required to suspend or lift a mass against gravity. Weight is equal to mass times the acceleration due to gravity, g, and is directed toward the center of the earth.

$$W = mg$$



Comparison of mass and weight

07 In SI, the basic unit of mass is the kilogram (kg), the units of acceleration are meters per square
08 second (m/s^2), and the unit of force is the Newton (N). Thus a person having a mass of 84 kg subject to the standard acceleration due to gravity, on earth, of 9.81 m/s^2 would have a weight of:

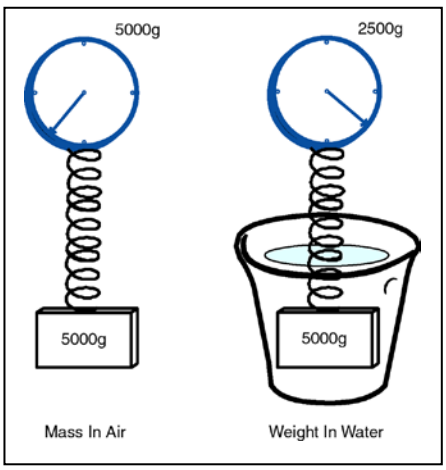
$$W = (84.0\ kg)(9.81\ m/s^2) = 824\ kg\text{-}m/s^2 = 824\ N$$

In the English system, mass can be measured in pounds-mass (lb_m), while acceleration is in feet per square second (ft/s^2), and force is in pounds-force (lb_f). A person weighing 185 lb_f on a scale has a mass of 185 lb_m when subjected to the earth's standard gravitational pull. If this person were to go to the moon, where the acceleration due to gravity is about one-sixth of what it is on earth, the person's weight would be about 31 lb_f, while his or her mass would remain 185 lb_m. Mass does not depend on location, but weight does.

While the acceleration due to gravity does vary with position on the earth (latitude and elevation), the variation is not significant except for extremely

precise work – the manufacture of electronic memory chips, for example.

As discussed above, there are two kinds of pounds, lb_m and lb_f. In laboratory measurements of mass, the gram or kilogram is the unit of choice. But, is this mass or force? Technically, it depends on the instrument used, but practically speaking, mass is the result of the measurement. When using a scale, force is being measured – either electronically by the stretching of strain gauges or mechanically by the stretching of a spring or other device. When using a balance, mass is being measured, because the mass of the object is being compared to a known mass built into the balance.



Submerged weight

In this document, mass, not weight, is used in test procedures except when determining "weight" in water. When an object is submerged in water (as is done in specific gravity tests), the term weight is used. Technically, what is being measured is the force the object exerts on the balance or scale while the object is submerged in water (or the submerged weight). This force is actually the weight of the object less the weight of the volume of water displaced.

In summary, whenever the common terms "weight" and "weighing" are used, the more appropriate terms "mass" and "determining mass" are usually implied, except in the case of weighing an object submerged in water.

Balances and Scales

Balances, technically used for mass determinations, and scales, used to weigh items, were discussed briefly above in the section on "Mass vs. Weight." In field operating procedures, we usually do not differentiate between the two types of instruments. When using either one for a material or object in air, we are determining <u>mass</u>. For those procedures in which the material or object is suspended in water, we are determining <u>weight</u> in water. AASHTO recognizes two general categories of instruments. Standard analytical balances are used in laboratories. For most field operations, general

purpose balances and scales are specified. Specifications for both categories are shown in Tables 1 and 2.

Table 1
Standard Analytical Balances

Class	Capacity	Readability and Sensitivity	Accuracy
A	200 g	0.0001 g	0.0002 g
B	200 g	0.001 g	0.002 g
C	1200 g	0.01 g	0.02 g

Table 2
General Purpose Balances and Scales

Class	Principal Sample Mass	Readability and Sensitivity	Accuracy
G2	2 kg or less	0.1 g	0.1 g or 0.1 percent
G5	2 kg to 5 kg	1 g	1 g or 0.1 percent
G20	5 kg to 20 kg	5 g	5 g or 0.1 percent
G100	Over 20 kg	20 g	20 g or 0.1 percent

15

Rounding

Numbers are commonly rounded up or down after measurement or calculation. For example, 53.67 would be rounded to 53.7 and 53.43 would be rounded to 53.4, if rounding were required. The first number was rounded up because 53.67 is closer to 53.7 than to 53.6. Likewise, the second number was rounded down because 53.43 is closer to 53.4 than to 53.5. The reasons for rounding are covered in the next section on “Significant Figures.”

If the number being rounded ends with a 5, two possibilities exist. In the more mathematically sound approach, numbers are rounded up or down depending on whether the number to the left of the 5 is odd or even. Thus, 102.25 would be rounded down to 102.2, while 102.35 would be rounded up to 102.4. This procedure avoids the bias that would exist if all numbers ending in 5 were rounded up or all numbers were rounded down. In some calculators, however, all rounding is up. This does result in some bias, or skewing of data, but the significance of the bias may or may not be significant to the calculations at hand.

Significant Figures

- General

16 A general purpose balance or scale, classified as G20 in AASHTO M 231, has a capacity of 20,000 g and an accuracy requirement of ±5 g. A mass of 18,285 g determined with such an instrument could actually range from 18,280 g to 18,290 g. Only <u>four</u> places in the measurement are significant. The fifth (last) place is <u>not</u> significant since it may change.

17 Mathematical rules exist for handling significant figures in different situations.

An example in Metric(**m**) or English(**ft**), when performing addition and subtraction, the number of significant figures in the sum or difference is determined by the least precise input. Consider the three situations shown below:

Situation 1	Situation 2	Situation 3
35.67	143.903	162
+ 423.938	- 23.6	+33.546
		- .022
= 459.61	= 120.3	= 196
not 459.608	not 120.303	not 195.524

Rules also exist for multiplication and division. These rules, and the rules for mixed operations involving addition, subtraction, multiplication, and/or division, are beyond the scope of these

materials. AASHTO covers this topic to a certain extent in the section called "Precision" or "Precision and Bias" included in many test methods, and the reader is directed to those sections if more detail is desired.

18 • Real World Limitations

While the mathematical rules of significant digits have been established, they are not always followed. For example, AASHTO Method of Test T 176, *Plastic Fines in Graded Aggregates and Soils by the Use of the Sand Equivalent Test*, prescribes a method for rounding and significant digits in conflict with the mathematical rules.

In this procedure, readings and calculated values are always rounded up. A clay reading of 7.94 would be rounded to 8.0 and a sand reading of 3.21 would be rounded to 3.3. The <u>rounded</u> numbers are then used to calculate the Sand Equivalent, which is the ratio of the two numbers multiplied by 100. In this case:

$$\frac{3.3}{8.0} \times 100 = 41.250 \ldots$$

rounded to 41.3 and reported as 42

$$Not\text{:}\ \frac{3.21}{7.94} \times 100 = 40.428 \ldots$$

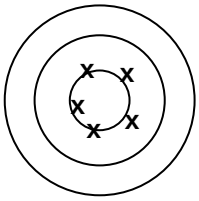
rounded to 40.0 and reported as 40)

It is extremely important that engineers and technicians understand the rules of rounding and significant digits just as well as they know procedures called for in standard test methods.

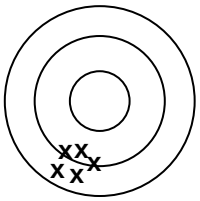
Accuracy and Precision

19 Although often used interchangeably, the terms accuracy and precision do not mean the same thing.
20 In an engineering sense, accuracy denotes nearness

to the truth or some value accepted as the truth, while precision relates to the degree of refinement or repeatability of a measurement.



ACCURATE BUT NOT PRECISE, SCATTERED



PRECISE BUT NOT ACCURATE, BIASED

Two bulls-eye targets are shown to the left. The upper one indicates hits that are scattered and, yet, are very close to the center. The lower one has a tight pattern, but all the shots are biased from the center. The upper one is more accurate, while the lower one is more precise. A biased, but precise, instrument can often be adjusted physically or mathematically to provide reliable single measurements. A scattered, but accurate, instrument can be used if enough measurements are made to provide a valid average.

21 Consider the measurement of the temperature of boiling water at standard atmospheric pressure by two thermometers. Five readings were taken with each, and the values were averaged.

Thermometer No. 1	Thermometer No. 2
101.2° 214.2°	100.6° 213.1°
101.1° 214.0°	99.2° 210.6°
101.2° 214.2°	98.9° 210.0°
101.1° 214.0°	101.0° 213.8°
101.2° 214.2°	100.3° 212.5°
AVG = 101.2° 214.2°	AVG = 100.0° 212°

22 No. 1 shows very little fluctuation, but is off the known boiling point (100°C or 212°F) by 1.2°C or 2.2°F. No. 2 has an average value equal to the known boiling point, but shows quite a bit of fluctuation. While it might be preferable to use neither thermometer, thermometer No. 1 could be
23 employed if 1.2°C or 2.2°F were subtracted from each measurement. Thermometer No. 2 could be used if enough measurements were made to provide a valid average.

24 Engineering and scientific instruments should be calibrated and compared against reference standards periodically to assure that measurements are accurate. If such checks are not performed, the
25 accuracy is uncertain, no matter what the precision. Calibration of an instrument removes fixed error, leaving only random error for concern.

Tolerance

26 Dimensions of constructed or manufactured objects, including laboratory test equipment, cannot be specified exactly. Some tolerance must be allowed. Thus, procedures for including tolerance in addition/subtraction and multiplication/division operations must be understood.

27

- Addition and Subtraction

  When adding or subtracting two numbers that individually have a tolerance, the tolerance of the sum or difference is equal to the sum of the individual tolerances.

  An example in Metric(**m**) or English(**ft.**), if the distance between two points is made up of two parts, one being 113.361 ±0.006 and the other being 87.242 ±0.005 then the tolerance of the sum (or the difference) is:

  $$(0.006) + (0.005) = 0.011$$

  and the sum would be 200.603 ±0.011.

- Multiplication and Division

28

  To demonstrate the determination of tolerance again in either Metric(**m**) or English(**ft.**) for the product of two numbers, consider determining the area of a rectangle having sides of 76.254 ±0.009 and 34.972 ±0.007. The percentage variations of the two dimensions are:

$$\frac{0.009}{76.254} \times 100 = 0.01\% \quad \frac{0.007}{34.972} \times 100 = 0.02\%$$

  The sum of the percentage variations is 0.03 percent – the variation that is employed in the area of the rectangle:

  Area =
  2666.8 (m^2 or ft^2) ±0.03 percent =
  2666.8 ± 0.8 (m^2 or ft^2).

29

- Real World Applications

Tolerances are used whenever a product is manufactured. For example, the mold used for determining soil density in AASHTO T 99 has a diameter of 101.60 ±0.41 mm(4.000 ±0.016 in) and a height of 116.43 ±0.13 mm(4.584 ±0.005 in).

Using the smaller of each dimension results in a volume of:

$(\pi/4)$ (101.19 mm)^2 (116.30 mm) =
935,287 mm^3 or 0.000935 m^3

$(\pi/4)$ (3.984 in)^2 (4.579 in) =
57.082in^3 or 0.0330 ft^3

Using the larger of each dimension results in a volume of:

$(\pi/4)$ (102.01 mm)^2 (116.56 mm) =
952,631 mm^3 or 0.000953 m^3

$(\pi/4)$ (4.016 in)^2 (4.589 in) =
58.130 in^3 or 0.0336 ft^3

The average value is 0.000944 m^3 (0.0333), and AASHTO T 99 specifies a volume of:

0.000943 ±0.000008 m^3
or a range of
0.000935 to 0.000951 m^3

0.0333 ±0.0003 ft^3
or a range of
0.0330 to 0.0336 ft^3

Because of the variation that can occur, some agencies periodically calibrate molds, and make adjustments to calculated density based on those calculations.

Summary

30

Mathematics has certain rules and procedures for making measurements and performing calculations that are well established. So are standardized test procedures. Sometimes these agree, but occasionally, they do not. Engineers and technicians must be familiar with both, but must follow test procedures in order to obtain valid, comparable results.

TERMINOLOGY

Many of the terms listed below are defined differently by various agencies or organizations. The definitions of the American Association of State Highway and Transportation Officials (AASHTO) are the ones most commonly used in this document.

Absorbed water – Water drawn into a solid by absorption, and having physical properties similar to ordinary water.

Absorption – The increase in the mass of aggregate due to water being absorbed into the pores of the material, but not including water adhering to the outside surface of the particles, expressed as a percentage of the dry mass.

Acceptance – See verification.

Acceptance program – All factors that comprise the State Transportation Department's (STD) determination of the quality of the product as specified in the contract requirements. These factors include verification sampling, testing, and inspection and may include results of quality control sampling and testing.

Admixture – Material other than water, cement, and aggregates in Portland cement concrete (PCC).

Adsorbed water – Water attached to the surface of a solid by electrochemical forces, and having physical properties substantially different from ordinary water.

Aggregate – Hard granular material of mineral composition, including sand, gravel, slag or crushed stone, used in roadway base and in Portland cement concrete (PCC) and asphalt mixtures.

Coarse aggregate – Aggregate retained on or above the No. 4 (4.75 mm) sieve.

- **Coarse-graded aggregate** – Aggregate having a predominance of coarse sizes.
- **Dense-graded aggregate** – Aggregate having a particle size distribution such that voids occupy a relatively small percentage of the total volume.
- **Fine aggregate** – Aggregate passing the No. 4 (4.75 mm) sieve.
- **Fine-graded aggregate** – Aggregate having a predominance of fine sizes.
- **Mineral filler** – A fine mineral product at least 70 percent of which passes a No. 200 (75 µm) sieve.
- **Open-graded gap-graded aggregate** – Aggregate having a particle size distribution such that voids occupy a relatively large percentage of the total volume.
- **Well-Graded Aggregate** – Aggregate having an even distribution of particle sizes.

Aggregate storage bins – Bins that store aggregate for feeding material to the dryer in a hot mix asphalt (HMA) plant in substantially the same proportion as required in the finished mix.

Agitation – Provision of gentle motion in Portland cement concrete (PCC) sufficient to prevent segregation and loss of plasticity.

Air voids (V_a) – Total volume of the small air pockets between coated aggregate particles in asphalt mixtures; expressed as a percentage of the bulk volume of the compacted paving mixture.

Ambient temperature – Temperature of the surrounding air

Angular aggregate – Aggregate possessing well-defined edges at the intersection of roughly planar faces

Apparent specific gravity (G_{sa}) – The ratio of the mass, in air, of a volume of the impermeable portion of aggregate to the mass of an equal volume of water at a stated temperature.

Asphalt – A dark brown to black cementitious material in which the predominate constituents are bitumens occurring in nature or obtained through petroleum processing. Asphalt is a constituent of most crude petroleums.

Asphalt emulsion – A mixture of asphalt binder and water.

Asphalt binder – An asphalt specially prepared in quality and consistency for use in the manufacture of asphalt mixtures.

Asphalt mixtures – A controlled mix of aggregate and asphalt binder.

Automatic cycling control – A control system in which the opening and closing of the weigh hopper discharge gate, the bituminous discharge valve, and the pugmill discharge gate are actuated by means of automatic mechanical or electronic devices without manual control. The system includes preset timing of dry and wet mixing cycles.

Automatic dryer control – A control system that automatically maintains the temperature of aggregates discharged from the dryer.

Automatic proportioning control – A control system in which proportions of the aggregate and asphalt binder fractions are controlled by means of gates or valves that are opened and closed by means of automatic mechanical or electronic devices without manual control.

Bag (of cement) – 94 lb of Portland cement (Approximately 1 ft^3 of bulk cement)

Base – A layer of selected material constructed on top of subgrade or subbase and below the paving on a roadway.

Bias – The offset or skewing of data or information away from its true or accurate position as the result of systematic error.

Binder – Asphalt binder or modified asphalt binder that binds the aggregate particles into a dense mass.

Boulders – Rock fragment, often rounded, with an average dimension larger than 300 mm (12 in.).

Bulk specific gravity– The ratio of the mass, in air, of a volume of aggregate (G_{sa}) or compacted HMA mix (G_{mb}) (including the permeable and impermeable voids in the particles, but not including the voids between particles) to the mass of an equal volume of water at a stated temperature.

Bulk specific gravity (SSD) **–** The ratio of the mass, in air, of a volume of aggregate (G_{sa} *SSD*) or compacted asphalt mixtures (G_{mb} *SSD*), including the mass of water within the voids (but not including the voids between particles), to the mass of an equal volume of water at a stated temperature. (See saturated surface dry.)

Cementitious Materials – cement and pozzolans used in concrete such as: Portland cement, fly ash, silica fume, and blast-furnace slag.

Clay – Fine-grained soil that exhibits plasticity over a range of water contents, and that exhibits considerable strength when dry, also, that portion of the soil finer than 2 µm.

Cobble – Rock fragment, often rounded, with an average dimension between 75 and 300 mm (3 and 12 in.).

Cohesionless soil – Soil with little or no strength when dry and unconfined or when submerged, such as sand

Cohesive soil – Soil with considerable strength when dry and that has significant cohesion when unconfined or submerged.

Compaction – Densification of a soil or asphalt mixtures by mechanical means.

Compaction curve (Proctor curve or moisture-density curve) – The curve showing the relationship between the dry unit weight or density and the water content of a soil for a given compactive effort.

Compaction test (moisture-density test) – Laboratory compaction procedure in which a soil of known water content is placed in a specified manner into a mold of given dimensions, subjected to a compactive effort of controlled magnitude, and the resulting density determined.

Compressibility – Property of a soil or rock relating to susceptibility to decrease in volume when subject to load.

Constant mass – The state at which a mass does not change more than a given percent, after additional drying for a defined time interval, at a required temperature.

Constructor – The builder of a project. The individual or entity responsible for performing and completing the construction of a project required by the contract documents. Often called a contractor, since this individual or entity contracts with the owner.

Cutback asphalt – Asphalt binder that has been modified by blending with a chemical solvent.

Crusher-run – The total unscreened product of a stone crusher.

Delivery tolerances – Permissible variations from the desired proportions of aggregate and asphalt binder delivered to the pugmill.

Density – The ratio of mass to volume of a substance. Usually expressed in lb/ft^3 (kg/m^3).

Design professional – The designer of a project. This individual or entity may provide services relating to the planning, design, and construction of a project, possibly including materials testing and construction inspection. Sometimes called a "contractor," since this individual or entity contracts with the owner.

Dryer – An apparatus that dries aggregate and heats it to specified temperatures.

Dry mix time – The time interval between introduction of aggregate into the pugmill and the addition of asphalt binder.

Durability – The property of concrete that describes its ability to resist disintegration by weathering and traffic. Included under weathering are changes in the pavement and aggregate due to the action of water, including freezing and thawing.

Dust Proportion – DP (Dust to Effective (asphalt) Binder Ratio) – The percent passing the No. 200 sieve divided by the percent of effective asphalt binder.

Effective specific gravity (G_{se}) – The ratio of the mass in air of a unit volume of a permeable material (excluding voids permeable to asphalt binder) at a stated temperature to the mass in air (of equal density) of an equal volume of gas-free distilled water at a stated temperature.

Effective diameter (effective size) – D_{10}, particle diameter corresponding to 10 percent finer or passing.

Embankment – Controlled, compacted material between the subgrade and subbase or base in a roadway.

End-result specifications – Specifications that require the Constructor to take the entire responsibility for supplying a product or an item of construction. The Owner's (the highway agency's) responsibility is to either accept or reject the final product or to apply a price

adjustment that is commensurate with the degree of compliance with the specifications. Sometimes called performance specifications, although considered differently in highway work. (See performance specifications.)

Family of curves – a group of soil moisture-density relationships (curves) determined using AASHTO T 99 or T 180, which reveal certain similarities and trends characteristic of the soil type and source.

Field operating procedure (FOP) – Procedure used in field testing on a construction site or in a field laboratory. (Based on AASHTO or NAQTC test methods.)

Fineness modulus – A factor equal to the sum of the cumulative percentages of aggregate retained on certain sieves divided by 100; the sieves are 150, 75, 37.5, 19.0, 9.5, 4.75, 2.36, 1.18, 0.60, 0.30, and 0.15 mm. Used in the design of concrete mixes. The lower the fineness modulus, the more water/cement paste that is needed to coat the aggregate.

Fines – Portion of a soil or aggregate finer than a 75 µm (No. 200) sieve. Also silts and clays.

Fractured Face – An angular, rough, or broken surface of an aggregate particle created by crushing or by other means. A face is considered a "fractured face" whenever one-half or more of the projected area, when viewed normal to that face, is fractured with sharp and well defined edges. This excludes small nicks.

Fractured particle – A particle of aggregate having at least the minimum number of fractured faces specified.

Free water – Water on aggregate available for reaction with hydraulic cement. Mathematically, the difference between total moisture content and absorbed moisture content.

Glacial till – Material deposited by glaciation, usually composed of a wide range of particle sizes, which has not been subjected to the sorting action of water.

Gradation (grain-size distribution) – The proportions by mass of a soil or fragmented rock distributed by particle size.

Gradation analysis (grain size analysis or sieve analysis) – The process of determining grain-size distribution by separation of sieves with different size openings.

Hot aggregate storage bins – Bins that store heated and separated aggregate before final proportioning into the mixer.

Hot mix asphalt (HMA) – High quality, thoroughly controlled hot mixture of asphalt binder and well-graded, high quality aggregate.

Hot Mix Asphalt (HMA) batch plant – A manufacturing facility for producing hot mix asphalt (HMA) that proportions aggregate by weight and asphalt by weight or volume.

HMA continuous mix plant – A manufacturing facility for producing HMA that proportions aggregate and asphalt binder by a continuous volumetric proportioning system without specific batch intervals.

Hydraulic cement – Cement that sets and hardens by chemical reaction with water.

Independent assurance – Unbiased and independent evaluation of all the sampling and testing procedures, equipment, and technicians involved with Quality Control (QC) and Verification/Acceptance.

In situ – Rock or soil in its natural formation or deposit.

Liquid limit – Moisture content corresponding to the boundary between the liquid and plastic states.

Loam – A mixture of sand, silt or clay, or a combination thereof, with organic matter.

Lot – A quantity of material to be controlled. It may represent a specified mass, a specified number of truckloads, or a specified time period during production.

Manual proportioning control – A control system in which proportions of the aggregate and asphalt binder fractions are controlled by means of gates or valves that are opened and closed by manual means. The system may or may not include power assisted devices in the actuation of gate and valve opening and closing.

Materials and methods specifications – Also called prescriptive specifications. Specifications that direct the Constructor to use specified materials in definite proportions and specific types of equipment and methods to place the material.

Maximum size – One sieve larger than nominal maximum size.

Mesh – The square opening of a sieve.

Moisture content – The ratio, expressed as a percentage, of the mass of water in a material to the dry mass of the material.

Nominal maximum size – One sieve larger than the first sieve to retain more than 10 percent of the material using an agency specified set of sieves based on cumulative percent retained. Where large gaps in specification sieves exist, intermediate sieve(s) may be inserted to determine nominal maximum size.
Note: The first sieve to normally retain more than 10 percent of the material usually is the second sieve in the stack but may be the third sieve.

Nuclear gauge – Instruments used to measure in-place density, moisture content, or asphalt binder content through the measurement of nuclear emissions.

Optimum moisture content (optimum water content) – The water content at which a soil can be compacted to a maximum dry density by a given compactive effort.

Organic soil – Soil with a high organic content.

Owner – The organization that conceives of and eventually operates and maintains a project. A State Transportation Departments (STD) is an Owner.

Paste – Mix of water and hydraulic cement that binds aggregate in Portland cement concrete (PCC).

Penetration – The consistency of a bituminous material, expressed as the distance in tenths of a millimeter (0.1 mm) that a standard needle vertically penetrates a sample of the material under specified conditions of loading, time, and temperature.

Percent of Absorbed (asphalt) Binder (P_{ba}) – The total percent of the asphalt binder that is absorbed into the aggregate, expressed as a percentage of the mass of aggregate rather than as a percentage of the total mass of the mixture. This portion of the asphalt binder content does not contribute to the performance of the mix.

Percent aggregate (stone) (P_s) – The percent aggregate (stone) content, expressed as a percentage of the total mass of the sample.

Percent of Effective (asphalt) Binder (P_{be}) – The total asphalt binder content of a paving mixture minus the portion of asphalt binder that is lost by absorption into the aggregate particles, expressed as a percentage of the mass of aggregate. It is the portion of the asphalt binder content that remains as a coating on the outside of the aggregate particles.

Percent compaction – The ratio of density of a soil, aggregate, or asphalt mixtures in the field to a maximum density determined by a standard compaction test, expressed as a percentage.

Performance specifications – Specifications that describe how the finished product should perform. For highways, performance is typically described in terms of changes over time in physical condition of the surface and its response to load, or in terms of the cumulative traffic required to bring the pavement to a condition defined as "failure." Specifications containing warranty/guarantee clauses are a form of performance specifications.

Plant screens – Screens located between the dryer and hot aggregate storage bins that separate the heated aggregates by size.

Plastic limit – Moisture content corresponding to the boundary between the plastic and the semisolid states.

Plasticity – Property of a material to continue to deform indefinitely while sustaining a constant stress.

Plasticity index – Numerical difference between the liquid limit and the plastic limit and, thus, the range of water content over which the soil is plastic.

Portland cement – Hydraulic cement produced by pulverizing Portland cement clinker.

Portland cement concrete (PCC) – A controlled mix of aggregate, Portland cement, and water, and possibly other admixtures.

PCC batch plant – A manufacturing facility for producing Portland cement concrete.

Prescriptive specifications – See Materials and Methods specification.

Proficiency samples – Homogeneous samples that are distributed and tested by two or more laboratories. The test results are compared to assure that the laboratories are obtaining the same results.

Pugmill – A shaft mixer designed to mix aggregate and cement.

Quality assurance – Planned and systematic actions necessary to provide confidence that a product or service will satisfy given requirements for quality. The overall system for providing quality in a constructed project, including Quality Control (QC), Verification/Acceptance, and Independent Assurance (IA).

Quality assurance specifications – Also called QC/QA specifications. A combination of end-result (performance) specifications and materials and methods (prescriptive) specifications. The Constructor is responsible for quality control, and the Owner (highway agency) is responsible for acceptance of the product.

Quality control (QC) – Operational, process control techniques or activities that are performed or conducted to fulfill contract requirements for material or equipment quality.

Random sampling – Procedure for obtaining non-biased, representative samples.

Sand – Particles of rock passing the No. 4 (4.75 mm) sieve and retained on the No. 200 (75 µm) sieve.

Saturated surface dry (SSD) – Condition of an aggregate particle, asphalt mixtures or Portland cement concrete (PCC) core, or other porous solid when the permeable voids are filled with water, but no water is present on exposed surfaces. (See bulk specific gravity.)

Segregation – The separation of aggregate by size resulting in a non-uniform material.

SHRP – The Strategic Highway Research Program (SHRP) established in 1987 as a five-year research program to improve the performance and durability of roads and to make those roads safe for both motorists and highway workers. SHRP research funds were partly used for the development of performance-based specifications to directly relate laboratory analysis with field performance.

Sieve – Laboratory apparatus consisting of wire mesh with square openings, usually in circular or rectangular frames.

Silt – Material passing the (75 µm) sieve that is non-plastic or very slightly plastic, and that exhibits little or no strength when dry and unconfined. Also, that portion of the soil finer than 75 µm and coarser than 2 µm.

Slump – Measurement related to the workability of concrete.

Soil – Sediments or unconsolidated accumulations of solid particles produced by the physical and chemical disintegration or rocks, and which may or may not contain organic matter.

Specific gravity – The ratio of the mass of a volume of a material to the mass of an equal volume of water at a stated temperature.

- $\mathbf{G_{mm}}$ – theoretical maximum specific gravity (Gravity $_{\text{mix max}}$)
  The ratio of the mass of a given volume of asphalt mixtures with no air voids to the mass of an equal volume of water, both at a stated temperature.

- $\mathbf{G_{mb}}$ – measured bulk specific gravity (Gravity $_{\text{mix bulk}}$)
  The ratio of the mass, in air, of a volume of compacted HMA mix (including the permeable and impermeable voids in the particles, but not including the voids between particles) to the mass of an equal volume of water at a stated temperature.

- $\mathbf{G_{sb}}$ – oven-dry bulk specific gravity of aggregate (Gravity $_{\text{stone bulk}}$)
  The ratio of the mass, in air, of a volume of aggregate (including the permeable and impermeable voids in the particles, but not including the voids between particles) to the mass of an equal volume of water at a stated temperature.

- $\mathbf{G_{sa}}$ – apparent specific gravity of aggregate (Gravity $_{\text{stone apparent}}$)
  The ratio of the mass, in air, of a volume of the impermeable portion of aggregate to the mass of an equal volume of water at a stated temperature.

- $\mathbf{G_{se}}$ – effective specific gravity of aggregate (Gravity $_{\text{stone effective}}$)
  The ratio of the mass in air of a unit volume of a permeable material (excluding voids permeable to asphalt binder) at a stated temperature to the mass in air (of equal density) of an equal volume of gas-free distilled water at a stated temperature.

- $\mathbf{G_{b}}$ – specific gravity of the binder (Gravity $_{\text{binder}}$)
  The ratio of the mass of a volume of asphalt binder to the mass of an equal volume of water at a stated temperature.

Spine – smooth line extending through the point of maximum density/optimum moisture content of a family of moisture-density curves.

Stability – The ability of an asphalt mixture to resist deformation from imposed loads. Stability is dependent upon internal friction, cohesion, temperature, and rate of loading.

Stratified random sampling – Procedure for obtaining non-biased, representative samples in which the established lot size is divided into equally-sized sublots.

Subbase – A layer of selected material constructed between the subgrade and the base coarse in a flexible HMA roadway, or between the subgrade and Portland cement concrete (PCC) pavement in a rigid PCC roadway.

Subgrade – Natural soil prepared and compacted to support a structure or roadway pavement.

Sublot – A segment of a lot chosen to represent the total lot.

Superpave™ – Superpave™ (Superior Performing Asphalt Pavement) is a trademark of the Strategic Highway Research Program (SHRP). Superpave™ is a product of the SHRP asphalt research. The Superpave™ system incorporates performance-based asphalt materials characterization with design environmental conditions to improve performance by controlling rutting, low temperature cracking and fatigue cracking. The three major components of Superpave™ are the asphalt binder specification, the mix design and analysis system, and a computer software system.

Theoretical maximum specific gravity (G_{mm}) – The ratio of the mass of a given volume of asphalt mixtures with no air voids to the mass of an equal volume of water, both at a stated temperature.

Topsoil – Surface soil, usually containing organic matter.

Uniformity coefficient – C_u, a value employed to quantify how uniform or well-graded an aggregate is: $C_u = D_{60}/D_{10}$. 60 percent of the aggregate, by mass, has a diameter smaller than D_{60} and 10 percent of the aggregate, by mass, has a diameter smaller than D_{10}.

Unit weight – The ratio of weight to volume of a substance. The term "density" is more commonly used.

µm – Micro millimeter (micron) Used as measurement for sieve size.

Vendor – Supplier of project-produced material that is other than the constructor.

Verification – Process of sampling and testing performed to validate Quality Control (QC) sampling and testing and, thus, the quality of the product. Sometimes called Acceptance.

Void in the mineral aggregate (VMA) – The volume of inter-granular void space between aggregate particles of compacted asphalt mixtures that includes air and asphalt binder; expressed as a percentage of the bulk volume of the compacted paving mixture.

Voids filled with asphalt (VFA) – The portion of the void in the mineral aggregate (VMA) that contains asphalt binder; expressed as a percentage of the bulk volume of mix or the VMA.

Wet mixing period – The time interval between the beginning of application of asphalt binder and the opening of the mixer gate.

Zero air voids curve (saturation curve) – Curve showing the zero air voids density as a function of water content.

SAFETY

The procedures included in this manual may involve hazardous materials, operations, and equipment. The procedures do not address all of the safety issues associated with their use. It is the responsibility of the employer to assess workplace hazards and to determine whether personal protective equipment (PPE) must be used. PPE must meet applicable American National Standards Institute (ANSI) standards, and be properly used and maintained. The employer must establish appropriate safety and health practices, in compliance with applicable state and federal laws, for these procedures and associated job site hazards. Hazardous materials must be addressed in a Hazard Communication program, and Material Safety Data Sheets (MSDS) must be obtained and available to workers. Supervisors and employees should be aware of job site hazards, and comply with their employers' safety and health program. The following table identifies some areas that may affect individuals performing the procedures in this manual.

Body Part Affected	Potential Hazards	PPE/Procedures That May Be Appropriate
Head	Falling or fixed overhead objects; electrical shock	Hard hat or other protective helmet
Eyes and Face	Flying objects, radiation, molten metal, chemicals	Safety glasses, goggles, face shields; prescription or filter lenses
Ears	Noise	Ear plugs, ear muffs
Respiratory System	Inhalation of dusts, chemicals; O_2 deficiency	Properly fit and used respiratory protection consistent with the hazard
Skin	Chemicals including cement; heat	Appropriate chemical or heat resistant gloves, long-sleeve shirts, coveralls
Mouth, digestive system	Ingestion of toxic materials	Disposable or washable gloves, coveralls; personal hygiene
Hands	Physical injury (pinch, cut, puncture), chemicals	Appropriate gloves for physical hazards and compatible with chemicals present
Feet	Falling, sharp objects; slippery surfaces, chemicals	Safety shoes or boots (steel toed, steel shank); traction soles; rubber boots – chemicals, wet conditions
Joints, muscles, tendons	Lifting, bending, twisting, repetitive motions	Proper training and procedures; procedure modifications
Body/Torso	Falls; burial	Fall protection; trench sloping or shoring
Miscellaneous	Traffic	Visibility, awareness, communication; driver training, safety awareness
Whole body	Radiation	Radiation safety training

RANDOM SAMPLING OF CONSTRUCTION MATERIALS

01

Significance

Sampling and testing are two of the most important functions in quality control (QC). Data from the tests are the tools with which the quality of product is controlled. For this reason, great care must be used in following standardized sampling and testing procedures.

In controlling operations, it is necessary to obtain numerous samples at various points along the production line. Unless precautions are taken, sampling can occur in patterns that can create a bias to the data gathered. Sampling at the same time, say noon, each day may jeopardize the effectiveness of any quality program. This might
02 occur, for example, because a material producer does certain operations, such as cleaning screens at an aggregate plant, late in the morning each day. To obtain a representative sample, a reliable system of random sampling must be employed.

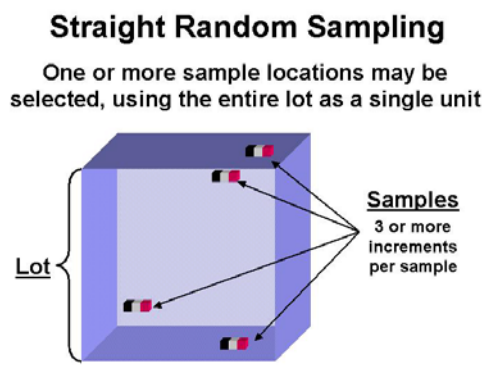
Scope

The procedure presented here eliminates bias in sampling materials. Randomly selecting a set of numbers from a table or calculator will eliminate the possibility for bias. Random numbers are used to identify sampling times, locations, or points within a lot or sublot. This method does not cover how to sample, but rather how to determine sampling times, locations, or points.

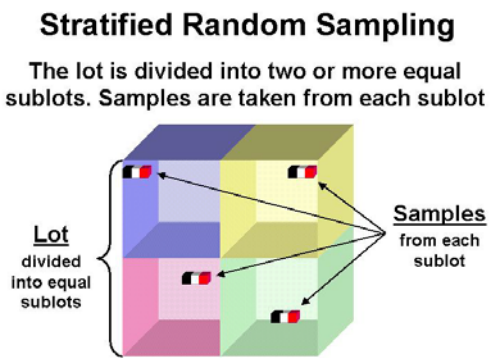
Sampling Concepts

03
04 A lot is the quantity of material evaluated by QC procedures. A lot is a preselected quantity that may represent hours of production, a quantity or number of loads of material, or an interval of time. A lot may be comprised of several portions that are called sublots or units. The number of sublots comprising a lot will be determined by the agency's specifications.

05



06



Straight Random Sampling vs. Stratified Random Sampling: Straight random sampling considers an entire lot as a single unit and determines each sample location based on the entire lot size. Stratified random sampling divides the lot into a specified number of sublots or units and then determines each sample location within a distinct sublot. Both methods result in random distribution of samples to be tested for compliance with the agency's specification.

Agencies stipulate when to use straight random sampling or stratified random sampling. AASHTO T 2, Sampling of Aggregates, for example, specifies a straight random sampling procedure.

Picking Random Numbers from a Table

07

Table 1 contains pairs of numbers. The first number is the "pick" number and the second is the Random Number, "RN." The table was generated with a spreadsheet and the cells (boxes at the intersection of rows and columns) containing the RNs actually contain the "random number function." Every time the spreadsheet is opened or changed, all the RNs change.

1. Select a Pick number in a random method. The first two or last two digits in the next automobile license plate you see would be one way to select. Another would be to start a digital stop watch and stop it several seconds later, using the decimal part of the seconds as your Pick number.
2. Find the RN matching the Pick number.

Picking Random Numbers with a Calculator

08
09

Many calculators have a built-in random number function. To obtain a random number, key in the code or push the button(s) the calculator's instructions call for. The display will show a number between 0.000 and 1.000 and this will be your random number.

TABLE 1
Random Numbers

Pick	RN	Pick	RN	Pick	RN	Pick	RN	Pick	RN
01	0.998	21	0.758	41	0.398	61	0.895	81	0.222
02	0.656	22	0.552	42	0.603	62	0.442	82	0.390
03	0.539	23	0.702	43	0.150	63	0.821	83	0.468
04	0.458	24	0.217	44	0.001	64	0.187	84	0.335
05	0.407	25	0.000	45	0.521	65	0.260	85	0.727
06	0.062	26	0.781	46	0.462	66	0.815	86	0.708
07	0.370	27	0.317	47	0.553	67	0.154	87	0.161
08	0.410	28	0.896	48	0.591	68	0.007	88	0.893
09	0.923	29	0.848	49	0.797	69	0.759	89	0.255
10	0.499	30	0.045	50	0.638	70	0.925	90	0.604
11	0.392	31	0.692	51	0.006	71	0.131	91	0.880
12	0.271	32	0.530	52	0.526	72	0.702	92	0.656
13	0.816	33	0.796	53	0.147	73	0.146	93	0.711
14	0.969	34	0.100	54	0.042	74	0.355	94	0.377
15	0.188	35	0.902	55	0.609	75	0.292	95	0.287
16	0.185	36	0.674	56	0.579	76	0.854	96	0.461
17	0.809	37	0.509	57	0.887	77	0.240	97	0.703
18	0.105	38	0.013	58	0.495	78	0.851	98	0.866
19	0.715	39	0.497	59	0.039	79	0.678	99	0.616
20	0.380	40	0.587	60	0.812	80	0.122	00	0.759

Examples of Straight Random Sampling Procedures Using Random Numbers

10

Sampling from a Belt or Flowing Stream: Agencies specify the frequency of sampling in terms of time, volumes, or masses. The specification might call for one sample from every 1,000,000 kg(1000 t) or 1100 Tons(T) of aggregate. If the random number was 0.317, the sample would be taken at (0.317)(1,000,000 kg) = 317,000 kg (317 t). Or (.317) (1100 T) = 349 T.

One sample per day might also be specified. If the day were 9 hours long and the random number 0.199, the sample would be taken at (0.199)(9 hrs) = 1.79 hr = 1 hr, 48 minutes into the day. AASHTO T 2 permits this time to be rounded to the nearest 5 minutes.

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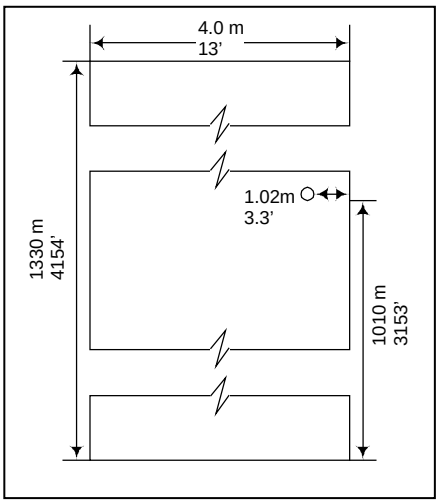
Sampling from Haul Units: Based on the agency's specifications – in terms of time, volume, or mass – determine the number of haul units that comprise a lot. Multiply the selected random

number(s) by the number of units to determine which unit(s) will be sampled.

For example, if 20 haul units comprise a lot and one sample is needed, pick one RN. If the RN were 0.773, then the sample would be taken from the (0.773) (20) = 15.46, or 16th haul unit.



Sampling from a roadway

Sampling from a Roadway with Previously Placed Material: The agency's specified frequency of sampling – in time, volume, or mass – can be translated into a location on a job. For example, if a sample is to be taken every 800 m^3 (1000yd^3) and material is being placed 0.15 m (0.50 ft) thick and 4.0 m (13 ft) wide, then the lot is 1330 m (4154 ft) long. You would select two RNs in this case. To convert yd^3 to ft^3 multiply by 27.

The first RN would be multiplied by the length to determine where the sample would be taken along the project. The second would be multiplied by the width to determine where, widthwise, the sample would be taken. For example, a first RN of 0.759 would specify that the sample would be taken at (0.759)(1330 m) or (4154 ft) = 1010 m or 3153 ft from the beginning. A second RN of 0.255 would specify that the sample would be taken at (0.255)(4.0 m) or (13 ft) = 1.02 m or 3.3 ft from the right edge of the material. To avoid problems associated with taking samples too close to the edge, no sample is taken closer than 0.3 m (1 ft) to the edge. If the RN specifies a location closer than 0.3 m (1 ft), then 0.3 m (1 ft) is added to or subtracted from the distance calculated.

Sampling from a Stockpile: AASHTO T 2 recommends against sampling from stockpiles. However, some agencies use random procedures in determining sampling locations from a stockpile. Bear in mind that stockpiles are prone to segregation and that a sample obtained from a stockpile may not be representative. Refer to AASHTO T 2 for guidance on how to sample from a stockpile.

In-Place Density Testing: Agency specifications will indicate the frequency of tests. For example, one test per 500 m^3 (650 yd^3) might be required. If the material is being placed 0.15 m (0.50 ft) thick and 10.0 m (33 ft) wide, then the lot is 333 m (1090 ft) long. You would select two RNs in this case.

The first RN would be multiplied by the length to determine where the sample would be taken along the project. The second would be multiplied by the width to determine where, widthwise, the sample would be taken. For example, a first RN of 0.387 would specify that the sample would be taken at (0.387)(333 m) or (1090 ft) = 129 m or (422 ft) from the beginning. A second RN of 0.588 would specify that the sample would be taken at (0.588)(10.0 m) or (33 ft) = 5.88 m or (19 ft) from the right edge of the material. To avoid problems associated with taking samples too close to the edge, no sample is taken closer than 0.3 m (1 ft) to the edge. If the RN specifies a location closer than 0.3 m (1 ft), then 0.3 m (1 ft) is added to or subtracted from the distance calculated.

BASICS OF ASPHALT

01

Introduction

02

Slice through asphalt core

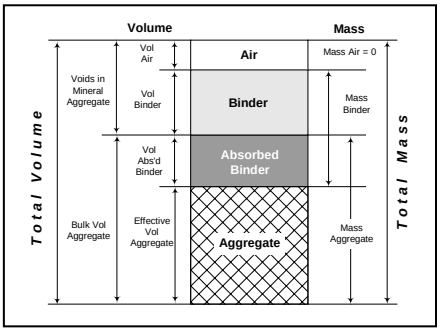
03

Asphalt mixtures are a mixture of two primary ingredients: mineral aggregate and asphalt binder. The asphalt binder holds the aggregate together in a moderately flexible rock-like mass. Hot mix asphalt (HMA) includes mixes that are produced at an elevated temperature. Asphalt mixtures and HMA are generally divided into three types of mixes, depending on the gradation of aggregate: dense-graded, open-graded, and gap-graded.

04

Dense-graded asphalt mixtures consist of asphalt binder and well-graded aggregate evenly distributed from small to large particles. Open-graded asphalt mixtures consist primarily of coarse aggregate, minimal fine aggregate, and asphalt binder. The mixture provides a very open surface texture — one that allows water to drain into the mix and in which large aggregate, stone-to-stone contact handles the load of a vehicle traveling over the surface. Gap-graded asphalt mixtures are similar to open-graded mix, except that mid-size aggregate between the 4.75 mm (No. 4) and 425 µm (No. 40) sieves is missing or present only in small amounts.

05



Asphalt mixture phase diagram

Asphalt mixtures contain air voids in addition to aggregate and asphalt binder. Also, the asphalt binder is divided into two categories: absorbed (into the aggregate) and effective (which remains on the surface for binding aggregate particles together).

06

Five factors affect pavement performance: structural design of pavement layers, mix design properties, workmanship used to produce, place, and compact the mix, loading factors, and environmental conditions. The best specifications, if not followed, will not assure a high quality, long-lasting pavement. The best mix design, if not duplicated at the plant, will not guarantee the life of the pavement. The most sophisticated equipment, if not operated properly, will not produce a roadway that withstands the effects of traffic and the environment. Poor workmanship can negate all

those items and cause premature failure of pavement materials and/or pavement structure. High quality materials testing and construction inspection are critical to a successful project.

Design Parameters

07 Whether a mix design is developed through a Marshall, Hveem, or Superpave mix design process there are basic volumetric requirements of all.
08 Volumetrics can include bulk specific gravity,
09 theoretical maximum specific gravity, air voids, and voids in mineral aggregate.

The total mass of the mix includes entrapped air, moisture, effective and absorbed asphalt binder, and mineral aggregate. This total mass divided by the corresponding bulk or total volume of a specimen yields a number known as bulk density. Bulk density is calculated by determining the bulk specific gravity, G_{mb}, of the sample and multiplying by the density of water.

10 There are two procedures for calculating G_{mb} – suspension and volumeter. In the suspension procedure, G_{mb} is calculated as follows.

$$G_{mb} = \frac{A}{B - C}$$

where:

G_{mb} = Bulk specific gravity
A = Mass of dry, compacted specimen in air
B = Mass of saturated surface dry (SSD) compacted specimen in air
C = Weight of compacted specimen in water at 25°C (77°F)

11 The combined masses of asphalt binder and aggregate divided by the volume of these components only is the maximum density. This density is “maximum” in that it contains no air voids. The maximum density provides a reference or base used to determine the amount of air actually present in the mix, among other things. Maximum

density is determined on uncompacted asphalt mixtures by determining the theoretical maximum specific gravity, G_{mm}, and multiplying by the density of water.

12

There are two procedures for calculating G_{mm} – bowl and flask. In the flask procedure, G_{mm} is calculated as follows.

$$G_{mm} = \frac{A}{A + D - E}$$

where:

G_{mm} = Theoretical maximum specific gravity
A = Mass of dry specimen in air
D = Mass of flask filled with water at 25°C (77°F)
E = Mass of flask filled with water and specimen at 25°C (77°F)

13

Air voids are expressed as a percentage of total sample volume. Percent air voids, V_a, is calculated as follows:

$$V_a = \left(\frac{G_{mm} - G_{mb}}{G_{mm}}\right) \times 100$$

where:

V_a = Percent air voids of total mix mass
G_{mb} = Bulk specific gravity of compacted mix
G_{mm} = Theoretical maximum specific gravity

14 Voids between aggregate particles may contain air or asphalt binder. Voids in the mineral aggregate, VMA, are those spaces in laboratory compacted specimens that include air and effective, but not absorbed, asphalt binder.

15

$$VMA = 100 - \left(\frac{G_{mb} \times P_s}{G_{sb}}\right)$$

where:

VMA = Voids in the mineral aggregate
G_{mb} = Bulk specific gravity of compacted mix
G_{sb} = Bulk specific gravity of aggregate
P_s = Percent aggregate content in mix by mass of total mix

16 Finally, the voids filled with asphalt (VFA) is expressed as the percentage of the VMA that contains asphalt.

$$VFA = \left(\frac{VMA - V_a}{VMA}\right) \times 100$$

where:

VFA = Voids filled with asphalt
VMA = Voids in the mineral aggregate
V_a = Percent air voids by total mass of mix

The above parameters are used in developing asphalt mixture mix designs. These items should be systematically monitored during construction to ensure a quality product.

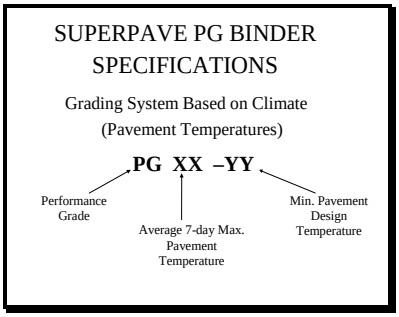
17 **Asphalt Binder**

Performance Graded (PG) asphalt binders were introduced in 1994 and are now the industry standard. The PG system of specifying asphalt binder is based on a complex series of performance based tests. The new specification system includes modified and unmodified asphalt binders.

18

Superpave PG Asphalt Binder specification

The Superpave PG asphalt binder specification, as outlined in AASHTO M 320, measures the physical properties of asphalt binders that can be directly related to field performance by engineering principles.



The Superpave asphalt binder grading system assigns a performance-based grade. This grade indicates the range of in-service temperatures of the asphalt binder to resist the various failure modes (rutting, fatigue and thermal cracking). The first number is the "high temperature grade," and means the asphalt binder possesses adequate physical properties up to at least this temperature. The second number is the "low temperature grade," and means the asphalt binder possesses adequate physical properties down to at least this temperature.

Asphalt Binder selection

The selection of the asphalt binder depends on the climatic condition of the project site:

- Low temperature
  Lowest pavement temperature (not air temperature)
- High temperature
  Average 7-day maximum pavement temperature (not air temperature)

The selection of the asphalt binder also makes some adjustments for the anticipated traffic speed.

Types of Manufacturing Plants

19

20

Aggregate feed bins

Two common types of plants are drum plants and batch plants. Both types are capable of producing the same quality asphalt mixtures. These plants are similar in that both have cold feed systems for aggregate. Material of different sizes is dropped from bins onto belts, transported to a mixer, blended, and then dropped onto another belt for transport to the dryer. The plants are different in the means of production following heating in the dryer.

21 **Drum Plants** – In drum plants, scales under the belts from each bin control the mass flow rate of each aggregate size. Moisture corrections are applied in order to base the process on dry mass. Asphalt binder flow rate is controlled by a metered delivery pump. Aggregate and asphalt binder are mixed in the far end (near the exit) of the drum and then stored temporarily in a silo.

With a drum plant supplying asphalt mixtures to a single project, the aggregate and asphalt binder, as measured by the scales and meter, can be compared with the material delivered to the job. After accounting for waste and reject, asphalt binder quantity, as measured by field tests, should agree within 1 percent with the quantity metered at the plant. The total mass of the aggregate and asphalt binder measured at the plant should agree within 2 percent of total mass delivered to the site as measured by the platform scales over which the delivery trucks pass.

22 Drum plants are typically used for large jobs and are more portable. Drum plants continuously feed aggregate and asphalt binder into the drum, and produce large quantities of asphalt mixtures during the course of a run. Drum plants, however, cannot switch mix designs with ease and require close control of material being fed to the dryer. Drum plants produce the same mix over an extended period, not several different mixes in a day as with batch plants.

Aggregate feed

23
24 **Batch Plants** – In batch plants, aggregate is rescreened and stored in separate bins after drying. Aggregate is taken from each bin on the basis of the mass called for in the mix design – the mass being determined in the aggregate hopper. A separate hopper is used for determining the mass of the asphalt binder. Aggregate and asphalt binder are mixed in a chamber, or pugmill, and then dropped into a truck or stored temporarily in a silo.

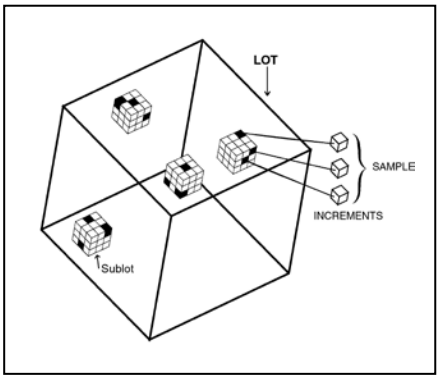
Batch plants are used where different mix designs are often needed. Batch plants are less efficient than drum plants because they only mix a certain

amount of asphalt mixtures at a time. They are more flexible, however, because several mixes can be made in a day. In fact, a batch plant can switch from one mix to another fairly quickly, as long as both mixes use aggregates from the same source.

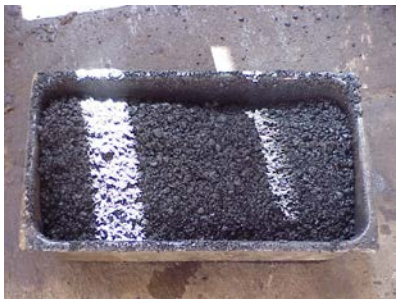
Summary

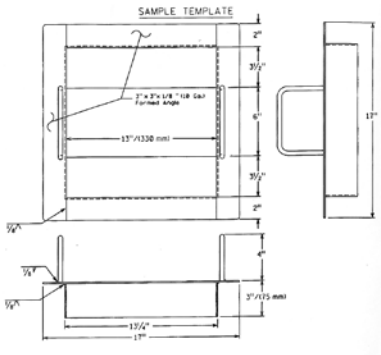
High quality asphalt mixtures require a proper combination of materials and workmanship. The testing technician plays a critical role in helping assure that materials incorporated into a roadway meet the requirements of the proper specification. No amount of proper workmanship can compensate for poor material quality.

SAMPLING OF BITUMINOUS PAVING MIXTURES FOP FOR AASHTO T 168



Sampling from a lot





Cookie Cutter Sampling Device

Significance

01 Testing bituminous paving mixtures in the field begins with obtaining and preparing the sample to be tested. Standardized procedures for obtaining a representative sample have been established. Producing strong, durable, reliable pavement in roadways requires careful sampling and accurate testing.

02 Technicians must be patient and follow these procedures. If one considers that the specifications require quality tests to be made on only a small portion of the total material placed, the need for a truly representative sample is apparent.

Scope

03 This procedure covers the sampling of bituminous paving mixtures from HMA plants; haul units, and roadways, in accordance with AASHTO T 168-03. Sampling is as important as testing, and every precaution must be taken to obtain a truly representative sample.

Apparatus

04 • Shovel

05 • Sample containers: Cardboard boxes, metal cans, stainless steel bowls, or other agency-approved containers

- Scoops, trowels, or other equipment to obtain mix
- Sampling plate: Thick metal plate, minimum 8 gauge, sized to accommodate sample requirements, with a wire attached to one corner long enough to reach from the center of the paver to the outside of the farthest auger extension. Holes ¼ in. in diameter should be provided in each corner.
- Cookie cutter sampling device: Formed steel angle with two 100 mm by 150 mm by 9 mm (4 in. by 6 in. by 3/8 in.) handles, sized to accommodate sample requirements. Minimum

2 in. smaller than the sampling plate when used together.

Example: Sampling plate 380 mm (15 in.) square and a cookie cutter sampling device 330 mm (13 in.) square.

- Mechanical sampling device

Sample Size

06 Sample size depends on the test methods specified by the agency for acceptance. Check agency requirement for the size required.

Sampling

07

General

- The material shall be tested to determine variations. The supplier/contractor shall provide equipment for safe and appropriate sampling including sampling devices on plants, when required.
- For dense graded mixture samples use cardboard boxes, stainless steel bowls or other agency approved containers. 08
- For hot open graded mixture samples use stainless steel bowls. Do not put open graded mixture samples in boxes until they have cooled to the point that bituminous material will not migrate from the aggregate.

Attached Sampling Devices

09 Some agencies require mechanical sampling devices for hot mix asphalt (HMA) and cold feed aggregate on some projects. These are normally permanently attached devices that allow a sample container to pass perpendicularly through the entire stream of material or divert the entire stream of material into the container. Operation may be hydraulic, pneumatic, or manual and allows the sample container to pass through the stream twice, once in each direction, without overfilling. Special caution is necessary with manually operated systems since a consistent speed is difficult to maintain and non-representative samples may result. Check agency requirements for the specifics of required sampling systems. 11

Attached Sampling device

Quadrants in a load

HMA in a haul unit

Cookie cutter and plate

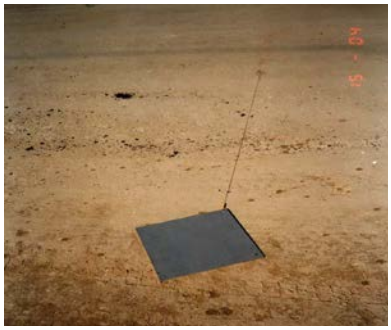


Plate on untreated base

1. Lightly coat the container attached to the sampling device with an agency-approved release agent or preheat it, or both to approximately the same discharge temperature of the mix.
2. Pass the container twice through the material perpendicularly without overfilling the container.
3. Repeat until proper sample size has been obtained.
4. Transfer the HMA to an agency-approved container without loss of material.

Sampling from Haul Units

1. Visually divide the haul unit into approximately four equal quadrants.
2. Identify one sampling location in each quadrant.
3. Dig down and remove approximately 0.3 m (1 ft.) of material to avoid surface segregation. Obtain each increment from below this level.
4. Combine the increments to form a sample of the required size.

Sampling from Roadway Prior to Compaction (Plate Method)

Plate Method using the “cookie cutter” sampling device.

There are two conditions that will be encountered when sampling Hot Mix Asphalt (HMA) from the roadway prior to compaction. The two conditions are:

- Laying HMA on grade or untreated base material requires Method 1.
- Laying HMA on existing asphalt or laying a second lift of HMA requires Method 2.

Cookie cutter and plate can be sized according to test sample needs.

SAFETY:

Sampling is performed behind the paving machine and in front of the breakdown roller. For safety, the roller must remain at least 3 m (10 ft.) behind the sampling operation until the sample has been taken and the hole filled with loose HMA.

Method 1 requires a plate to be placed in the roadway in front of the paving operation. There is always concern when working in the path of moving equipment. It is safest to stop the paving train while a plate is installed in front of the paver. When this is not possible the following safety rules must be followed.

1. The plate placing operation must be at least 3 m (10 ft.) in front of the paver or pickup device. The technician placing the plate must have eye contact and communication with the paving machine operator. If eye contact cannot be maintained at all time, a third person must be present to provide communication between the operator and the technician.
2. No technician is to be between the asphalt supply trucks and the paving machine. The exception to this rule is if the supply truck is moving forward creating a windrow, in which case the technician must be at least 3 m (10 ft.) behind the truck.
3. If at any time the Engineer feels that the sampling technique is creating an unsafe condition, the operation is to be halted until it is made safe or the paving operation will be stopped while the plate is being placed.

18

Using the cookie cutter

19

Method 1 - Obtaining a Sample on Untreated Base:

1. Following the safety rules detailed above, the technician is to:
    a. Smooth out a location in front of the paver at least 0.5 m (2 ft.) inside the edge of the mat.
    b. Lay the plate down diagonally with the direction of travel, keeping it flat and

tight to the base with the lead corner facing the paving machine.

2. Secure the plate in place with a nail through the hole in the lead corner of the plate.
3. Pull the wire, attached to the outside corner of the plate, taut past the edge of the HMA mat and secure with a nail.
4. Let the paving operation proceed over the plate and wire. Immediately proceed with the sampling.
5. Using the exposed end of the wire, pull the wire up through the fresh HMA to locate the corner of the plate. Place the "cookie cutter" sampling device, just inside the end of the wire; align the cutter over the plate. Press "cookie cutter" device down through the HMA to the plate.
6. Using a small square tipped shovel or scoop, or both, carefully remove all the HMA from inside of the cutter and place in a sample container. Care shall be taken to prevent contamination of bituminous mixes by dust or other foreign matter, and to avoid segregation of aggregate and bituminous materials.
7. Remove the sample cutter and the plate from the roadway. The hole made from the sampling must be filled by the contractor with loose HMA.

Method 2 – Obtaining a Sample on Asphalt Surface:

1. After the paving machine has passed the sampling point, immediately place the "cookie cutter" sampling device on the location to be sampled. Push the cutter down through the HMA until it is flat against the underlying asphalt mat.
2. Using a small square-tipped shovel or scoop, or both, carefully remove all the HMA from inside of the cutter and place in a sample container. The hole made from the sampling must be filled by the contractor with loose HMA.

Identification and Shipping

22

1. Identify sample containers as required by the agency.
2. Ship samples in containers that will prevent loss, contamination, or damage.

23

Report

- On forms approved by the agency
- Sample ID
- Date
- Time
- Location
- Quantity represented

24

Tips!

Check agency requirements for:

- Sample size needed
- Sampling device requirements
- Allowable sampling techniques

REVIEW QUESTIONS

1. Bituminous paving mixture sample sizes are based on what?

2. What types of containers are used for HMA samples?

3. Describe how samples are obtained from:

   - Plants with attached sampling devices

   - Truck transports

   - Roadway

PERFORMANCE EXAM CHECKLIST

SAMPLING BITUMINOUS PAVING MIXTURES
FOP FOR AASHTO T 168

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	Trial 1	Trial 2
1. Was sample taken with an attached sampling device correctly?	_____	_____
a. Container coated or preheated or both?	_____	_____
b. Sampling device passed through stream twice perpendicular to material?	_____	_____
c. Sampling device not over filled?	_____	_____
2. Samples from truck transports taken from four quadrants at required depth of 300 mm (12 in)?	_____	_____
3. Samples from roadway taken correctly with plate(s).		
a. When on untreated base plate placed well in front of paver?	_____	_____
b. Wire pulled to locate plate corner?	_____	_____
c. Cookie cutter placed on asphalt and pushed through to plate?	_____	_____
d. All material removed from inside the cutter?	_____	_____
4. Sample placed in appropriate container.	_____	_____
5. Sample size meets agency requirements?	_____	_____
6. Sample identified as required?	_____	_____

Comments: First attempt: Pass_____Fail_____ Second attempt: Pass_____Fail_____

_____
_____
_____
_____
_____
_____

Examiner Signature _____ WAQTC #:_____

PERFORMANCE EXAM CHECKLIST (ORAL)

SAMPLING BITUMINOUS PAVING MIXTURES
FOP FOR AASHTO T 168

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	**Trial 1**	**Trial 2**
1. At the hot plant how must a sample be obtained using an attached sampling device?		
a. Coat or preheat sample container.	____	_____
b. Sampling device passed through stream twice perpendicular to material.	____	_____
c. The sampling device cannot be overfilled.	____	_____
2. What must be done to sample from transport units?		
a. Divide the unit into four quadrants.	_____	_____
b. Obtain increments from each quadrant, 300 mm (12 in) below surface.	_____	_____
3. Describe how to take samples from the roadway using a plate.		
a. Place the plate well in front of the paver.	_____	_____
b. Pull the wire to locate the corner of the plate.	_____	_____
c. Place the cutter on the HMA above the plate and push it down to the plate.	_____	_____
d. Collect all the material inside the cutter.	_____	_____
4. What types of containers can be used?		
a. Cardboard boxes, stainless steel bowls, or other agency approved containers.	_____	_____
5. What dictates size of sample?		
a. Agency requirements.	_____	_____
b. Specified by test method.	_____	_____

Comments: First attempt: Pass_____Fail_____ Second attempt: Pass_____Fail_____

_____
_____
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Examiner Signature _____ WAQTC #:_____

REDUCING SAMPLES OF HOT MIX ASPHALT (HMA) TO TESTING SIZE FOP FOR AASHTO R 47

Mix sample

Mechanical Splitter Type A (Quartermaster)

Significance

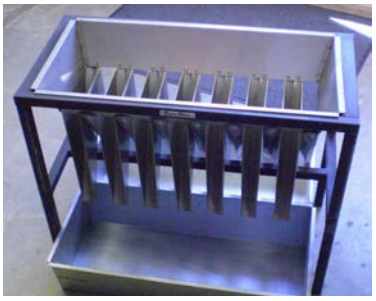
Samples of bituminous paving mixes taken in accordance with the FOP for AASHTO T 168 are composites and typically large in size. Materials sampled in the field need to be reduced to appropriate sizes for testing. It is extremely important that the procedure used to reduce the field sample not modify the material properties.

Scope

This procedure covers sample reduction of Hot Mix Asphalt (HMA) to testing size in accordance with AASHTO R 47-14. The reduced portion is to be representative of the original sample.

Apparatus

- Thermostatically controlled oven capable of maintaining a temperature of at least 110°C (230°F) or high enough to heat the material to a pliable condition for splitting.
- Non-contact temperature measuring device.
- Metal spatulas, trowels, metal straightedges, or drywall taping knives, or a combination thereof; for removing HMA samples from the quartering device, cleaning surfaces used for splitting, etc.
- Square-tipped, flat-bottom scoop, shovel or trowel for mixing HMA prior to quartering.
- Miscellaneous equipment including hot plate, non-asbestos heat-resistant gloves or mittens, pans, buckets, and cans.
- Sheeting: Non-stick heavy paper, heat-resistant plastic, or other material as approved by the agency.
- Agency-approved release agent, free of solvent or petroleum-based material that could affect asphalt binder.



Mechanical Splitter Type B (Riffle)

- Mechanical Splitter Type A (Quartermaster): with four equal-width chutes discharging into four appropriately sized sample receptacles. Splitter is to be equipped with a receiving hopper that will hold the sample until the release lever is activated with four sample receptacles of sufficient capacity to accommodate the reduced portion of the HMA sample from the mechanical splitter. Refer to AASHTO R 47, Figures 1 through 3, for configuration and required dimensions of the mechanical splitter.
- Mechanical Splitter Type B (Riffle): having a minimum of eight equal-width chutes discharging alternately to each side with a minimum chute width of at least 50% larger than the largest particle size. A hopper or straight-edged pan with a width equal to or slightly smaller than the assembly of chutes in the riffle splitter to permit uniform discharge of the HMA through the chutes without segregation or loss of material. Sample receptacles of sufficient width and capacity to receive the reduced portions of HMA from the riffle splitter without loss of material.
- Quartering Template: formed in the shape of a cross with equal length sides at right angles to each other. Template shall be manufactured of metal that will withstand heat and use without deforming. The sides of the quartering template should be sized so that the length exceeds the diameter of the flattened cone of HMA by an amount allowing complete separation of the quartered sample. Height of the sides must exceed the thickness of the flattened cone of HMA.
- Non-stick mixing surface that is hard, heat-resistant, clean, level, and large enough to permit HMA samples to be mixed without contamination or loss of material.

Sampling

Obtain samples according to the FOP for AASHTO T 168.

Sample Preparation

09 The sample must be warm enough to separate. If not, warm in an oven until it is sufficiently soft to mix and separate easily. Do not exceed either the temperature or time limits specified in the test method(s) to be performed.

Selection of Procedure (Method)

Refer to agency requirements when determining the appropriate method(s) of sample reduction. It
10 is recommended that, for large amounts of material, the initial reduction be performed using a mechanical splitter. In general, the selection of a particular method to reduce a sample depends on the initial size of the sample vs. the size of the sample needed for the specific test to be performed. It is recommended that, for large amounts of material, the initial reduction be performed using a mechanical splitter. This decreases the time needed for reduction and
11 minimizes temperature loss. Further reduction of the remaining HMA may be performed by a combination of the following methods, as approved by the agency.

The methods for reduction are:

12
- Mechanical Splitter Method
  - Type A (Quartermaster)
  - Type B (Riffle Splitter)
- Quartering Method
  - Full Quartering
  - By Apex
- Incremental Method

Procedure

13

Mechanical Splitter Type A (Quartermaster)

Quartermaster

1. Clean the splitter and apply a light coating of approved release agent to the surfaces that will contact HMA.
2. Close and secure hopper gates.
3. Place the four sample receptacles in the splitter so that there is no loss of material.
4. Remove the sample from the agency-approved container(s) and place in the mechanical splitter hopper. Avoid segregation, loss of HMA or the accidental addition of foreign material.

14

15

5. Release the handle, allowing the HMA to drop through the divider chutes and discharge into the four receptacles.
6. Any HMA that is retained on the surface of the splitter shall be removed and placed into the appropriate receptacle.
7. Close and secure the hopper gates.
8. Reduce the remaining HMA as needed by this method or a combination of the following methods as approved by the agency.
9. Combine the material contained in the receptacles from opposite corners and repeat the splitting process until an appropriate sample size is obtained.
10. Retain and properly identify the remaining unused portion of the HMA sample for further testing if required by the agency.

16

Mechanical Splitter Type B (Riffle)

1. When heating of the testing equipment is desired, it shall be heated to a temperature not to exceed 110ºC (230ºF).
2. Clean the splitter and apply a light coating of approved release agent to the surfaces that

will come in contact with HMA (hopper or straight-edged pan, chutes, receptacles).

3. Place two empty receptacles under the splitter.
4. Carefully empty the HMA from the agency-approved container(s) into the hopper or straight-edged pan without loss of material. Uniformly distribute from side to side of the hopper or pan.
5. Discharge the HMA at a uniform rate, allowing it to flow freely through the chutes.
6. Any HMA that is retained on the surface of the splitter shall be removed and placed into the appropriate receptacle.

17

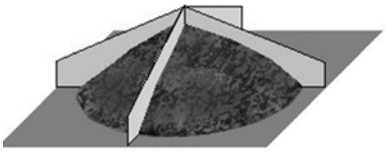
7. Reduce the remaining HMA as needed by this method or a combination of the following methods as approved by the agency.
8. Using one of the two receptacles containing HMA, repeat the reduction process until the HMA contained in one of the two receptacles is the appropriate size for the required test.
9. After each split, remember to clean the splitter hopper and chute surfaces if needed.
10. Retain and properly identify the remaining unused HMA sample for further testing if required by the agency.

18

Quartering Method

1. When heating of the testing equipment is desired, it shall be heated to a temperature not to exceed the mix temperature.
2. If needed, apply a light coating of release agent to quartering template.
3. Dump the sample from the agency approved container(s) into a conical pile on a hard, “non-stick,” clean, level surface where there will be neither a loss of material nor the accidental addition of foreign material. The surface can be made non-stick by the application of an approved asphalt release agent or sheeting.

19 4. Mix the material thoroughly by turning the entire sample over a minimum of four times with a flat-bottom scoop; or by alternately lifting each corner of the sheeting and pulling it over the sample diagonally toward the opposite corner, causing the material to be rolled. Create a conical pile by either depositing each scoop or shovelful of the last turning on top of the preceding one, or lifting both opposite corners.



Quartering Template (In Place)

20 5. Flatten the conical pile to a uniform diameter
21 and thickness where the diameter is four to eight times the thickness. Make a visual observation to ensure that the material is homogeneous.

6. Divide the flattened cone into four equal quarters using the quartering template. Press the template down until it is in complete contact with the surface on which the sample has been placed, assuring complete separation.

***Note 1**:* Straightedges may be used in lieu of the quartering device to completely separate the material in approximately equal quarters.

Quartered sample

23 7. Reduce the sample by quartering the sample completely or by removing the sample from the apex.

8. Full Quartering

22 8a Remove two diagonally opposite quarters, including all of the fine material.

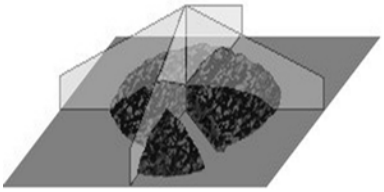
8b Remove the quartering template and combine the remaining quarters, again forming a conical pile.

24 8c Repeat steps 4, 5, 6, 8a, and 8b until a sample of the required size has been obtained. The final sample must consist of the two remaining diagonally opposite quarters.

8d Retain and properly identify the remaining unused portion of the HMA sample for further testing if required by the agency.

9. By Apex

25



26

HMA from the apex of the quarter to the outer edge.

9a Using a straightedge, slice through a quarter of the HMA from the center point to the outer edge of the quarter.

9b Pull or drag the material from the quarter with two straight edges or hold one edge of the straightedge in contact with quartering device.

9c Remove an equal portion from the opposite quarter and combine these increments to create the required sample size.

27

9d Continue using the apex method with the unused portion of the HMA until samples have been obtained for all required tests.

9e Retain and properly identify the remaining unused portion of the HMA sample for further testing if required by the agency.

28

Incremental Method

29

Mixing the sample

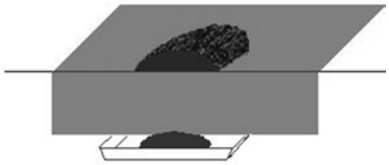
1. Cover a hard, clean, level surface with sheeting. This surface shall be large enough that there will be neither a loss of material nor the accidental addition of foreign material.

30

2. Place the sample from the agency approved container(s) into a conical pile on that surface.

Mixing the sample

3. Mix the material thoroughly by turning the entire sample over a minimum of four times with a flat-bottom scoop; or by alternately lifting each corner of the sheeting and pulling it over the sample diagonally toward the opposite corner, causing the material to be rolled. Create a conical pile by either depositing each scoop or shovelful of the last turning on top of the preceding one, or lifting both opposite corners.
4. Grasp the sheeting and roll the conical pile into a cylinder (loaf), then flatten the top.



Material dropped into container

Make a visual observation to determine that
31 the material is homogenous.

5. Pull the sheeting so at least ¼ of the length of the loaf is off the edge of the counter. Allow this material to drop into a container to be saved. As an alternate, using a straightedge, slice off approximately ¼ of the length of the loaf and place in a container to be saved.

6. Pull material off the edge of the counter and drop into an appropriate size sample pan or container for the test to be performed.
32 Continue removing material from the loaf until the proper size sample has been acquired. As an alternate, using a straightedge, slice off an appropriate size sample from the length of the loaf and place in a sample pan or container.

7. Repeat step 6 until all the samples for testing have been obtained.

Note 2: When reducing the sample to test size it is advisable to take several small increments, determining the mass each time until the proper minimum size is achieved. Unless the sample size is grossly in excess of the minimum or exceeds the maximum test size, use the sample as reduced for the test.

8. Retain and properly identify the remaining unused portion of the HMA sample for further testing if required by the agency.

Tips!

- Remember, the reduced sample must be representative of the whole. 33
- Proceed quickly so that splitting is done when the material is hot.
- Check agency requirements about what splitting device(s) or method(s) may be used. 34
- With Mechanical Method (Type A), further reduction requires using HMA from diagonally opposite receptacles.
- With both Mechanical Methods, inspect splitter surfaces for build-up of HMA, ensuring they are cleaned such that the material falls into the appropriate receptacles.
- With full quartering, remember that the final sample consists of the two remaining diagonally opposite quarters. 35

REVIEW QUESTIONS

1. Describe how the material is mixed before quartering.

2. What is the difference between full quartering and quartering by apex?

3. How many types of mechanical splitters are there and how are they different?

4. Are any of the reduction methods preferred? When and why?

5. Can multiple splitting methods be used in reducing a sample?

PERFORMANCE EXAM CHECKLIST

REDUCING SAMPLES OF HOT MIX ASPHALT (HMA) TO TESTING SIZE FOP FOR AASHTO R 47

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	Trial 1	Trial 2
1. Sample made soft enough to separate easily without exceeding temperature limits?	_____	_____
Mechanical Splitter Method Type A (Quartermaster)		
2. Splitter cleaned and surfaces coated with release agent?	_____	_____
3. Hopper closed and receptacles in place?	_____	_____
4. Sample placed into hopper without segregation or loss of material?	_____	_____
5. Hopper handle released allowing the HMA to uniformly flow into receptacles?	_____	_____
6. Splitter surfaces cleaned of all retained HMA, allowing it to fall into appropriate receptacles?	_____	_____
7. Further reduction with the quartermaster:		
a. Material in receptacles from opposite corners combined?	_____	_____
b. Splitting process repeated until appropriate sample size is obtained?	_____	_____
8. Remaining HMA stored in suitable container and properly labeled?	_____	_____
Mechanical Splitter Method Type B (Riffle)		
9. Splitting apparatus and tools, if preheated, not exceeding 110ºC (230ºF)?	_____	_____
10. Splitter cleaned and surfaces coated with release agent?	_____	_____
11. Two empty receptacles placed under splitter?	_____	_____
12. Sample placed in hopper or straight edged pan without loss of material and uniformly distributed from side to side?	_____	_____
13. Material discharged across chute assembly at controlled rate allowing free flow of HMA through chutes?	_____	_____
14. Splitter surfaces cleaned of all retained HMA allowing it to fall into appropriate receptacles?	_____	_____

OVER

Procedure Element	**Trial 1**	**Trial 2**
15. Further reduction with the riffle splitter:		
a. Material from one receptacle discharged across chute assembly at controlled rate, allowing free flow of HMA through chutes?	_____	_____
b. Splitting process continued until appropriate sample size obtained, with splitter surfaces cleaned of all retained HMA after every split?	_____	_____
16. Remaining unused HMA stored in suitable container, properly labeled?	_____	_____
Quartering Method		
17. Testing equipment preheated to a temperature not to exceed mix temperature?	_____	_____
18. Sample placed in a conical pile on a hard, non-stick, heat-resistant splitting surface such as metal or sheeting?	_____	_____
19. Sample mixed by turning the entire sample over a minimum of 4 times?	_____	_____
20. Conical pile formed and then flattened uniformly to diameter equal to about 4 to 8 times thickness?	_____	_____
21. Sample divided into 4 equal portions either with a metal quartering template or straightedges such as drywall taping knives?	_____	_____
22. Reduction by Full Quartering:		
c. Two diagonally opposite quarters removed and returned to sample container?	_____	_____
d. Two other diagonally opposite quarters combined and process continued until appropriate sample size has been achieved?	_____	_____
23. Reduction by Apex:		
e. Using two straightedges or a splitting device and one straightedge, was one of the quarters split from apex to outer edge of material?	_____	_____
f. Similar amount of material taken from opposite quarter?	_____	_____
g. Increments combined to produce appropriate sample size?	_____	_____
24. Remaining unused HMA stored in suitable container, properly labeled?	_____	_____
Incremental Method		
25. Sample placed on hard, non-stick, heat-resistant splitting surface covered with sheeting?	_____	_____
26. Sample mixed by turning the entire sample over a minimum of 4 times?	_____	_____

OVER

Procedure Element	**Trial 1**	**Trial 2**
27. Conical pile formed?	_____	_____
28. HMA rolled into loaf and then flattened?	_____	_____
29. The first quarter of the loaf removed by slicing off or dropping off edge of counter and set aside?	_____	_____
30. Proper sample size sliced off or dropped off edge of counter into sample container?	_____	_____
31. Process continued until all samples are obtained?	_____	_____
31. All remaining unused HMA stored in suitable container, properly labeled?	_____	_____

Comments: First attempt: Pass_____Fail_____ Second attempt: Pass_____Fail_____

_____
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Examiner Signature _____ WAQTC #:_____

MOISTURE CONTENT OF ASPHALT MIXTURES BY OVEN METHOD FOP FOR AASHTO T 329

Significance

01 Even though aggregate used in asphalt mixtures is heated and dried at high temperatures, some types of rock retain moisture. The moisture content of the mix must be known in order to correctly determine

02 the asphalt binder content of the mix. Moisture (water) in the mix will yield erroneously high asphalt binder content values whether asphalt binder content is determined by the nuclear content gauge or ignition furnace method.

Scope

03 This procedure covers the determination of moisture content of asphalt mixtures in accordance with AASHTO T 329-15.

Overview

04 Moisture content is determined by comparing the wet mass of a sample and the mass of the sample after drying to constant mass. The term constant mass is used to define when a sample is dry.

Constant mass – the state at which a mass does not change more than a given percent, after additional drying for a defined time interval, at a required temperature.

Oven

Quartering

Apparatus

05
- Balance or scale: 2 kg capacity, readable to 0.1 g and conforming to AASHTO M 231
- Forced draft, ventilated, or convection oven: Capable of maintaining the temperature surrounding the sample at 163 ±14°C (325 ±25°F)

06
- Sample Container: Clean, dry, not affected by heat and of sufficient size to contain a test sample without danger of spilling
- Thermometer or other suitable device with a temperature range of 10-260°C (50-500°F)

07

Sample

The test sample shall be obtained in accordance with the FOP for AASHTO T 168, and reduced in accordance with the FOP for AASHTO R 47. The size of the test sample shall be a minimum of 1000 g.

08

Procedure

09

1. Preheat the oven to the Job Mix Formula (JMF) mixing temperature range. If the mixing temperature is not supplied, a temperature of 163 ±14ºC (325 ±25ºF) is to be used.

Note 1: For repeatability between laboratories, the preferred practice is to dry the sample at no less than 9°C (15°F) below the JMF mixing temperature.

2. Determine and record the mass of the sample container including release media to the nearest 0.1 g.

Mass of sample container

10

Note 2: When using paper or other absorptive material to line the sample container ensure it is dry before determining initial mass of sample container..

3. Place the test sample in the sample container.
4. Determine and record the temperature of the test sample.

11

5. Determine and record the total mass of the sample container and test sample to the nearest 0.1 g.
6. Calculate the initial, moist mass (M_i) of the test sample by subtracting the mass of the sample container determined in Step 2 from the total mass of the sample container and the test sample as determined in Step 5.

Mass determination

12

13

7. The test sample shall be initially dried for 90 ± 5 minutes, and its mass determined. Then it shall be dried at 30 ± 5 min intervals until further drying does not alter the mass by more than 0.05 percent.

14

8. Cool the sample container and test sample to ±9°C (±15°F) of the temperature determined in Step 4.
9. Determine and record the total mass of the sample container and test sample to the nearest 0.1 g.

Note 3: Do not attempt to remove the test sample from the sample container for the purposes of determining mass.

10. Calculate the final, dry mass (M_f) of the test sample by subtracting the mass of the sample container determined in Step 2 from the total mass of the sample container and the test sample determined in Step 9.

Note 4: Moisture content and the number of samples in the oven will affect the rate of drying at any given time. Placing wet samples in the oven with nearly dry samples could affect the drying process.

Calculations

Constant Mass:

Calculate constant mass using the following formula:

15

$$\%\ Change = \frac{M_p - M_n}{M_p} \times 100$$

Where:

M_p = previous mass measurement

M_n = new mass measurement

Example:

Mass of container: 232.6 g 16

Mass of container and sample after first drying cycle: 1361.8 g

Mass, M_p, of possibly dry sample: 1361.8 g – 232.6 g = 1129.2 g

Mass of container and possibly dry sample after second drying cycle: 1360.4 g

Mass, M_n, of dry sample: 1360.4 g – 232.6 g = 1127.8 g

$$\frac{1129.2\ g - 1127.8\ g}{1129.2\ g} \times 100 = 0.12\%$$

0.12 percent is not less than 0.05 percent, so continue drying the sample.

Mass of container and possibly dry sample after third drying cycle: 1359.9 g

Mass, M_n, of dry sample: 1359.9 g – 232.6 g = 1127.3 g 17

$$\frac{1127.8\ g - 1127.3\ g}{1127.8\ g} \times 100 = 0.04\%$$

0.04 percent is less than 0.05 percent, so constant mass has been reached.

Moisture Content:

Calculate the moisture content, as a percent, using the following formula. 18

$$Moisture\ Content = \frac{M_i - M_f}{M_f} \times 100$$

Where:

M_i = initial, moist mass

M_f = final, dry mass

Example:

M_i = 1134.9 g

M_f = 1127.3 g 19

$$Moisture\ Content = \frac{1134.9\ g - 1127.3\ g}{1127.3\ g} \times 100 = 0.674, \text{say } 0.67\%$$

20

Report

- Results on forms approved by the agency
- Sample ID
- Moisture content to 0.01 percent

21

Tips!

- Moisture is a percent of final dry mass

REVIEW QUESTIONS

1. What is the minimum sample size needed?

2. The sample shall be initially dried for _____ minutes.

3. Further drying shall be in _____ minute intervals.

4. How is constant mass defined for this procedure?

PERFORMANCE EXAM CHECKLIST

MOISTURE CONTENT OF ASPHALT MIXTURES BY OVEN METHOD FOP FOR AASHTO T 329

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	Trial 1	Trial 2
1. Mass of clean dry container including release media determined to 0.1 g?	_____	_____
2. Representative sample obtained; 1000 g minimum?	_____	_____
3. Initial temperature taken and recorded?	_____	_____
4. Mass of sample determined to 0.1 g?	_____	_____
5. Sample placed in drying oven for 90 ±5 minutes?	_____	_____
6. Sample dried at a temperature not to exceed the JMF mixing temp?	_____	_____
7. Constant mass checked at 30 ±5 minute intervals and reached?	_____	_____
8. Sample and container cooled to ±9°C (15°F) of the initial temperature before final mass determined to 0.1 g?	_____	_____
9. Calculation of moisture content performed correctly to 0.01 percent?	_____	_____

$$Moisture\ Content = \frac{M_i - M_f}{M_f} \times 100$$

Comments: First attempt: Pass_____Fail_____ Second attempt: Pass_____Fail_____

_____
_____
_____
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_____

Examiner Signature _____WAQTC #:_____

DETERMINING THE ASPHALT BINDER CONTENT OF HOT MIX ASPHALT (HMA) BY THE IGNITION METHOD FOP FOR AASHTO T 308

01 ## Significance

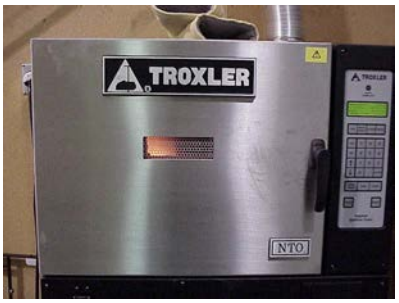
The quality of hot mix asphalt (HMA) is greatly dependent on having the correct content of asphalt
02 binder. HMA placed on the job must be tested to
03 ensure that the binder content is within the specified range.

04 ## Scope

This procedure covers the determination of asphalt binder content of hot mix asphalt (HMA) by ignition of the binder in accordance with AASHTO T 308-16.

05 ## Overview

06 The sample is heated in a furnace at 538°C (1000°F) or less; samples may be heated by convection or direct infrared irradiation (IR). The aggregate remaining after burning can be used for sieve analysis using the FOP for AASHTO T 30.



Ignition furnace

Some agencies allow the use of recycled HMA. When using recycled HMA, check with the agency for specific correction procedures.

Asphalt binder in the HMA is ignited in a furnace. Asphalt binder content is calculated as the percentage difference between the initial mass of the HMA and the mass of the residual aggregate, with asphalt binder correction factor, and moisture content subtracted. The asphalt binder content is expressed as a percent of moisture-free mix mass.

Two methods, A and B, are presented

Apparatus

Note 1: The apparatus must be calibrated for the specific mix
07 design. See "Correction Factors" at the end of this FOP.

Ignition furnace

08 There are two methods – A and B. The apparatus for the two methods are the same except that the
09 furnace for Method A has an internal balance.

- Ignition Furnace – A forced air ignition furnace that heats the specimens by either the convection or direct IR irradiation method. The

convection-type furnace must be capable of maintaining the temperature at 538 ± 5°C (1000 ± 9°F).

For Method A, the furnace will be equipped with an internal scale thermally isolated from the furnace chamber and accurate to 0.1 g. The scale shall be capable of determining the mass of a 3500 g sample in addition to the sample baskets. A data collection system will be included so that mass can be automatically determined and displayed during the test. The furnace shall have a built-in computer program to calculate change in mass of the sample baskets and provide for the input of a correction factor for aggregate loss. The furnace shall provide a printed ticket with the initial specimen mass, specimen mass loss, temperature compensation, correction factor, corrected asphalt binder content, test time, and test temperature. The furnace shall provide an audible alarm and indicator light when the sample mass loss does not exceed 0.01 percent of the total sample mass for three consecutive minutes.

Note 2: The furnace shall be designed to permit the operator to change the ending mass loss percentage from 0.01 percent to 0.02 percent.

For both Method A and Method B, the furnace chamber dimensions shall be adequate to accommodate a 3500 g sample. The furnace door shall be equipped so that it cannot be opened during the ignition test. A method for reducing furnace emissions shall be provided and the furnace shall be vented so that no emissions escape into the laboratory. The furnace shall have a fan to pull air through the furnace to expedite the test and to eliminate the escape of smoke into the laboratory.

- Sample Basket Assembly: Consisting of sample basket(s), catch pan, and basket guards. Sample basket(s) will be of appropriate size allowing samples to be thinly spread and allowing air to flow through and around the sample particles. Sets of two or more baskets shall be nested. A catch pan: of sufficient size to hold the sample basket(s) so that aggregate particles and melting

asphalt binder falling through the screen mesh are caught. Basket guards will completely enclose the basket and be made of screen mesh, perforated stainless steel plate, or other suitable material.

- Thermometer, or other temperature measuring device, with a temperature range of 10 -260°C (50 - 500°F).
- Oven capable of maintaining 110 ±5°C (230 ±9°F).
- Balance or scale: Capacity sufficient for the sample mass and conforming to the requirements of M 231, Class G2.
- **Safety equipment**: Safety glasses or face shield, high temperature gloves, long sleeved jacket, a heat resistant surface capable of withstanding 650°C (1202°F), a protective cage capable of surrounding the sample baskets during the cooling period, and a particle mask for use during removal of the sample from the basket assembly.
- Miscellaneous equipment: A pan larger than the sample basket(s) for transferring sample after ignition, spatulas, bowls, and wire brushes.

Sampling

11 1. Obtain samples of HMA in accordance with the FOP for AASHTO T 168.

2. Reduce HMA samples in accordance with the FOP for AASHTO R 47.

12 3. If the mixture is not sufficiently soft to separate with a spatula or trowel, place it in a large flat pan in an oven at 110 ±5°C (230 ±9°F) until workable.

4. Test sample size shall conform to the mass requirement shown in Table 1.

Note 3: When the mass of the test specimen exceeds the capacity of the equipment used, the test specimen may be divided into suitable increments, tested, and the results appropriately combined through a weighted average for calculation of the asphalt binder content.

Table 1

Nominal Maximum Size* mm (in.)	Minimum Mass Specimen g	Maximum Mass Specimen g
37.5 (1 ½)	4000	4500
25.0 (1)	3000	3500
19.0 (3/4)	2000	2500
12.5 (1/2)	1500	2000
9.5 (3/8)	1200	1700
4.75 (No. 4)	1200	1700

* One sieve larger than the first sieve to retain more than 10 percent of the material using an agency specified set of sieves based on cumulative percent retained. Where large gaps in specification sieves exist, intermediate sieve(s) may be inserted to determine nominal maximum size.

13

Sample

Procedure – Method A (Internal Balance)

14

1. For the convection-type furnace, preheat the ignition furnace to 538 ± 5°C (1000 ± 9°F) or to the temperature determined in the "Correction Factor" section (Step 9 of this method). Manually record the furnace temperature (set point) prior to the initiation of the test if the furnace does not record automatically. For the direct IR irradiation-type furnace, use the same burn profile as used during the correction factor determination.

16

Two nested baskets and catch pan

2. Dry the sample to constant mass according to the FOP for AASHTO T 329; or determine the moisture content of a companion sample in accordance with the FOP for AASHTO T 329.
3. Determine and record the mass to the nearest 0.1 g of the sample basket assembly.

15

4. Evenly distribute the sample in the sample basket assembly, taking care to keep the material away from the edges of the basket. Use a spatula or trowel to level the sample.

5. Determine and record the total mass of the sample and sample basket assembly to the nearest 0.1 g. Calculate and record the initial mass of the sample (total mass minus the mass of the sample basket assembly) to the nearest 0.1 g. Designate this mass as (M_i).

17 6. Record the asphalt binder correction factor or input into the furnace controller for the specific HMA.

Placing sample in furnace

7. Input the initial mass (M_i) of the sample into the ignition furnace controller. Verify that the correct mass has been entered.

18

CAUTION: Operator should wear safety equipment – high temperature gloves, face shield, fire-retardant shop coat – when opening the door to load or unload the sample.

8. Open the chamber door and gently set the sample basket assembly in the furnace. Carefully position the sample basket assembly so it is not in contact with the furnace wall. Close the chamber door and verify that the sample mass displayed on the furnace scale equals the total mass of the sample and sample basket assembly recorded in Step 5 within ±5 g.

Note 4: Furnace temperature will drop below the set point when the door is opened, but will recover when the door is closed and ignition begins. Sample ignition typically increases the temperature well above the set point – relative to sample size and asphalt binder content.

9. Initiate the test by pressing the start button. This will lock the sample chamber and start the combustion blower.

19

Safety note: Do not attempt to open the furnace door until the asphalt binder has been completely burned off.

10. Allow the test to continue until the stable light and audible stable indicator indicate that the change in mass does not exceed 0.01 percent for three consecutive minutes. Press the stop button. This will unlock the sample chamber and cause the printer to print out the test results.

Note 5: An ending mass loss percentage of 0.02 may be used, if allowed by the agency, when aggregate that exhibits an excessive amount of loss during ignition testing is used.

Sample basket(s) and protective cage

20 11. Open the chamber door, remove the sample basket assembly, and place on the cooling plate or block. Place the protective cage over the sample basket assembly and allow it to cool to room temperature (approximately 30 minutes).

12. Determine and record the total after ignition mass to the nearest 0.1 g. Calculate and record the mass of the sample, after ignition (total after ignition mass minus the mass of the sample basket assembly) to the nearest 0.1 g. Designate this mass as M_f.

21 13. Use the asphalt binder content percentage from the printed ticket. Subtract the moisture content from the printed ticket asphalt binder content and report the difference as the corrected asphalt binder content.

Asphalt binder content percentage can also be calculated using the formula from step 16 of Method B.

Calculation

Corrected asphalt binder content:

$$P_b = BC - MC - C_f$$

(if not input in the furnace controller)

where:

P_b = Corrected asphalt binder content as a percent by mass of the HMA

BC = Asphalt binder content shown on printed ticket

MC = Moisture content of the companion HMA sample, percent, as determined by the FOP for AASHTO T 329 (if the specimen was oven-dried prior to initiating the procedure, MC=0).

C_f= Asphalt binder correction factor as a percent by mass of the HMA sample

Procedure – Method B (External Balance)

23 1. Preheat the ignition furnace to 538 ± 5°C (1000 ± 9°F) or to the temperature determined in the "Correction Factor" section Step 9 of this method. Manually record the furnace temperature (set point) prior to the initiation of the test if the furnace does not record automatically.

2. Dry the sample to constant mass according to the FOP for AASHTO T 329 or determine the moisture content of a companion sample in accordance with the FOP for AASHTO T 329.
3. Determine and record the mass to the nearest 0.1 g of the sample basket assembly.
4. Place the sample basket(s) in the catch pan. Evenly distribute the sample in the sample basket(s), taking care to keep the material away from the edges of the basket. Use a spatula or trowel to level the sample.
5. Determine and record the total mass of the sample and sample basket assembly to the nearest 0.1 g. Calculate and record the initial mass of the sample (total mass minus the mass of the sample basket assembly) to the nearest 0.1 g. Designate this mass as (M_i).
6. Record the asphalt binder correction factor for the specific HMA.
7. Open the chamber door and gently set the sample basket assembly in the furnace. Carefully position the sample basket assembly so it is not in contact with the furnace wall. Burn the HMA sample in the furnace for 45 minutes or the length of time determined in the “Correction Factors" section.
8. Open the chamber door, remove the sample basket assembly, and place on the cooling plate or block. Place the protective cage over the sample and allow it to cool to room temperature (approximately 30 min).
9. Determine and record the total after ignition mass to the nearest 0.1 g. Calculate and record the mass of the sample, after ignition, (total after ignition mass minus the mass of the sample basket assembly) to the nearest 0.1 g.
10. Place the sample basket assembly back into the furnace.
11. Burn the sample for at least 15 minutes after the furnace reaches the set temperature.
12. Open the chamber door, remove the sample basket assembly, and place on the cooling plate or block. Place the protective cage over the

sample basket assembly and allow it to cool to room temperature (approximately 30 min.).

13. Determine and record the total after ignition mass to the nearest 0.1 g. Calculate and record the mass of the sample, after ignition (total after ignition mass minus the mass of the sample basket assembly) to the nearest 0.1 g.

28 14. Repeat Steps 10 through 13 until the change in measured mass of the sample after ignition does not exceed 0.01 percent of the previous sample mass after ignition.

Note 5: An ending mass loss percentage of 0.02 may be used, if allowed by the agency, when aggregate that exhibits an excessive amount of loss during ignition testing is used.

29 15. Determine and record the total after ignition mass to the nearest 0.1 g. Calculate and record the mass of the sample, after ignition (total after ignition mass minus the mass of the sample basket assembly) to the nearest 0.1 g. Designate this mass as M_f.

30 16. Calculate the asphalt binder content of the sample.

Calculations

Calculate the asphalt binder content of the sample as follows:

$$P_b = \frac{M_i - M_f}{M_i} \times 100 - MC - C_f$$

where:

P_b	=	the corrected asphalt binder content as a percent by mass of the HMA sample
M_f	=	the final mass of aggregate remaining after ignition
M_i	=	the initial mass of the HMA sample prior to ignition
MC	=	moisture content of the companion HMA sample, percent, as determined by the FOP for AASHTO T 329 (if the specimen was oven-dried prior to initiating the procedure, MC=0)
C_f	=	asphalt binder correction factor as a percent by mass of the HMA sample

Example

31

Correction Factor	= 0.42%
Moisture Content	= 0.04%
Initial Mass of Sample and Basket	= 5292.7 g
Mass of Basket Assembly	= 2931.5 g
M_i	= 2361.2 g
Total Mass after First ignition + basket	= 5154.4 g
Sample Mass after First ignition	= 2222.9 g
Sample Mass after additional 15 min ignition	= 2222.7 g

$$\frac{2222.9\ g - 2222.7\ g}{2222.9\ g} \times 100 = 0.009\%$$

Not greater than 0.01 percent, so $\mathbf{M_f}$ = 2222.7 g

32

$$P_b = \frac{2361.2\ g - 2222.7\ g}{2361.2\ g} \times 100 - 0.42\% - 0.04\% = 5.41\%$$

$\mathbf{P_b}$= 5.41%

Emptying sample baskets

33

34

Gradation

1. Empty contents of the basket(s) into a flat pan, being careful to capture all material. Use a small wire brush to ensure all residual fines are removed from the baskets.

Note 6: Particle masks are a recommended safety precaution.

2. Perform the gradation analysis in accordance with the FOP for AASHTO T 30.

35

Report

- Results on forms approved by the agency
- Sample ID
- Method of test (A or B)
- Corrected asphalt binder content, P_b, per agency standard
- Correction factor, C_f, to 0.01 percent
- Temperature compensation factor (if applicable)
- Total percent loss
- Sample mass
- Moisture content to 0.01 percent
- Test temperature

Attach the original printed ticket with all intermediate values (continuous tape) to the report for furnaces with internal balances.

36 ## Annex – Correction Factors

(Mandatory Information)

Asphalt Binder and Aggregate

Asphalt binder content results may be affected by the type of aggregate in the mixture and by the ignition furnace. Asphalt binder and aggregate correction factors must, therefore, be established by testing a set of correction specimens for each Job Mix Formula (JMF) mix design. Each ignition furnace will have its own unique correction factor determined in the location where testing will be performed.

37 This procedure must be performed before any acceptance testing is completed, and repeated each time there is a change in the mix ingredients or design.

Any changes greater than 5 percent in stockpiled aggregate proportions should require a new correction factor.

38 Historical data or scientific studies may be used to determine the correction factor(s) in lieu of using this testing procedure if the testing agency provides reference to the studies/data.

All correction samples will be prepared by a central / regional laboratory unless otherwise directed.

39 **Asphalt binder correction factor**: A correction factor must be established by testing a set of correction specimens for each Job Mix Formula (JMF). Certain aggregate types may result in unusually high correction factors (> 1.00 percent). Such mixes should be corrected and tested at a lower temperature as described below.

Aggregate correction factor: Due to potential aggregate breakdown during the ignition process, a correction factor will need to be determined for the following conditions:

40

a) Aggregates that have a proven history of excessive breakdown

b) Aggregate from an unknown source

This correction factor will be used to adjust the acceptance gradation test results obtained according to the FOP for AASHTO T 30.

41 **Procedure**

1. Obtain samples of aggregate in accordance with the FOP for AASHTO T 2.
2. Obtain samples of asphalt binder in accordance with the FOP for AASHTO R 66.

42 ***Note 7:*** Include other additives that may be required by the JMF.

3. Prepare an initial, or "butter," mix at the design asphalt binder content. Mix and discard the butter mix prior to mixing any of the correction specimens to ensure accurate asphalt content.
4. Prepare two correction specimens at the JMF design asphalt binder content. Aggregate used for correction specimens shall be sampled from material designated for use on the project. An agency approved method will be used to combine aggregate. An additional "blank" specimen shall be batched and tested for aggregate gradation in accordance with the FOP for AASHTO T 30. The gradation from the "blank" shall fall within the agency specified mix design tolerances.

43

44 5. Place the freshly mixed specimens directly into the sample basket assembly. If mixed specimens are allowed to cool prior to placement in the sample basket assembly, the specimens must be dried to constant mass according to the FOP for AASHTO T 329. Do not preheat the sample basket assembly.
6. Test the specimens in accordance with Method A or Method B of the procedure.
7. Once both of the correction specimens have been burned, determine the asphalt binder content for each specimen by calculation or from the printed oven tickets, if available.
8. If the difference between the asphalt binder contents of the two specimens exceeds 0.15 percent, repeat with two more specimens and, from the four results, discard the high and low

45

result. Determine the correction factor from the two original or remaining results, as appropriate. Calculate the difference between the actual and measured asphalt binder contents for each specimen to 0.01 percent. The asphalt binder correction factor, C_f, is the average of the differences expressed as a percent by mass of HMA.

9. If the asphalt binder correction factor exceeds 1.00 percent, the test temperature must be lowered to 482 ± 5°C (900 ± 9°F) and new samples must be burned. The temperature for determining the asphalt binder content of HMA samples by this procedure shall be the same temperature determined for the correction samples.

10. For the direct IR irradiation-type burn furnaces, the **default** burn profile should be used for most materials. The operator may select burn-profile Option 1 or Option 2 to optimize the burn cycle. The burn profile for testing HMA samples shall be the same burn profile selected for correction samples.

    Option 1 is designed for aggregate that requires a large asphalt binder correction factor (greater than 1.00 percent) – typically very soft aggregate (such as dolomite).

    Option 2 is designed for samples that may not burn completely using the **default** burn profile.

11. Perform a gradation analysis on the residual aggregate in accordance with the FOP for AASHTO T 30, if required. The results will be utilized in developing an "Aggregate Correction Factor" and should be calculated and reported to 0.1 percent.

12. Subtract the percent passing for each sieve, for each sample, from the percent passing each sieve of the "Blank" specimen gradation results in Step 4.

13. Determine the average difference of the two values. If the difference for any single sieve exceeds the allowable difference of that sieve as listed in Table 2, then aggregate gradation

51 correction factors (equal to the resultant average differences) for all sieves shall be applied to all acceptance gradation test results determined by the FOP for AASHTO T 30. If the 75 µm (No. 200) is the only sieve outside the limits in Table 2, apply the aggregate correction factor to only the 75 µm (No. 200) sieve.

52

Table 2
Permitted Sieving Difference

Sieve	Allowable Difference
Sizes larger than or equal to 2.36 mm (No.8)	± 5.0%
Sizes larger than to 75 µm (No.200) and smaller than 2.36 mm (No.8)	± 3.0%
Sizes 75 µm (No.200) and smaller	± 0.5%

Examples:

53

Sieve Size mm (in.)	Correction Factor Blank Sample, % Passing	Correction Factor Sample #1, % Passing	Correction Factor Sample #2, % Passing	Difference 1 / 2	Avg. Diff.	Sieves to adjust
19.0(3/4)	100	100	100	0/0	0.0	
12.5(1/2)	86.3	87.4	86.4	-1.1/-0.1	-0.6	
9.5(3/8)	77.4	76.5	78.8	+0.9/-1.4	-0.2	
4.75(No. 4)	51.5	53.6	55.9	-2.1/-4.4	-3.2	
2.36(No. 8)	34.7	36.1	37.2	-1.4/-2.5	-2.0	
01.18(No. 16)	23.3	25.0	23.9	-1.7/-0.6	-1.2	
0.600 (No. 30)	16.4	19.2	18.1	-2.8/-1.7	-2.2	
0.300 (No. 50)	12.0	11.1	12.7	+0.9/-0.7	+0.1	
0.150 (No. 100)	8.1	9.9	6.3	-1.8/+1.8	0.0	
75 µm (No. 200)	5.5	5.9	6.2	-0.4/-0.7	-0.6	**- 0.6**

In this example all gradation test results performed on the residual aggregate (FOP for AASHTO T 30) would have an aggregate correction factor applied to the percent passing the 75 µm (No. 200) sieve. The correction factor must be applied because the average difference on the 75 µm (No. 200) sieve is outside the tolerance from Table 2.

In the following example, aggregate correction factors would be applied to each sieve because the average difference on the 4.75mm (No. 4) is outside the tolerance from Table 2.

54

Sieve Size mm (in.)	Correction Factor Blank Sample, % Passing	Correction Factor Sample #1, % Passing	Correction Factor Sample #2, % Passing	Difference 1 / 2	Avg. Diff.	Sieves to adjust
19.0 (3/4)	100	100	100	0/0	0.0	0.0
12.5 (1/2)	86.3	87.4	86.4	-1.1/-0.1	-0.6	-0.6
9.5 (3/8)	77.4	76.5	78.8	+0.9/-1.4	-0.2	-0.2
4.75 (No. 4)	51.5	55.6	57.9	-4.1/-6.4	-5.2	**-5.2**
2.36 (No. 8)	34.7	36.1	37.2	-1.4/-2.5	-2.0	-2.0
01.18 (No. 16)	23.3	25.0	23.9	-1.7/-0.6	-1.2	-1.2
0.600 (No. 30)	16.4	19.2	18.1	-2.8/-1.7	-2.2	-2.2
0.300 (No. 50)	12.0	11.1	12.7	+0.9/-0.7	+0.1	+0.1
0.150 (No. 100)	8.1	9.9	6.3	-1.8/+1.8	0.0	0.0
75 µm (No. 200)	5.5	5.9	6.2	-0.4/-0.7	-0.6	-0.6

55

Tips!

- Check specific agency requirements
- Make sure apparatus is calibrated to specific mix design
- Do <u>not</u> open door until asphalt binder has burned off

REVIEW QUESTIONS

1. Summarize the sampling procedures used for the various materials tested.

2. Upon what is the size of the test sample based?

3. Describe when and how the two Correction Factors are used.

4. Describe the difference in the apparatus for the two methods – A and B.

5. Describe one of the two methods – A or B.

6. What is done with the material removed from the ignition oven?

PERFORMANCE EXAM CHECKLIST

DETERMINING THE ASPHALT BINDER CONTENT OF HOT MIX ASPHALT (HMA) BY THE IGNITION METHOD FOP FOR AASHTO T 308

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	Trial 1	Trial 2
1. Oven at correct temperature 538 ± 5°C (1000 ± 9°F) or correction factor temperature?	_____	_____
Or: for IR ovens, correct burn profile applied?	_____	_____
2. Sample reduced to correct size?	_____	_____
3. HMA sample or companion moisture sample taken and dried per FOP for AASHTO T 329?	_____	_____
4. Mass of sample basket assembly recorded to 0.1 g?	_____	_____
5. With pan below basket(s) sample evenly distributed in basket(s)?	_____	_____
6. Sample conforms to the required mass and mass recorded to 0.1 g?	_____	_____
7. Method A		
a. Initial mass entered into furnace controller?	_____	_____
b. Sample correctly placed into furnace?	_____	_____
c. Test continued until stable indicator signals?	_____	_____
d. Uncorrected asphalt binder content obtained on printed ticket?	_____	_____
e. Sample mass determined to nearest 0.1 g.?	_____	_____
8. Method B		
a. Sample correctly placed into furnace?	_____	_____
b. Sample burned for 45 min or time determined by correction process?	_____	_____
c. Sample cooled to room temperature?	_____	_____
d. Sample burned to constant mass?	_____	_____
e. Sample mass determined to nearest 0.1 g.?	_____	_____
f. Uncorrected asphalt binder content calculated correctly and recorded?	_____	_____

OVER

Procedure Element	**Trial 1**	**Trial 2**
9. Asphalt binder content corrected for Correction Factor if needed?	_____	_____
10. Asphalt binder content corrected for moisture per the FOP for AASHTO T 329 if needed?	_____	_____
11. Corrected asphalt binder content recorded?	_____	_____
12. Contents of the basket(s) carefully emptied into a pan?	_____	_____

Comments: First attempt: Pass_____Fail_____ Second attempt: Pass_____Fail_____

_____

_____

Examiner Signature _____WAQTC #:_____

THEORETICAL MAXIMUM SPECIFIC GRAVITY (G_{mm}) AND DENSITY OF HOT MIX ASPHALT (HMA) PAVING MIXTURES FOP FOR AASHTO T 209

Significance

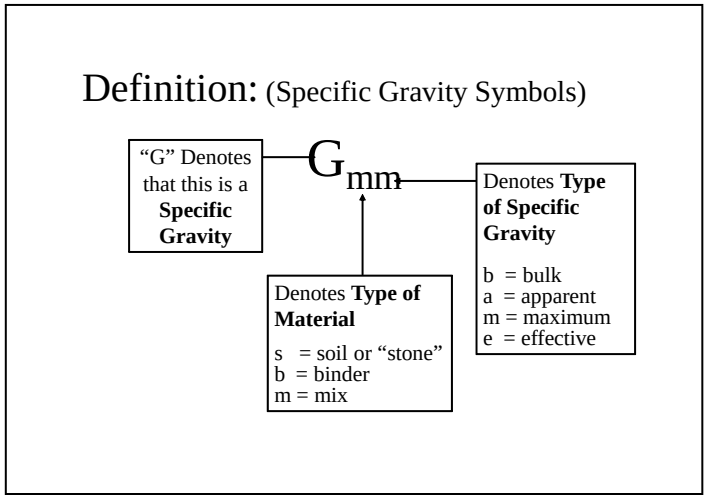
01 Maximum specific gravity (G_{mm}) is the ratio of the mass of a given volume of cooled hot mix asphalt (HMA) at 25°C (77°F) to the mass of an equal volume of water at the same temperature. The procedure is often called the Rice test after its developer, James Rice. G_{mm} is used in conjunction with bulk specific gravity to determine in-place

02 density or percent air voids or both in compacted HMA. Percentage of air voids, V_a, is significant because durability characteristics of HMA are influenced by the amount of voids in the compacted material.

Scope

03 This procedure covers the determination of the maximum specific gravity (G_{mm}) of uncompacted hot mix asphalt (HMA) paving mixtures in accordance with AASHTO T 209-12. Two methods using different containers – bowl and pycnometer / volumetric flask – are covered.

Specimens prepared in the laboratory shall be cured according to the agency standard.



04

05 **Apparatus**

Metal container/ Volumetric Flask

Vacuum pump

- Balance or scale: 10,000 g capacity, readable to 0.1 g
- Container: A glass, metal, or plastic bowl, pycnometer or volumetric flask between 2000 and 10,000 mL as required by the minimum sample size requirements in Table 1 and capable of withstanding a partial vacuum
- Pycnometer / volumetric flask cover: A glass plate or a metal or plastic cover with a vented opening 06
- Vacuum lid: A transparent lid with a suitable vacuum connection. The vacuum opening to be covered with a fine wire mesh 07
- Vacuum pump or water aspirator: Capable of evacuating air from the container to a residual pressure of 4.0 kPa (30 mm Hg)
- Residual pressure manometer or vacuum gauge: Traceable to NIST and capable of measuring residual pressure down to 4.0 kPa (30 mm Hg) or less
- Manometer or vacuum gauge: Capable of measuring the vacuum being applied at the source of the vacuum
- Water bath: A constant-temperature water bath (optional)
- Thermometers: Standardized liquid-in-glass, or electronic digital total immersion type, accurate to 0.5°C (1°F)
- Bleeder valve to adjust vacuum
- Timer

08 **Standardization of Pycnometer or Volumetric Flask**

Use a pycnometer / volumetric flask that is standardized to accurately determine the mass of water, at 25 ±0.5°C (77 ±1°F), in the pycnometer / volumetric flask. The pycnometer / volumetric flask shall be standardized periodically in conformance with procedures established by the agency.

09

Test Sample Preparation

1. Obtain samples in accordance with the FOP for AASHTO T 168 and reduce according to AASHTO R 47.
2. Test sample size shall conform to the requirements of Table 1. Samples larger than the capacity of the container may be tested in two or more increments. Results will be combined and averaged. If the increments have a specific gravity difference greater than 0.014 the test must be re-run.

Table 1
Test Sample Size for G_{mm}

Nominal Maximum Aggregate Size* mm (in.)	Minimum Mass g
37.5 or greater (1 ½)	4000
19 to 25 (3/4 to 1)	2500
12.5 or smaller (1/2)	1500

*Nominal maximum size: One sieve larger than the first sieve to retain more than 10 percent of the material using an agency specified set of sieves based on cumulative percent retained.

10

Separating particles

12

Placing sample in flask

11

13

Determining mass

14

Procedure – General

Two procedures – bowl and pycnometer / volumetric flask – are covered. The first 11 steps are the same for both.

1. Separate the particles of the sample, taking care not to fracture the mineral particles, so that the particles of the fine aggregate portion are not larger than 6.3 mm (1/4 in.). If the mixture is not sufficiently soft to be separated manually, place it in a large flat pan and warm in an oven only until it is pliable enough for separation.
2. Cool the sample to room temperature.
3. Determine and record the mass of the dry container to the nearest 0.1 g.
4. Place the sample in the container.
5. Determine and record the mass of the container and sample to the nearest 0.1 g.

15

Manually agitating container

Mechanically agitating container

Manometer

6. Determine and record the mass of the sample by subtracting the mass determined in Step 3 from the mass determined in Step 5. Designate this mass as "A."

7. Add sufficient water at approximately 25°C (77°F) to cover the sample by about 25 mm (1 in).

Note 1: The release of entrapped air may be facilitated by the addition of a wetting agent. Check with the agency to see if this is permitted and, if it is, for a recommended agent.

8. Place the lid on the container and attach the vacuum line. To ensure a proper seal between the container and the lid, wet the O-ring or use a petroleum gel.

9. Remove entrapped air by subjecting the contents to a partial vacuum of 3.7 ±0.3 kPa (27.5 ±2.5 mm Hg) residual pressure for 15 ±2 minutes.

10. Agitate the container and contents, either continuously by mechanical device or manually by vigorous shaking, at 2 minute intervals. This agitation facilitates the removal of air.

11. Release the vacuum, increasing the pressure to atmospheric pressure in 10 to 15 seconds, turn off the vacuum pump, and remove the lid. When performing the pycnometer / volumetric flask method, complete steps 12B through 16B within 10 ±1 minutes.

Procedure – Bowl

12A. Fill the water bath to overflow level with water at 25 ±1°C (77 ±2°F) and allow the water to stabilize.

13A. Zero or tare the balance with the immersion apparatus attached, ensuring that the device is not touching the sides or the bottom of the water bath.

14A Suspend and immerse the bowl and contents in water at 25 ±1°C (77 ±2°F) for 10 ±1 minutes. The holder shall be immersed sufficiently to cover both it and the bowl.

15A. Determine and record the submerged weight of the bowl and contents to the nearest 0.1 g.

16A. Refill the water bath to overflow level.

17A. Empty and re-submerge the bowl following step 12A to determine the submerged weight of the bowl to the nearest 0.1 g.

18A. Determine and record the submerged weight of the sample the nearest 0.1 g by subtracting the submerged weight of the bowl from the submerged weight determined in Step 15A. Designate this submerged weight as "C."

Procedure – Pycnometer or Volumetric Flask

22 12B. Immediately fill the pycnometer / volumetric flask with water.

Determining temperature

23 13B. Stabilize the temperature of the pycnometer / volumetric flask and contents so that final temperature is within 25 ±1°C (77 ±2°F).

24 14B. Finish filling the pycnometer / volumetric flask with water that is 25 ±1°C (77 ±2°F), place the metal or plastic cover or a glass plate on the pycnometer / volumetric flask, and eliminate all air.

25

Note 2: When using a metal pycnometer and cover, place the cover on the pycnometer and push down slowly, forcing excess water out of the hole in the center of the cover. Use care when filling the pycnometer to avoid reintroducing air into the water.

Determining mass

26 15B. Towel dry the outside of the pycnometer / volumetric flask and cover.

27 16B. Determine and record the mass of the pycnometer / volumetric flask, cover, de-aired water, and sample to the nearest 0.1 g. within 10 ±1 minutes of completion of Step 11. Designate this mass as "E."

Procedure – Mixtures Containing Uncoated Porous Aggregate

28 If the pores of the aggregates are not thoroughly sealed by a bituminous film, they may become saturated with water during the vacuuming procedure, resulting in an error in maximum density.

To determine if this has occurred, complete the general procedure and then:

29

1. Carefully drain water from sample through a towel held over the top of the container to prevent loss of material.
2. Spread sample in a flat shallow pan and place before an electric fan to remove surface moisture.
3. Determine the mass of the sample when the surface moisture appears to be gone.
4. Continue drying and determine the mass of the sample at 15-minute intervals until less than a 0.5 g loss is found between determinations.
5. Record the mass as the saturated surface dry mass to the nearest 0.1 g. Designate this mass as "$A_{SSD.}$"
6. Calculate, as indicated below, G_{mm} using "A" and "$A_{SSD,}$" and compare the two values.

Calculation

Calculate the G_{mm} to three decimal places as follows.

Bowl Procedure 30

$$G_{mm} = \frac{A}{A - C} \qquad or \qquad G_{mm} = \frac{A}{A_{SSD} - C}$$

(for mixes containing uncoated aggregate materials)

where:

A = mass of dry sample in air, g

A_{SSD} = Mass of saturated surface dry sample in air, g

C = submerged weight of sample in water, g

Example

A = 1432.7 g

A_{SSD} = 1434.2 g

C = 848.6 g

$$G_{mm} = \frac{1432.7\ g}{1432.7\ g - 848.6\ g} = 2.453 \qquad or \qquad G_{mm} = \frac{1432.7\ g}{1434.2\ g - 848.6\ g} = 2.447$$

Pycnometer / Volumetric Flask Procedure 31

$$G_{mm} = \frac{A}{A + D - E} \qquad or \qquad G_{mm} = \frac{A}{A_{SSD} + D - E}$$

(for mixtures containing uncoated materials)

where:

A = Mass of dry sample in air, g

A_{SSD} = Mass of saturated surface dry sample in air, g

D = Mass of pycnometer / volumetric flask filled with water at 25°C (77°F), g, determined during the Standardization of Pycnometer / Volumetric Flask procedure

E = Mass of pycnometer / volumetric flask filled with water and test sample at test temperature, g

Example (in which two increments of a large sample are averaged):

32

Increment 1	Increment 2
A = 2200.3 g	A = 1960.2 g
D = 7502.5 g	D = 7525.5 g
E = 8812.0 g	E = 8690.8 g
Temperature = 26.2°C	Temperature = 25.0°C

$$G_{mm_1} = \frac{2200.3\ g}{2200.3\ g + 7502.5\ g - 8812.0\ g} = 2.470$$

$$G_{mm_2} = \frac{1960.2\ g}{1960.2\ g + 7525.5\ g - 8690.8\ g} = 2.466$$

Allowable variation is: 0.014

2.470 - 2.466 = 0.004, which is < 0.014, so they can be averaged.

Average

2.470 + 2.466 = 4.936 4.936 ÷ 2 = 2.468

Theoretical Maximum Density

33

To calculate the theoretical maximum density at 25°C (77°F) use one of the following formulas. The density of water at 25°C (77°F) is 997.1 in Metric units or 62.245 in English units.

Theoretical maximum density $kg/m^3 = G_{mm} \times 997.1\ kg/m^3$

$$2.468 \times 997.1\ kg/m^3 = 2461\ kg/m^3$$

Or:

Theoretical maximum density $lb/ft^3 = G_{mm} \times 62.245\ lb/ft^3$

$$2.468 \times 62.245\ lb/ft^3 = 153.6\ lb/ft^3$$

34

Report

- Results on forms approved by the agency
- Sample ID
- G_{mm} to three decimal places
- Theoretical maximum density to 1 kg/m^3 (0.1 lb/ft^3)

Tips!

35

- Use a standardized pycnometer or volumetric flask with known mass when filled, if using pycnometer or volumetric procedure.
- Check for absorption in uncoated aggregate.

REVIEW QUESTIONS

1. A mix with the nominal maximum aggregate size of 25 mm (1 in.) should use what size sample?

2. At what temperature should the sample be for testing?

3. Removing entrapped air from the contents of the flask by a partial vacuum is done for how long?

4. How and why is the flask agitated?

PERFORMANCE EXAM CHECKLIST

THEORETICAL MAXIMUM SPECIFIC GRAVITY AND DENSITY OF HOT MIX ASPHALT (HMA) PAVING MIXTURES
FOP FOR AASHTO T 209

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	Trial 1	Trial 2
1. Sample reduced to correct size?	_____	_____
2. Particles carefully separated insuring that aggregate is not fractured?	_____	_____
3. After separation, fine aggregate particles not larger than 6.3 mm (1/4 in.)?	_____	_____
4. Sample at room temperature?	_____	_____
5. Mass of container determined to 0.1 g?	_____	_____
6. Mass of sample and container determined to 0.1 g?	_____	_____
7. Mass of sample calculated and conforms to required size?	_____	_____
8. Water at approximately 25°C (77°F) added to cover sample?	_____	_____
9. Entrapped air removed using partial vacuum for 15 ±2 min?	_____	_____
10. Container and contents agitated continuously by mechanical device or manually by vigorous shaking at intervals of about 2 minutes?	_____	_____
11. Bowl determination:		
a. Water bath filled to the overflow level?	_____	_____
b. Bowl and contents suspended in water at 25 ±1°C (77 ±2°F) for 10 ±1 minutes?	_____	_____
c. Submerged weight of bowl and contents determined to 0.1 g?	_____	_____
d. Submerged weight of empty bowl determined to 0.1 g?	_____	_____
e. Net submerged weight of contents calculated?	_____	_____
12. Pycnometer / Volumetric Flask determination:		
a. Pycnometer / volumetric flask filled with water without reintroducing air into the sample?	_____	_____
b. Contents stabilized at 25 ±1°C (77 ±2°F)	_____	_____
c. Pycnometer / volumetric flask completely filled with water that is 25 ±1°C (77 ±2°F)?		

OVER

Procedure Element	**Trial 1**	**Trial 2**
d. Mass of filled pycnometer / volumetric flask and cover determined to 0.1 g, 10 ±1 minutes after removal of entrapped air completed?	_____	_____
e. Mass of pycnometer / volumetric flask, cover, and water obtained from the Standardization of Pycnometer or Volumetric Flask procedure?	_____	_____
13. G_{mm} calculated correctly and reported to 0.001?	_____	_____
14. Density calculated correctly and reported to 1 kg/m^3 (0.1 lb/ft^3)?	_____	_____

Comments: First attempt: Pass_____Fail_____ Second attempt: Pass_____Fail_____

_____
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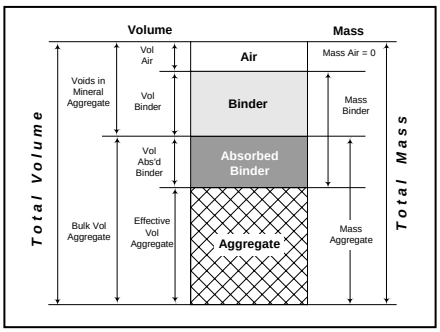
Examiner Signature _____WAQTC #:_____

BULK SPECIFIC GRAVITY (G_{mb}) OF COMPACTED HOT MIX ASPHALT (HMA) MIXTURES USING SATURATED SURFACE-DRY SPECIMENS FOP FOR AASHTO T 166

01

HMA core

02



HMA phase diagram

03

04

Significance

Compacted hot mix asphalt (HMA) includes voids that may contain gas, such as air, or liquid, such as water. The voids may be permeable; that is, they connect to the surface and can fill with water. They may also be impermeable and, thus, filled only with air.

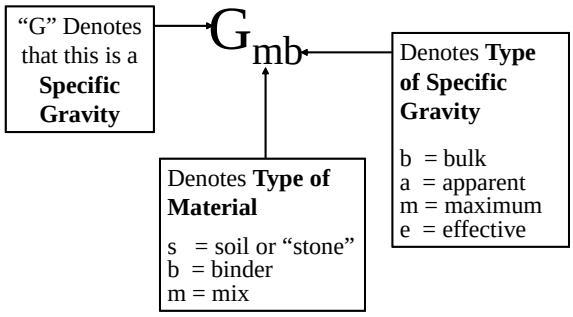
Because voids exist and contain air or water, the overall, or bulk, density of the compacted mix is less than the density of a theoretical mix of aggregate and binder having no voids. Thus, bulk density and associated bulk specific gravity are indications of void and air content – both of which impact various properties of bituminous roadways.

Bulk specific gravity is the ratio of the mass of a given volume of dry, compacted mix at 25°C (77°F) in air to the mass of an equal volume of water at the same temperature. The weight of the sample in water is subtracted from the mass of a saturated surface-dry (SSD) sample in air in order to determine the mass of the water displaced by the specimen. The measurement of void volume, which includes permeable internal and surface pores occupied by water, is useful for mix quality control because it takes into consideration the volume of voids permeable to water within the specimen.

Scope

05 This procedure covers the determination of bulk specific gravity (G_{mb}) of compacted HMA using three methods – A, B, and C – in accordance with AASHTO T 166-16. This FOP is for use on specimens not having open or interconnecting voids or not absorbing more than 2.00 percent water by volume, or both. When specimens have open or interconnecting voids and/or absorbing more than 2.00 percent water by volume AASHTO T 275 or AASHTO T 331 should be performed.

Definition: (Specific Gravity Symbols)



06

Overview

07

- Method A: Suspension
- Method B: Volumeter
- Method C: Rapid test for A or B

Test Specimens

08

Test specimens may be either laboratory-molded or from HMA pavement. For specimens it is recommended that the diameter be equal to four times the maximum size of the aggregate and the thickness be at least one and one half times the maximum size of the aggregate.

Test specimens from HMA pavement will be sampled according to AASHTO R 67.

Terminology

09

Constant Mass: The state at which a mass does not change more than a given percent, after additional drying for a defined time interval, at a required temperature.

Suspension apparatus

Apparatus - Method A (Suspension)

- Balance or scale: 5 kg capacity, readable to 0.1 g, and fitted with a suitable suspension apparatus and holder to permit weighing the specimen while suspended in water, conforming to AASHTO M 231.
- Suspension apparatus: Wire of the smallest practical size and constructed to permit the container to be fully immersed.
- Water bath: For immersing the specimen in water while suspended under the balance or scale, and equipped with an overflow outlet for maintaining a constant water level.
- Towel: Damp cloth towel used for surface drying specimens.
- Oven: Capable of maintaining a temperature of 110 ±5°C (230 ±9°F) for drying the specimens to a constant mass.
- Pan: Pan or other suitable container of known mass, large enough to hold a sample for drying in oven.
- Thermometer: Having a range of 19 to 27°C (66 to 80°F), graduated in 0.1°C (0.2°F) subdivisions.

12 **Procedure - Method A (Suspension)**

Recently molded laboratory samples that have not been exposed to moisture do not need drying.

1. Dry the specimen to constant mass, if required.
   a. Initially dry overnight at 52 ±3°C (125 ±5°F).
   b. Determine and record the mass of the specimen (M_p).
   c. Return the specimen to the oven for at least 2 hours.
   d. Determine and record the mass of the specimen (M_n).
   e. Determine percent change by subtracting the new mass determination (M_n) from the previous mass determination (M_p) divide by the previous mass determination (M_p) multiply by 100.
   f. Continue drying until there is less than 0.05 percent change in specimen mass after 2-hour drying intervals (constant mass).
   g. Constant mass has been achieved, sample is defined as dry.

Note 1: To expedite the procedure, steps 1 and 2 may be performed last. To further expedite the process, see Method C.

2. Cool the specimen in air to 25 ±5°C (77 ±9°F), and determine and record the dry mass to the nearest 0.1 g. Designate this mass as "A."

13

3. Fill the water bath to overflow level with water at 25 ±1°C (77 ±1.8°F) and allow the water to stabilize.

4. Zero or tare the balance with the immersion apparatus attached, ensuring that the device is not touching the sides or the bottom of the water bath.

14

5. Immerse the specimen shaking to remove the air bubbles. Place the specimen on its side in the suspension apparatus. Leave it immersed for 4 ±1 minutes.

15

6. Determine and record the submerged weight to the nearest 0.1 g. Designate this submerged weight as "C."
7. Remove the sample from the water and quickly surface dry with a damp cloth towel within 5 seconds.
8. Zero or tare the balance.
9. Immediately determine and record the mass of the SSD specimen to nearest 0.1 g. Designate this mass as "B." Any water that seeps from the specimen during the mass determination is considered part of the saturated specimen. Do not to exceed 15 seconds performing Steps 7 through 9.

Calculations - Method A (Suspension)

Constant Mass: 16

Calculate constant mass using the following formula:

$$\%Change = \frac{M_p - M_n}{M_p} \times 100$$

Where:

M_p = previous mass measurement, g

M_n = new mass measurement, g

Bulk specific gravity (G_{mb}) and percent water absorbed:

17

$$G_{mb} = \frac{A}{B - C}$$

$$Percent\ Water\ Absorbed\ (by\ volume) = \frac{B - A}{B - C} \times 100$$

where:

G_{mb} = Bulk specific gravity

A = Mass of dry specimen in air, g

B = Mass of SSD specimen in air, g

C = Weight of specimen in water, g

Example:

18

$$G_{mb} = \frac{4833.6\ g}{4842.4\ g - 2881.3\ g} = 2.465$$

$$\%\ \boldsymbol{Water\ Absorbed\ (by\ volume)} = \frac{\mathbf{4842.4\ g - 4833.6\ g}}{\mathbf{4842.4\ g - 2881.3\ g}} \times \mathbf{100} = \mathbf{0.45}\%$$

Apparatus - Method B (Volumeter)

19

- Balance or scale: 5 kg capacity, readable to 0.1 g and conforming to AASHTO M 231.
- Water bath: Thermostatically controlled to 25 ±0.5°C (77 ±0.9°F).
- Thermometer: Range of 19 to 27°C (66 to 80°F), and graduated in 0.1°C (0.2°F) subdivisions.
- Volumeter: Calibrated to 1200 mL or appropriate capacity for test sample and having a tapered lid with a capillary bore.

20

- Oven: Capable of maintaining a temperature of 110 ±5°C (230 ±9°F) for drying the specimens to a constant mass.

- Pan: Pan or other suitable container of known mass, large enough to hold a sample for drying in oven.
- Towel: Damp cloth towel used for surface drying specimens.

21 **Procedure - Method B (Volumeter)**

Recently molded laboratory samples that have not been exposed to moisture do not need drying.

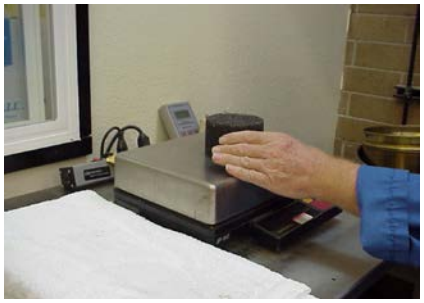
1. Dry the specimen to constant mass, if required.
   a. Initially dry overnight at 52 ±3°C (125 ±5°F).
   b. Determine and record the mass of the specimen (M_p).
   c. Return the specimen to the oven for at least 2 hours.
   d. Determine and record the mass of the specimen (M_n).
   e. Determine percent change by subtracting the new mass determination (M_n) from the previous mass determination (M_p) divide by the previous mass determination (M_p) multiply by 100.
   f. Continue drying until there is less than 0.05 percent change in specimen mass after 2-hour drying intervals (constant mass).
   g. Constant mass has been achieved, sample is defined as dry.

Note 1: To expedite the procedure, steps 1 and 2 may be performed last. To further expedite the process, see Method C.

22 2. Cool the specimen in air to 25 ±5°C (77 ±9°F), and determine and record the dry mass to the nearest 0.1 g. Designate this mass as "A."
3. Immerse the specimen in the temperature controlled water bath for at least 10 minutes.
4. Fill the volumeter with distilled water at 25 ±1°C (77 ±1.8°F), making sure some water escapes through the capillary bore of the tapered lid. Wipe the volumeter dry. Determine the mass of

23

Drying surface



Determining mass of SSD specimen

the volumeter to the nearest 0.1 g. Designate this mass as "D."

5. At the end of the ten minute period, remove the specimen from the water bath and quickly surface dry with a damp towel within 5 seconds.
6. Immediately determine and record the mass of the SSD specimen to the nearest 0.1 g. Designate this mass as "B." Any water that seeps from the specimen during the mass determination is considered part of the saturated specimen.
7. Place the specimen in the volumeter and let stand 60 seconds.
8. Bring the temperature of the water to 25 ±1°C (77 ±1.8°F) and cover the volumeter, making sure some water escapes through the capillary bore of the tapered lid.
9. Wipe the volumeter dry.
10. Determine and record the mass of the volumeter and specimen to the nearest 0.1 g. Designate this mass as "E."

Note 2: Method B is not acceptable for use with specimens that have more than 6 percent air voids.

Calculations - Method B (Volumeter)

Constant Mass:

Calculate constant mass using the following formula:

$$\%Change = \frac{M_p - M_n}{M_p} \times 100$$

Where:

M_p = previous mass measurement

M_n = new mass measurement

Bulk specific gravity (G_{mb}) and percent water absorbed: 30

$$G_{mb} = \frac{A}{B + D - E}$$

$$Percent\ Water\ Absorbed\ (by\ volume) = \frac{B - A}{B + D - E} \times 100$$

where:

G_{mb} = Bulk specific gravity

A = Mass of dry specimen in air, g

B = Mass of SSD specimen in air, g

D = Mass of volumeter filled with water at 25 ±1°C (77 ±1.8°F), g

E = Mass of volumeter filled with specimen and water, g

Example: 31

$$G_{mb} = \frac{4833.6\ g}{4842.4\ g + 2924.4\ g - 5806.0\ g} = 2.465$$

$$\%\ Water\ Absorbed\ (by\ volume) = \frac{4842.4\ g - 4833.6\ g}{4842.4\ g + 2944.4\ g - 5806.0\ g} \times 100 = 0.45\%$$

32 **Apparatus - Method C (Rapid Test for Method A or B)**

See Methods A or B.

Note 3: This procedure can be used for specimens that are not required to be saved and contain substantial amounts of moisture. Cores can be tested the same day as obtained by this method.

Procedure - Method C (Rapid Test for Method A or B)

33 1. Start on Step 3 of Method A or B, and complete that procedure, then determine dry mass, "A," as follows.

2. Determine and record mass of a large, flat-bottom container.
3. Place the specimen in the container.
4. Place in an oven at a minimum of 105°C (221°F). Do not exceed the Job Mix Formula mixing temperature.
5. Dry until the specimen can be easily separated into fine aggregate particles that are not larger than 6.3 mm (¼ in.).
6. Determine and record the mass of the specimen (M_p).
7. Return the specimen to the oven for at least 2 hours.
8. Determine and record the mass of the specimen (M_n).
9. Determine percent change by subtracting the new mass determination (M_n) from the previous mass determination (M_p) divide by the previous mass determination (M_p) multiply by 100.
10. Continue drying until there is less than 0.05 percent change in specimen mass after 2-hour drying intervals (constant mass).
11. Constant mass has been achieved, sample is defined as dry.
12. Cool in air to 25 ±5°C (77 ±9°F).
13. Determine and record the mass of the container and dry specimen to the nearest 0.1 g.
14. Determine and record the mass of the dry specimen to the nearest 0.1 g by subtracting the mass of the container from the mass determined in Step 13. Designate this mass as “A.”

32

Calculations - Method C (Rapid Test for Method A or B)

Complete the calculations as outlined in Methods A or B, as appropriate.

33

Report

- Results on forms approved by the agency
- Sample ID
- G_{mb} to 0.001
- Absorption to 0.01 percent
- The method performed

Tips!

32

- Use method approved by agency.
- Check for open or interconnecting voids and/or absorption over 2.00 percent.
- Check temperature of water in water bath.

REVIEW QUESTIONS

1. For how long must samples be submerged prior to determining immersed weight for Method A?

2. In determining the SSD mass of a specimen, how must the sample be dried?

3. At what temperature and for how long should core samples be dried?

4. How do methods A and B differ?

PERFORMANCE EXAM CHECKLIST

BULK SPECIFIC GRAVITY OF COMPACTED HOT MIX ASPHALT (HMA) USING SATURATED SURFACE-DRY SPECIMENS
FOP FOR AASHTO T 166

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	**Trial 1**	**Trial 2**
Method A:		
1. Mass of dry sample in air determined.		
a. Dried overnight at 52 ±3°C (125 ±5°F) and at successive 2-hour intervals to constant mass?	_____	_____
b. Cooled in air to 25 ±5°C (77 ±9°F)?	_____	_____
c. Dry mass determined to 0.1g?	_____	_____
2. Water at the overflow?	_____	_____
3. Balance zeroed?	_____	_____
4. Immersed weight determined.		
a. Water at 25 ±1°C (77 ±1.8°F)?	_____	_____
b. Immersed, shaken, on side, for 4 ±1 minutes?	_____	_____
c. Immersed weight determined to 0.1g?	_____	_____
5. Sample rapidly surface dried with damp towel and saturated surface dry (SSD) mass determined to 0.1 g (entire operation performed within 15 seconds)?	_____	_____
6. G_{mb} calculated to 0.001?	_____	_____
7. Absorption calculated to 0.01 percent	_____	_____
Method B:		
1. Specimen dried, cooled, and mass determined as in Method A?	_____	_____
2. Saturated surface dry (SSD) mass determined to 0.1g.		
a. Immersed at least 10 minutes at 25 ±1°C (77 ±1.8°F)?	_____	_____
b. Sample rapidly dried with damp towel?	_____	_____
c. Specimen mass determined to 0.1 g?	_____	_____
d. Any water that seeps from specimen included in mass?	_____	_____
3. Mass of volumeter filled with distilled water at 25 ±1°C (77 ±1.8°F) determined?	_____	_____
4. SSD specimen placed into volumeter and let stand for 1 minute?	_____	_____

OVER

Procedure Element	Trial 1	Trial 2
5. Temperature of water brought to 25 ±1°C (77 ±1.8°F) and volumeter covered, allowing some water to escape through the capillary bore of the tapered lid?	_____	_____
6. Volumeter wiped dry, and mass of volumeter and contents determined?	_____	_____
7. G_{mb} calculated to 0.001?	_____	_____
8. Absorption calculated to 0.01 percent?	_____	_____
Method C/A:		
1. Immersed weight determined.		
a. Water at 25 ±1°C (77 ±1.8°F)?	_____	_____
b. Immersed, shaken, on side, for 4 ±1 minutes?	_____	_____
c. Immersed weight determined to 0.1 g?	_____	_____
2. Sample rapidly surface dried with damp cloth (within 5 seconds)?	_____	_____
3. Saturated surface dry mass determined to 0.1 g?	_____	_____
4. Dry mass determined by:		
a. Heating in oven at a minimum of 105°C (221°F)?	_____	_____
b. Breaking down to 6.3 mm (¼ in.) particles?	_____	_____
c. Drying in oven to constant mass (change less than 0.05 percent in 2 hours of additional drying)?	_____	_____
d. Cooled in air to 25 ±5°C (77 ±9°F) and mass determined to 0.1 g?	_____	_____
5. G_{mb} calculated to 0.001?	_____	_____
6. Absorption calculated to 0.01?	_____	_____
Method C/B:		
1. Saturated surface dry (SSD) mass determined to 0.1g.		
a. Immersed at least 10 minutes at 25 ±1°C (77 ±1.8°F)?	_____	_____
b. Sample rapidly dried with damp towel (within 5 seconds)?	_____	_____
c. Specimen mass determined to 0.1g?	_____	_____
d. Any water that seeps from specimen included in mass?	_____	_____
2. Mass of volumeter filled with distilled water at 25 ±1°C (77 ±1.8°F) determined to 0.1 g?	_____	_____
3. SSD specimen placed into volumeter and let stand for 1 minute?	_____	_____
4. Temperature of water brought to 25 ±1°C (77 ±1.8°F) and volumeter covered, allowing some water to escape through the capillary pore of the tapered lid?	_____	_____
5. Volumeter wiped dry, and mass of volumeter and contents determined to 0.1 g?	_____	_____

OVER

Procedure Element	**Trial 1**	**Trial 2**
6. Dry mass determined by:		
a. Warming in oven at a minimum of 105°C (221°F)?	_____	_____
b. Breaking down to 6.3 mm (¼ in.) particles?	_____	_____
c. Drying in oven to constant mass (change less than 0.05 percent in 2 hours of additional drying)?	_____	_____
d. Cooled in air to 25 ±5°C (77 ±9°F) and mass determined to 0.1 g?	_____	_____
7. G_{mb} calculated to 0.001?	_____	_____
8. Absorption calculated to 0.01 percent?	_____	_____

Comments: First attempt: Pass_____Fail_____ Second attempt: Pass_____Fail_____

_____
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Examiner Signature _____WAQTC #:_____

SAMPLING ASPHALT MATERIALS
FOP FOR AASHTO R 66

01

Significance

The quality of asphalt materials has a tremendous impact on a roadway project. The grade of binder selected is based on a number of factors, including local temperature extremes and characteristics of expected traffic. Using a grade of binder material other than that specified will have serious impacts on roadway performance and durability.

02

Scope

The procedure covers obtaining samples of liquid asphalt materials in accordance with AASHTO R 66-16. Sampling of solid and semi-solid asphalt materials – included in AASHTO R 66 – is not covered here.

Agencies may be more specific on exactly who samples, where to sample, and what type of sampling device to use.

03

Warning: Always use appropriate safety equipment and precautions for hot liquids.

04

Terminology

- Asphalt binder: Asphalt cement or modified asphalt cement that binds the aggregate particles into a dense mass.
- Asphalt emulsion: A mixture of asphalt binder and water.
- Cutback asphalt: Asphalt binder that has been modified by blending with a chemical solvent.

Sampling liquid binder

Procedure

05

1. Coordinate sampling with contractor or supplier.
2. Allow a minimum of 4 L (1 gal) to flow before obtaining a sample(s).
3. Obtain samples of:

06

   - Asphalt binder from hot mix asphalt (HMA) plant: from the line between the storage tank and the mixing plant while the plant is in operation, or from the delivery truck.

07

08

- Cutback and emulsified asphalt from distributor spray bar or application device, or from the delivery truck before it is pumped into the distributor: Sample emulsified asphalt at delivery or prior to dilution.

Containers

Sampling from the spray bar

09

Sample containers must be new, and the inside may not be washed or rinsed. The outside may be wiped with a clean, dry cloth.

10

All samples shall be put in 1 L (1 qt) containers and properly identified on the outside of the container with contract number, date sampled, data sheet number, brand and grade of material, and sample number. Include lot and sublot numbers when appropriate.

11

- Emulsified asphalt: Use wide-mouth plastic jars with screw caps. Protect the samples from freezing since water is a part of the emulsion. The sample container should be completely filled to minimize a skin formation on the sample.
- Asphalt binder and cutbacks: Use metal cans.

Note: The filled sample container shall not be submerged in solvent, nor shall it be wiped with a solvent saturated cloth. If cleaning is necessary, use a clean dry cloth.

12

Report

- On forms approved by the agency
- Sample ID
- Date
- Time
- Location
- Quantity represented

13

Tips!

- Remember to identify sample on outside of container.

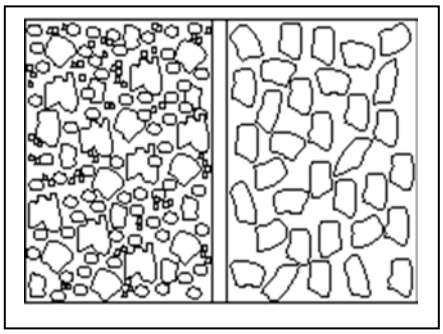
REVIEW QUESTIONS

1. Describe how liquid asphalt material is obtained at an HMA plant.

2. Describe how liquid asphalt material is obtained from a spray distributor.

3. Describe the containers used for sampling.

MECHANICAL ANALYSIS OF EXTRACTED AGGREGATE FOP FOR AASHTO T 30

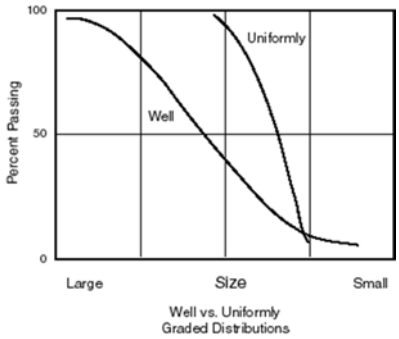


01

02

03

Well- vs. uniformly graded



05

04

06

Gradation curves

07

Apparatus

Significance

The amount and gradation of aggregate in bituminous paving mixes are specified by the agency and relate to strength, flexibility, and durability considerations. Mix designs are based on those specifications, as is mix production. To confirm that the amount and gradation of aggregate in the finished product are correct, tests must be conducted. Compliance with the specification will help ensure a good roadway. Non-compliance may result in failure of the roadway. For these reasons, analysis of aggregate in bituminous mixes is extremely important.

Scope

This procedure covers mechanical analysis of aggregate recovered from bituminous mix samples in accordance with AASHTO T 30-15. This FOP utilizes the aggregate recovered from the ignition oven used in AASHTO T 308. AASHTO T 30 was developed for analysis of extracted aggregate and thus includes references to extracted bitumen and filter element, which do not apply in this FOP.

Apparatus

- Balance or scale: capacity sufficient for the sample mass, accurate to 0.1 percent of the sample mass or readable to 0.1 g and conforming to AASHTO M 231
- Sieves
- Mechanical sieve shaker
- Mechanical Washing Apparatus (optional)
- Suitable drying equipment (see FOP for AASHTO T 255)
- Containers and utensils: a pan or vessel of a size sufficient to contain the sample covered with water and to permit vigorous agitation without loss of any part of the sample or water

Hand shaking

Sample Sieving

08 • In this procedure it is required to shake the sample over nested sieves. Sieves are selected to furnish information required by specification.

09 • Sieves are nested in order of decreasing size from the top to the bottom and the sample, or a portion of the sample, is placed on the top sieve.

10 • Sieves are shaken in a mechanical shaker for approximately 10 minutes or the minimum time determined to provide complete separation for the sieve shaker being used, as established by the Time Evaluation.

11 **Time Evaluation**

The sieving time for each mechanical sieve shaker shall be checked at least annually to determine the time required for complete separation of the sample by the following method:

1. Shake the sample over nested sieves for approximately 10 minutes.
2. Provide a snug-fitting pan and cover for each sieve, and hold in a slightly inclined position in one hand.
3. Hand-shake each sieve by striking the side of the sieve sharply and with an upward motion against the heel of the other hand at the rate of about 150 times per minute, turning the sieve about one sixth of a revolution at intervals of about 25 strokes.

If more than 0.5 percent by mass of the total sample prior to sieving passes any sieve after one minute of continuous hand sieving adjust shaker time and re-check.

In determining sieving time for sieve sizes larger than 4.75 mm (No. 4), limit the material on the sieve to a single layer of particles.

12

Overload Determination

- For sieves with openings smaller than 4.75 mm (No. 4), the mass retained on any sieve shall not exceed 7 kg/m^2 (4 g/in^2) of sieving surface.
- For sieves with openings 4.75 mm (No. 4) and larger, the mass (in kg) shall not exceed the product of 2.5 x (sieve opening in mm) x (effective sieving area). See Table 1.

Additional sieves may be necessary to keep from overloading the specified sieves. The sample may also be sieved in increments or sieves with a larger sieving area.

13

TABLE 1
Maximum Allowable Mass of Material Retained on a Sieve, g
Nominal Sieve Size, mm (in.)
Exact size is smaller (see AASHTO T 27)

Sieve Size mm (in.)		203 dia (8)	305 dia (12)	305 by 305 (12 × 12)	350 by 350 (14 ×14)	372 by 580 (16 ×24)
		Sieving Area m^2				
		0.0285	0.0670	0.0929	0.1225	0.2158
90	(3 1/2)	*	15,100	20,900	27,600	48,500
75	(3)	*	12,600	17,400	23,000	40,500
63	(2 1/2)	*	10,600	14,600	19,300	34,000
50	(2)	3600	8400	11,600	15,300	27,000
37.5	(1 1/2)	2700	6300	8700	11,500	20,200
25.0	(1)	1800	4200	5800	7700	13,500
19.0	(3/4)	1400	3200	4400	5800	10,200
16.0	(5/8)	1100	2700	3700	4900	8600
12.5	(1/2)	890	2100	2900	3800	6700
9.5	(3/8)	670	1600	2200	2900	5100
6.3	(1/4)	440	1100	1500	1900	3400
4.75	(No. 4)	330	800	1100	1500	2600
-4.75	(-No. 4)	200	470	650	860	1510

Mass Verification

14 1. Using the aggregate sample obtained from the FOP for AASHTO T 308, determine and record the mass of the sample, $M_{(T30)}$, to 0.1 g . This mass shall agree with the mass of the aggregate remaining after ignition, M_f from T 308, within 0.10 percent. If the variation
15 exceeds 0.10 percent the results cannot be used for acceptance.

Calculation

$$\frac{M_{f\,(T308)} - M_{(T30)}}{M_{f\,(T308)}} \times 100$$

Where:

$M_{(T30)}$ = 2422.3 g

$M_{f(T308)}$ = 2422.5 g

Example:

$$\frac{\mathbf{2422.5}\ \boldsymbol{g} - \mathbf{2422.3}\ \boldsymbol{g}}{\mathbf{2422.5}\ \boldsymbol{g}} \times \mathbf{100} = \mathbf{0.01}\%$$

Separation of material

Procedure

16 1. Nest a sieve, such as a 2.0 mm (No. 10) or
17 1.18 mm (No. 16), above the 75µm (No. 200) sieve.

2. Place the test sample in a container and add sufficient water to cover it. Add a detergent, dispersing agent, or other wetting solution to the water to assure a thorough separation of the material finer than the 75µm (No. 200) sieve from the coarser particles. There should be enough wetting agent to produce a small amount of suds when the sample is agitated. Excessive suds may overflow the sieves and carry material away with them.

Pouring wash water over nested sieves

3. Agitate vigorously to ensure complete separation of the material finer than 75 µm (No. 200) from coarser particles and bring the fine material into suspension above the coarser material. When using a mechanical washing device, exercise caution to avoid degradation of the sample. Maximum agitation is 10 min.

Note 1: When mechanical washing equipment is used, the introduction of water, agitating, and decanting may be a continuous operation. Use care not to overflow or overload the 75µm (No. 200) sieve.

4. Immediately pour the wash water containing the suspended and dissolved solids over the nested sieves, being careful not to pour out the coarser particles.
5. Add a second change of water to the sample remaining in the container, agitate, and repeat Step 5. Repeat the operation until the wash water is reasonably clear. Continue washing until the agent is removed.
6. Rinse the material retained on the nested sieves until water passing through the sieve is reasonably clear.
7. Remove the upper sieve, return material retained to the washed sample.
8. Rinse the material retained on the 75µm (No. 200) sieve until water passing through the sieve is reasonably clear.
9. Return all material retained on the 75µm (No. 200) sieve to washed sample by flushing into the washed sample.
10. Dry the washed aggregate to constant mass in accordance with the FOP for AASHTO T 255, and then cool prior to sieving. Record the "dry mass after washing."
11. Select sieves to furnish information required by the specifications. Nest the sieves in order of decreasing size from top to bottom and place the sample, or a portion of the sample, on the top sieve.

Small sieve shaker

12. Place sieves in mechanical shaker and shake for the minimum time determined to provide complete separation for the sieve shaker being used (approximately 10 minutes).

Note 2: Excessive shaking (more than 10 minutes) may result in degradation of the sample.

13. Determine the mass retained (individual/ cumulative) on each sieve to the nearest 0.1 g. Ensure that all material trapped in full openings of the sieves are cleaned out and included in the mass retained.

Note 3: For sieves No. 4 and larger, material trapped in less than a full opening shall be checked by sieving over a full opening. Use coarse wire brushes to clean the 600 µm (No. 30) and larger sieves, and soft bristle brushes for smaller sieves.

Brushing sieve

23 14. Verify the total mass of material after sieving agrees with the mass before sieving within 0.2 percent. (Check sum). When the masses before and after sieving differ by more than 0.2 percent, do not use the results for acceptance purposes.

15. Divide the masses for each sieve (individual/cumulative) by the total dry mass before washing and multiply by 100 to determine the percent retained on and passing each sieve.

16. Calculate the percent retained and passing each sieve to the nearest 0.1 percent.

24 17. Apply the Aggregate Correction Factor to the calculated percent passing, as required in the FOP for AASHTO T 308 “Correction Factor” Steps 10 through 12, to obtain the reported percent passing.

18. Report percentages to the nearest 1 percent except for the percent passing the 75 µm (No. 200) sieve, which shall be reported to the nearest 0.1 percent.

Calculations

Total mass of material after sieving must agree with mass before sieving to within 0.2 percent.

$$check\ sum = \frac{dry\ mass\ after\ washing - mass\ after\ sieving}{dry\ mass\ after\ washing} \times 100$$

PERCENT RETAINED:

$$\text{IPR} = \frac{IMR}{M_{T30}} \times 100 \quad \textbf{OR} \quad \text{CPR} = \frac{CMR}{M_{T30}} \times 100$$

Where:

IPR	=	Individual Percent Retained
CPR	=	Cumulative Percent Retained
M_{T30}	=	Total Dry Sample mass before washing
IMR	=	Individual Mass Retained
CMR	=	Cumulative Mass Retained

26, 27, 28

<u>PERCENT PASSING and REPORTED PERCENT PASSING:</u>

$$PP = PCP - IPR \quad \boldsymbol{OR} \quad PP = 100 - CPR$$

$$RPP = PP + \text{Aggregate Correction Factor}$$

Where:

PP	=	Calculated Percent Passing
PCP	=	Previous Calculated Percent Passing
RPP	=	Reported Percent Passing

29

Example

Dry mass of total sample, before washing (M_{T30}): 2422.3 g

Dry mass of sample, after washing out the 75 µm (No. 200) minus: 2296.2 g

Amount of 75 µm (No. 200) minus washed out: 2422.3 – 2296.2 g = 126.1 g

Percent Retained 75 µm (No. 200) 30, 31, 32

$$\frac{63.5\ g}{2422.3\ g} \times 100 = 2.6\% \quad or \quad \frac{2289.6\ g}{2422.3\ g} \times 100 = 94.5\%$$

Percent Passing 8.1% – 2.6% = 5.5% or 100.0%– 94.5% = 5.5%

Reported Percent Passing 5.5% + (-0.6%) = 4.9%

Gradation on All Screens 33

Sieve Size mm (in.)	Mass Retained, g (MR)	Percent Retained (PR)	Cumulative Mass Retained (CMR)	Cumulative Percent Retained (CPR)	Calc'd Percent Passing (PP)	Agg. Corr. Factor T 308 (ACF)	Reported Percent Passing (RPP)
19.0 (3/4)	0.0		0.0	0	100.0		100
12.5 (1/2)	346.9	14.3	346.9	14.3	85.7		86
9.5 (3/8)	207.8	8.6	554.7	22.9	77.1		77
4.75 (No. 4)	625.4	25.8	1180.1	48.7	51.3		51
2.36 (No. 8)	416.2	17.2	1596.3	65.9	34.1		34
01.18 (No. 16)	274.2	11.3	1870.5	77.2	22.8		23
0.600 (No. 30)	152.1	6.3	2022.6	83.5	16.5		16
0.300 (No. 50)	107.1	4.4	2129.7	87.9	12.1		12
0.150 (No. 100)	96.4	4.0	2226.1	91.9	8.1		8
75 µm (No. 200)	63.5	2.6	2289.6	94.5	5.5	-0.6	4.9
Pan	5.7		2295.3				

Check sum: 34

$$\frac{2296.2\ g - 2295.3\ g}{2296.2\ g} \times 100 = 0.04\%$$

This is less than 0.2 percent therefore the results can be used for acceptance purposes.

Report

35

- Results on forms approved by the agency
- Sample ID
- Depending on the agency, this may include:
  - Individual mass retained on each sieve
  - Individual percent retained on each sieve
  - Cumulative mass retained on each sieve
  - Cumulative percent retained on each sieve
  - Aggregate Correction Factor for each sieve from AASHTO T 308
  - Calculated percent passing each sieve to 0.1 percent

36

Reported percent passing to the nearest 1 percent, except 75 µm (No. 200) sieve to the nearest 0.1 percent.

Tips!

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- Do not lose <u>any</u> material when running the test.
- Remember to base calculations on <u>the total mass of the initial dry sample</u>.
- Check calculations, and sieves for damage or plugging, if results look “odd” or if the material suddenly goes out of spec.
- Save all material for rerunning.

REVIEW QUESTIONS

1. What is the maximum mass that can be retained on a 4.75 mm (No. 4) sieve with a 12 in. diameter?

2. Describe how sieves should be cleaned.

3. What should be done to protect the 75 µm (No. 200) sieve during washing?

4. Once a washed sample is placed in the oven and dried to a constant mass, what is the next step?

5. For how long should material be sieved on the shaker?

6. How much unexplained sample mass after sieve analysis may be lost before you would have to rerun an aggregate sample?

PERFORMANCE EXAM CHECKLIST

MECHANICAL ANALYSIS OF EXTRACTED AGGREGATE FOP FOR AASHTO T 30

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	Trial 1	Trial 2
1. Total dry mass determined to 0.1 g	_____	_____
2. Dry mass agrees with sample mass after ignition (M_f) from AASHTO T 308 within 0.1 percent?	_____	_____
3. Sample placed in container and covered with water?	_____	_____
4. Wetting agent added?	_____	_____
5. Contents of container agitated vigorously?	_____	_____
6. Wash water poured through proper nest of two sieves?	_____	_____
7. Washing continued until wash water is clear and no wetting agent remaining?	_____	_____
8. Retained material returned to washed sample?	_____	_____
9. Washed material coarser than 75 µm (No. 200) dried to constant mass at 110 ±5°C (230 ±9°F)?	_____	_____
10. Sample cooled to room temperature?	_____	_____
11. Dry mass after washing determined to 0.1 g?	_____	_____
12. Material sieved on specified sieves?	_____	_____
13. Mass of each fraction of aggregate, including minus 75 µm (No. 200), determined and recorded to 0.1 g?	_____	_____
14. Percent passing on each sieve determined correctly to the nearest 0.1 percent?	_____	_____
15. Aggregate correction factor applied?	_____	_____
16. Percent passing on each sieve reported correctly to the nearest 1 percent and nearest 0.1 percent on the 75 µm (No. 200)?	_____	_____
17. Does summation of sieve masses check total washed dry mass to within 0.2 percent?	_____	_____

Comments: First attempt: Pass_____Fail_____ Second attempt: Pass_____Fail_____

_____

_____

_____

Examiner Signature _____WAQTC #:_____

ASPHALT MIXTURE SPECIMENS BY MEANS OF THE SUPERPAVE GYRATORY COMPACTOR FOP FOR AASHTO T 312

01

Significance

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The Superpave gyratory compactor (SGC) is used to compact cylindrical specimens of asphalt mixtures by means of gyrations under a specified compressive stress and angle of inclination. The intent of this compactive effort is to simulate the in-place density of asphalt mixtures after it has endured several years of traffic. The specimens produced, using asphalt mixtures mixed in the laboratory or sampled from a plant, are intended to model the density, aggregate orientation, and structural characteristics of a properly constructed in-place pavement.

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Specimen

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Scope

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This procedure covers preparing specimens, using samples of plant produced asphalt mixtures, for determining the mechanical and volumetric properties of asphalt mixtures in accordance with AASHTO T 312-15.

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Apparatus

- Superpave Gyratory Compactor (SGC) meeting the requirements of AASHTO T 312
- Molds meeting the requirements of AASHTO T 312
- Chute, mold funnel or both (Optional)
- Scale meeting the requirements of AASHTO M 231 Class G 5
- Oven, thermostatically controlled, capable of maintaining set temperature within ±3ºC (±5ºF)
- Thermometers accurate to ±1ºC (±2°F) between 10 and 232°C (50 - 450°F)

Pine AFGB1

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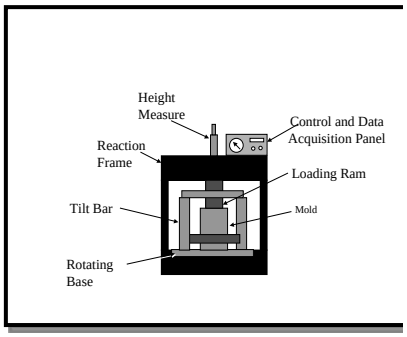
Note 1: Non-Contact thermometers are not acceptable.

- Miscellaneous pans, spoons, spatulas, hot pads, gloves, paper discs, markers, etc.

09 **Equipment Requirements**

10 The calibration shall be performed on the SGC per the Manufacturer's instructions. See agency requirements for the calibration frequency.

The mold and base plate dimensions shall be checked every twelve months or 80 hours of operation to determine that they are within the tolerances listed in AASHTO T 312.



Schematic of SGC

11 **Equipment Preparation**

Prepare the equipment in accordance with manufacturer's recommendations. At a minimum preparation includes:

- Warm-up gyratory compactor
- Verify machine settings
  - Internal Angle: 1.16 ±0.02°
  - Ram Pressure: 600 kPa ±18 kPa
  - Number of gyrations

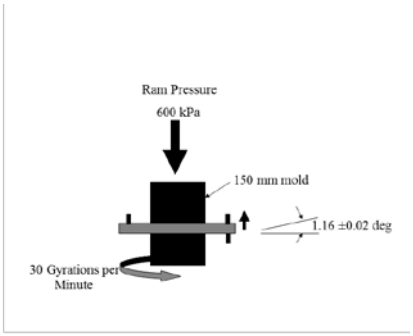


Illustration of device movement

12 ***Note 2:*** The number of gyrations (N_{des}) is obtained from the Job Mix Formula (JMF).

- Lubricate bearing surfaces

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- Prepare recording device as required
- Pre-heat molds and plates at the compaction temperature range (minimum of 30 min.) or before reuse reheat (minimum of 5 min.)

Note 3: The use of multiple molds will speed up the compaction process.

- Pre-heat chute, mold funnel, spatulas, and other apparatus (not to exceed the maximum compaction temperature)

14

Sample Preparation

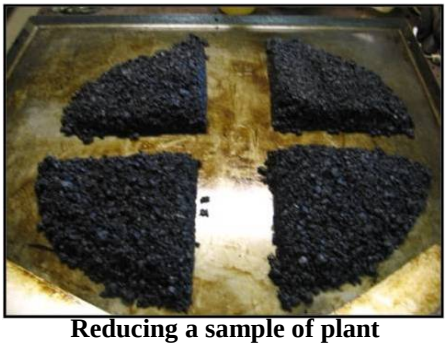
Laboratory Prepared Asphalt Mixtures

This is a sample produced during the Mix Design process using aggregate and binder that is combined in the laboratory. When designing asphalt mixes using the gyratory compactor refer to AASHTO T 312.

Plant Produced Asphalt Mixtures

- Determine initial sample size, number of gyrations (N_{des}), and compaction temperature range from the Job Mix Formula (JMF).
- Obtain the sample in accordance with the FOP for AASHTO T 168.
- Reduce the sample in accordance with the FOP for AASHTO R 47.
- The sample size should be such that it results in a compacted specimen that is 115 ±5mm at the desired number of gyrations.

Note 4: Replicate specimens are generally prepared. Refer to agency requirements.



Reducing a sample of plant produced asphalt mixture

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If the material is not in the compaction temperature range:

1. Place the appropriate sample mass into a container
2. Spread to a depth of 1 to 2 in. for even heating of mixture
3. Place in the oven until the material is within the compaction temperature is range.

Note 5: The material properties may be altered when the times of delivery of the test sample and the placement of the material on the roadway are different.

Heating to compaction temperature

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Placing paper disc in mold

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Compaction Procedure

Follow the manufacturer's recommended loading procedure. This may require the steps below to be performed in a different order. Steps 1 through 8 must be performed before the sample and mold cools below minimum compaction temperature.

1. Remove pre-heated mold and plate(s) from the oven (Verify mold has been cleaned if previously used).

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2. Place the base plate and paper disc in bottom of mold
3. Place the mix into the mold in a single lift (care should be taken to avoid segregation or loss of material).
4. Level the mix in the mold
5. Place a paper disc and the heated upper plate (if required) on top of the leveled sample

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6. Load the mold into the compactor, check settings.
7. Start the compaction process
    a. Check the pressure (600 ±18 kPa)
    b. Check the angle (1.16 ±0.02°)
8. Upon completion of the compaction process and record the number of gyrations and specimen height

21

Note 6: If the specimen is not 115 ±5 mm follow agency requirements

9. Extrude the specimen from the mold; a brief cooling period may be necessary before fully extruding some specimens to ensure the specimens are not damaged.

22

Note 7: Clean molds after each use.

23

10. Carefully remove the paper discs
11. Cool the compacted specimen to room temperature
12. Identify the specimen with chalk or other marker

Using chute to place HMA in mold

Specimen identification

24

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Tips!

- Install base plate and paper disc in bottom of mold prior to filling.
- Level the material in the mold.
- Cooling of extruded specimens may be required to prevent damage due to handling.
- Remove the paper discs as soon as possible from the hot specimens.
- Use clean molds.
- Verify height is 115 ±5 mm.

Report

- On forms approved by the agency
- Sample ID
- Number of gyrations
- Specimen height

REVIEW QUESTIONS

1. What is the purpose of the SGC?

2. What if the sample is not in compaction temperature range?

3. How many kPa of pressure is applied to the specimen?

4. At what angle is the specimen compacted?

5. What height should the compacted specimen be?

PERFORMANCE EXAM CHECKLIST

GYRATORY COMPACTION OF ASPHALT MIXTURES
FOP FOR AASHTO T 312

Participant Name _____ Exam Date _____

Record the symbols "P" for passing or "F" for failing on each step of the checklist.

Procedure Element	Trial 1	Trial 2
1. Angle, pressure and number of gyrations set?	_____	_____
2. Bearing surfaces, rotating base surface, and rollers lubricated?	_____	_____
3. Representative sample obtained according to the FOP for AASHTO T 168?	_____	_____
4. Sample reduced according to FOP AASHTO R 47?	_____	_____
5. Asphalt mixture heated to compaction temperature range?	_____	_____
6. Mold, base plate, and upper plate heated to compaction temperature range?	_____	_____
7. Mold, base plate, and upper plate (if required) removed from oven and paper disk placed on bottom of mold?	_____	_____
8. Mix placed into mold in one lift without segregation?	_____	_____
9. Paper disk placed on top of the asphalt mixture?	_____	_____
10. Mold placed into compactor and upper plate clamped into place?	_____	_____
11. Pressure applied at 600 kPa ±18 kPa?	_____	_____
12. Specified number of gyrations applied?	_____	_____
13. Proper angle confirmed from display?	_____	_____
14. Compacted specimen removed from mold, paper disc(s) removed, and allowed to cool to room temperature?	_____	_____
15. Asphalt mixture sample measured to a height of 115 ±5 mm at required gyrations?	_____	_____

Comments: First attempt: Pass_____Fail_____ Second attempt: Pass_____Fail_____

_____
_____
_____
_____
_____
_____
_____
_____

Examiner Signature _____WAQTC #:_____

VOLUMETRIC PROPERTIES OF HOT MIX ASPHALT (HMA) WAQTC TM 13

Scope

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02 This procedure covers the determination of volumetric properties of plant produced Hot Mix Asphalt, i.e., air voids (V_a), voids in mineral aggregate (VMA), voids filled with asphalt binder (VFA), effective asphalt binder content (P_{be}) and Dust to Binder Ratio ($P_{\#200}/P_{be}$). The in-production volumetric properties are then compared to agency specifications.

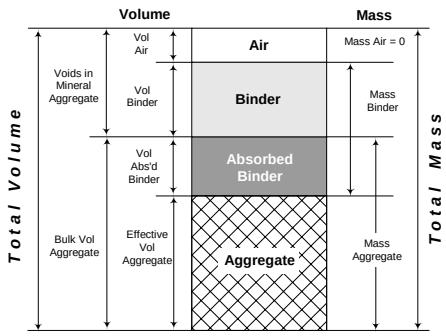
Definition of Terms

- G_{mm} = theoretical maximum specific gravity (Gravity $_{mix\ max}$)
- G_{mb} = measured bulk specific gravity (Gravity $_{mix\ bulk}$)
- G_{sb} = oven-dry bulk specific gravity of aggregate (Gravity $_{stone\ bulk}$)
- G_{sa} = apparent specific gravity of aggregate (Gravity $_{stone\ apparent}$)
- G_{se} = effective specific gravity of aggregate (Gravity $_{stone\ effective}$)
- G_b = specific gravity of the binder (Gravity $_{binder}$)
- V_a = air Voids (Voids $_{air}$)
- VMA = Voids in Mineral Aggregate
- VFA = Voids Filled with Asphalt (binder)
- V_{ba} = absorbed binder volume (Voids $_{binder\ absorbed}$)
- V_{be} = effective binder volume (Voids $_{binder\ effective}$)
- P_b = percent binder content (Percent $_{binder}$)
- P_{ba} = percent absorbed binder (Percent $_{binder\ absorbed}$)
- P_{be} = percent effective binder content (Percent $_{binder\ effective}$)
- P_s = percent of aggregate (Percent $_{stone}$)
- DP = Dust proportion to effective binder ratio ($P_{\#200}/P_{be}$)

03

Background

Whether a mix design is developed through a Marshall, Hveem, or Superpave mix design process there are basic volumetric requirements of all. Volumetric properties are the properties of a defined material contained in a known volume. HMA Volumetric properties can include bulk specific gravity, theoretical maximum specific gravity, air voids, and voids in mineral aggregate.



HMA Phase Diagram

04

Many agencies specify values of the volumetric properties to ensure optimum performance of the pavement. The HMA must be designed to meet these criteria. In production the HMA is evaluated to determine if the mix still meets the specifications and is consistent with the original mix design (JMF). The production HMA may vary from the mix design and may need to be modified to meet the specified volumetric criteria.

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To compare the in-production volumetric properties to agency specifications and the JMF a sample of loose HMA mix is obtained in accordance with FOP for AASHTO T 168. The sample is then compacted in a gyratory compactor to simulate the in-place HMA pavement after it has been placed, compacted, and the volumetric properties of the compacted sample are determined.

07

Each of the properties in the HMA phase diagram can be measured or calculated. For example: The mass of the aggregate is measured; the voids in mineral aggregate (VMA) is calculated; total asphalt binder can be measured but the amount available to act as a binder in the mix must be calculated because it is the quantity left after the aggregate has absorbed some of the asphalt binder.

08

The volumetric proportions of the asphalt binder and aggregate components of an asphalt mixture and their relationship to the other

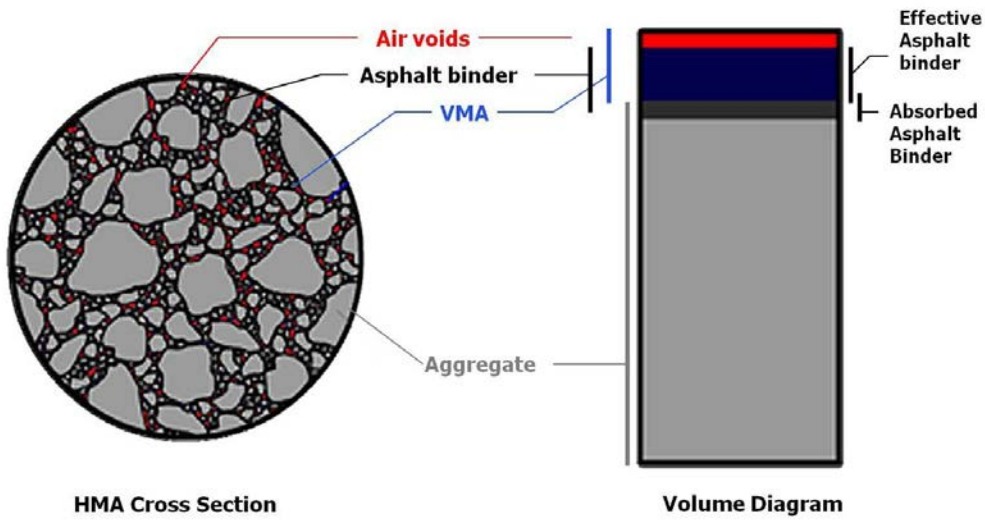
09

components are considered. The mass of the components and their specific gravities are used to determine the volumes of each of the components in the mix. The volumetric properties of a compacted HMA paving mixture: air voids (V_a), voids in mineral aggregate (VMA), voids filled with asphalt binder (VFA), and effective asphalt binder content (P_{be}) provide some indication of the mixtures probable performance.

Volumetric Properties

10

Volumetric Relationship of HMA Constituents



Required Values

The specific gravities listed in Table 1 and the percent by mass of each of the components in the HMA are needed to determine the volumetric properties. Other values required are also listed. Some of these values are obtained from the JMF and some are measured from a plant produced HMA sample.

11, 12

Table 1

Data	Test Method	Obtained
G_{sb} - combined aggregate bulk specific gravity	AASHTO T 84 / T 85 or agency approved test method	JMF or performed at the beginning of placement
G_b – measured specific gravity of the asphalt binder	AASHTO T 228	JMF or from the supplier
G_{mm} – measured maximum specific gravity of the loose mix	FOP for AASHTO T 209	Performed on the field test sample
G_{mb} – measured bulk specific gravity of the compacted paving mix	FOP for AASHTO T 166	Performed on the field compacted specimen
P_b – percent asphalt binder	FOP for AASHTO T 308	Performed on the field test sample
$P_{-\#200}$ – aggregate passing the #200 (75 µm) sieve	FOP for AASHTO T 30	Performed on the field test sample

13

Air Voids (V_a)

Air voids are the total volume of the small pockets of air between the coated aggregate particles throughout a compacted paving mixture. Appropriate air voids contribute to the stability of the HMA and help the pavement withstand the combined action of environment and traffic loads. The designated percent air voids allows for thermal expansion of the asphalt binder and contributes a cushion for future compaction. Air voids are expressed as a percent of the bulk volume of the compacted mixture (G_{mb}) when compared to the maximum specific gravity (G_{mm}).

14

$$V_a = 100\left[\frac{(G_{mm} - G_{mb})}{G_{mm}}\right]$$

Where:

V_a = air voids in compacted mixture, percent of total volume (report to 0.1)

G_{mm} = maximum specific gravity of paving mixture (AASHTO T 209)

G_{mb} = bulk specific gravity of compacted mixture (AASHTO T 166)

15 **Percent Aggregate (Stone) (P_s)**

P_s is the percent aggregate (stone) content, expressed as a percentage of the total mass of the sample.

$$P_s = 100 - P_b$$

Where:

P_s = percent aggregate (stone) percent by total weight

P_b = asphalt binder content (AASHTO T 308)

16 **Voids in the Mineral Aggregate (VMA)**

VMA is the volume of intergranular void space between the aggregate particles of the compacted paving mixture that includes the air voids and the effective binder content, expressed as a percent of the total volume of the sample.

$$VMA = 100 - \left[\frac{(G_{mb} \times P_s)}{G_{sb}}\right]$$

Where:

VMA = voids in mineral aggregate, percent of bulk volume (report to 0.1**)**

G_{sb} = bulk specific gravity of combined aggregate (AASHTO T 85 / T 84 or agency approved method from Job Mix Formula)

G_{mb} = bulk specific gravity of compacted mixture (AASHTO T 166)

P_s = aggregate content, percent by total weight = 100 – P_b

P_b = asphalt binder content (AASHTO T 308) percent by total weight

17 **Voids Filled with Asphalt (binder) (VFA)**

VFA is the volume of space between the aggregate particles of the compacted paving mixture filled with asphalt binder, expressed as a percent of the total volume of the sample. The VFA increases as the asphalt binder content increases as it is the percent of voids that are filled with asphalt which doesn't include the absorbed asphalt.

$$VFA = 100\left[\frac{(VMA - V_a)}{VMA}\right]$$

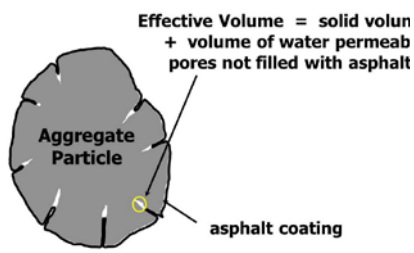
Where:

VFA = voids filled with asphalt, percent of VMA (report to 1)

VMA = voids in mineral aggregate, percent of bulk volume

V_a = air voids in compacted mixture, percent of total volume.

18 **Effective Specific Gravity of the**
19 **Aggregate (Stone) (G_{se})**



G_{se}

The G_{se} is used to quantify the asphalt binder absorbed into the aggregate particle. This is a calculated value based on the specific gravity of the mixture, G_{mm}, and the specific gravity of the asphalt binder, G_b This measurement includes the volume of the aggregate particle plus the void volume that becomes filled with water during the test soak period minus the volume of the voids that absorb asphalt binder. Effective specific gravity lies between apparent and bulk specific gravity.

G_{se} is formally defined as the ratio of the mass in air of a unit volume of a permeable material (excluding voids permeable to asphalt binder) at a stated temperature to the mass in air (of equal density) of an equal volume of gas-free distilled water at a stated temperature.

$$G_{se} = \frac{P_s}{\left[\left(\frac{100}{G_{mm}}\right) - \left(\frac{P_b}{G_b}\right)\right]}$$

Where:

G_{se} = effective specific gravity of combined aggregate (report to 0.001)

P_s = aggregate content, percent by total weight = 100 – P_b

G_{mm} = maximum specific gravity of mix (AASHTO T 209)

P_b = asphalt binder content (AASHTO T 308) percent by total weight

G_b = specific gravity of asphalt binder (JMF or asphalt binder supplier)

20

Percent of Absorbed (asphalt) Binder (P_{ba})

P_{ba} is the total percent of the asphalt binder that is absorbed into the aggregate, expressed as a percentage of the mass of aggregate rather than as a percentage of the total mass of the mixture. This portion of the asphalt binder content does not contribute to the performance of the mix.

$$P_{ba} = 100\left[\frac{(G_{se} - G_{sb})}{(G_{sb} \times G_{se})}\right]G_b$$

Where:

P_{ba} = absorbed asphalt binder (report to 0.01) percent of aggregate

G_{se} = effective specific gravity of combined aggregate

G_{sb} = bulk specific gravity of combined aggregate (AASHTO T 85 / T 84 or agency approved method from Job Mix Formula)

G_b = specific gravity of asphalt binder (JMF or asphalt binder supplier)

21

Percent of Effective (asphalt) Binder (P_{be})

P_{be} is the total asphalt binder content of a paving mixture minus the portion of asphalt binder that is lost by absorption into the aggregate particles, expressed as a percentage of the mass of aggregate. It is the portion of the asphalt binder content that remains as a coating on the outside of the aggregate particles. This is the asphalt content that controls the performance of the mix.

$$P_{be} = P_b - \left[\frac{P_{ba}}{100} \times P_s\right]$$

Where:

P_{be} = effective asphalt binder content (report to 0.01), percent by total weight

P_s = aggregate content, percent by total weight = 100 – P_b

P_b = asphalt binder content (AASHTO T 308) percent by total weight

P_{ba} = absorbed asphalt binder

22

Dust Proportion – DP (Dust to Effective (asphalt) Binder Ratio)

The DP is the percent passing the No. 200 (75 µm) sieve of the gradation divided by the percent of effective asphalt binder. Excessive dust reduces asphalt binder film thickness on the aggregate which reduces the durability. Insufficient dust may allow excessive asphalt binder film thickness, which may result in a tender, unstable mix.

$$DP = \frac{P_{-\#200}}{P_{be}}$$

Where:

DP = Dust Proportion, (dust-to-binder ratio) (report to 0.01)

$P_{-\#200}$ = aggregate passing the No. 200 (75 µm) sieve, percent by mass of aggregate (AASHTO T 30)

P_{be} = effective asphalt binder content, percent by total weight

Mix Design and Production Values

Job Mix Formula

23

Table 2 includes example data required from the JMF. Some of these values are used in the example calculations.

Note: Some of the targets may change after the HMA is in production based on field test data.

Table 2 24

JMF Data	
Asphalt binder grade	PG 64-28
N_{values}	N_{ini} = 7 **N_{des} = 75** N_{max} = 115
G_{sb} (combined specific gravity of the aggregate)	2.678
Target P_b	4.75%
Initial sample mass for gyratory specimens	4840 grams
Mixing temperature range	306 – 312 °F
Laboratory compaction temperature range	286 – 294 °F
G_b (specific gravity of the asphalt binder)	1.020

Target gradation	
Sieve Size mm (in.)	**Percent Passing**
19.0 (3/4)	100
12.5 (1/2)	85
9.5 (3/8)	80
4.75 (No. 4)	50
2.36 (No. 8)	30
01.18 (No. 16)	25
0.600 (No. 30)	15
0.300 (No. 50)	10
0.150 (No. 100)	7
75 µm (No. 200)	5.0

Sample Test Result

25

Tables 3 and 4 include data from test results performed on a field sample of HMA used in the example calculations.

Table 3

Field Data		
	Test method	**Example values**
P_b	FOP for AASHTO T 308	4.60%
G_{mb}	FOP for AASHTO T 166	2.415
G_{mm}	FOP for AASHTO T 209	2.516

Table 4

26

Sieve Analysis FOP for AASHTO T 30	
Sieve Size mm (in.)	**Percent Passing**
19.0 (3/4)	100
12.5 (1/2)	86
9.5 (3/8)	77
4.75 (No. 4)	51
2.36 (No. 8)	34
01.18 (No. 16)	23
0.600 (No. 30)	16
0.300 (No. 50)	12
0.150 (No. 100)	8
75 µm (No. 200)	4.9

Sample Calculations

Air Voids (V_a)

27

$$V_a = 100\left[\frac{(G_{mm} - G_{mb})}{G_{mm}}\right]$$

$$V_a = 100\left[\frac{(2.516 - 2.415)}{2.516}\right] = 4.01431\%\ report\ 4.0\%$$

Given:

G_{mm} = 2.516

G_{mb} = 2.415

Percent Aggregate (Stone) (P_s)

28

$$P_s = 100 - P_b$$

$$P_s = 100.0 - 4.60\% = 95.40\%$$

Given:

P_b = 4.60%

Voids in the Mineral Aggregate (VMA)

29

$$VMA = 100 - \left[\frac{(G_{mb} \times P_s)}{G_{sb}}\right]$$

$$VMA = 100.0 - \left[\frac{2.415 \times 95.40\%)}{2.678}\right] = 13.96\%\ report\ 14.0\%$$

Given:

G_{sb} =2.678

Voids Filled with Asphalt (binder) (VFA)

30

$$VFA = 100\left[\frac{(VMA - V_a)}{VMA}\right]$$

$$VFA = 100\left[\frac{(14.0\% - 4.0\%)}{14.0\%}\right] = 71.4\%\ report\ 71\%$$

Effective Specific Gravity of the Aggregate (Stone) (G_{se})

31, 32

$$G_{se} = \frac{P_s}{\left[\left(\frac{100}{G_{mm}}\right) - \left(\frac{P_b}{G_b}\right)\right]}$$

$$G_{se} = \frac{(100 - 4.60\%)}{\left[\left(\frac{100}{2.516}\right) - \left(\frac{4.60\%}{1.020}\right)\right]} =$$

$$G_{se} = \frac{95.40\%}{39.7456 - 4.5098} = 2.70747\ report\ 2.707$$

Given:

G_b = 1.020

Percent of Absorbed (asphalt) Binder (P_{ba})

33, 34

$$P_{ba} = 100\left[\frac{(G_{se} - G_{sb})}{(G_{sb} \times G_{se})}\right] G_b$$

$$P_{ba} = 100\left[\frac{(2.707 - 2.678)}{(2.678 \times 2.707)}\right] 1.020 =$$

$$P_{ba} = 100\left[\frac{0.0290}{7.2493}\right] 1.020 = 0.40804\%\ \text{report}\ 0.41\%$$

Percent of Effective (asphalt) Binder (P_{be})

35

$$P_{be} = P_b - \left[\frac{P_{ba}}{100} \times P_s\right]$$

$$P_{be} = 4.60 - \left[\frac{0.41\%}{100} \times (100.0 - 4.60\%)\right] = 4.20886\% \text{ report } 4.21\%$$

Dust Proportion – DP (Dust to Effective (asphalt) Binder Ratio)

36

$$DP = \frac{P_{-\#200}}{P_{be}}$$

$$DP = \frac{4.9\%}{4.21\%} = 1.16390 \text{ report } 1.16$$

Given:

$P_{-\#200}$ = 4.9%

37

Report

38

- Results on forms approved by the agency
- Sample ID
- Air Voids, V_a to 0.1 percent
- Voids in the Mineral Aggregate, VMA to 0.1 percent
- Voids Filled with Asphalt, VFA to nearest whole value
- Effective Specific Gravity of Aggregate (stone), G_{se} to 0.001
- Percent Absorbed (asphalt) Binder Absorbed, P_{ba} to 0.01
- Percent Effective (asphalt) Binder, P_{be} to 0.01
- Dust Proportion, DP to 0.01

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Appendix - Formulas

Air Voids (V_a)

$$V_a = 100\left[\frac{(G_{mm} - G_{mb})}{G_{mm}}\right]$$

Where:

V_a = air voids in compacted mixture, percent of total volume (report to 0.1)
G_{mm} = maximum specific gravity of paving mixture (AASHTO T 209)
G_{mb} = bulk specific gravity of compacted mixture (AASHTO T 166)

Percent Aggregate (Stone) (P_s)

$$P_s = 100 - P_b$$

Where:

P_s = percent aggregate (stone) percent by total weight
P_b = asphalt binder content (AASHTO T 308)

Voids in the Mineral Aggregate (VMA)

$$VMA = 100 - \left[\frac{(G_{mb} \times P_s)}{G_{sb}}\right]$$

Where:

VMA = voids in mineral aggregate, percent of bulk volume (report to 0.1**)**

G_{sb} = bulk specific gravity of combined aggregate (AASHTO T 85 / T 84 or agency approved method from Job Mix Formula)

G_{mb} = bulk specific gravity of compacted mixture (AASHTO T 166)

P_s = aggregate content, percent by total weight = 100 – P_b

P_b = asphalt binder content (AASHTO T 308) percent by total weight

Voids Filled with Asphalt (binder) (VFA)

$$VFA = 100\left[\frac{(VMA - V_a)}{VMA}\right]$$

Where:

VFA = voids filled with asphalt, percent of VMA (report to 1)
VMA = voids in mineral aggregate, percent of bulk volume
V_a = air voids in compacted mixture, percent of total volume.

Effective Specific Gravity of the Aggregate (Stone) (G_{se})

$$G_{se} = \frac{P_s}{\left[\left(\frac{100}{G_{mm}}\right) - \left(\frac{P_b}{G_b}\right)\right]}$$

Where:

G_{se} = effective specific gravity of combined aggregate (report to 0.001)
P_s = percent aggregate (stone) (report to 0.1) percent by total weight
G_{mm} = maximum specific gravity of mix (AASHTO T 209)
P_b = asphalt binder content (AASHTO T 308) percent by total weight
G_b = specific gravity of asphalt binder (JMF or asphalt binder supplier)

Percent of Absorbed (asphalt) Binder (P_{ba})

$$P_{ba} = 100\left[\frac{(G_{se} - G_{sb})}{(G_{sb} \times G_{se})}\right]G_b$$

Where:

P_{ba} = absorbed asphalt binder (report to 0.1) percent of aggregate
G_{se} = effective specific gravity of combined aggregate
G_{sb} = bulk specific gravity of combined aggregate (AASHTO T 85 from Job Mix Formula)
G_b = specific gravity of asphalt binder (JMF or asphalt binder supplier)

Percent of Effective (asphalt) Binder (P_{be})

$$P_{be} = P_b - \left[\frac{P_{ba}}{100} \times P_s\right]$$

Where:

P_{be} = effective asphalt binder content, percent by total weight

P_s = aggregate content, percent by total weight = 100 – P_b

P_b = asphalt binder content (AASHTO T 308) percent by total weight

P_{ba} = absorbed asphalt binder

Dust Proportion – DP (Dust to Effective (asphalt) Binder Ratio)

$$DP = \frac{P_{-\#200}}{P_{be}}$$

Where:

DP = Dust Proportion, (dust-to-binder ratio)

$P_{-\#200}$ = aggregate passing the #200 (0.075 mm) sieve, percent by mass of aggregate (AASHTO T 30)

P_{be} = effective asphalt binder content, percent by total weight

REVIEW QUESTIONS

1. Why is it important to determine volumetric properties?

2. Where does P_s come from?

3. What specific gravities are necessary to determine V_a?

4. What is the volume that is not filled with aggregate (stone)?

5. What does VMA include?

APPENDIX A
FIELD OPERATING PROCEDURES - SHORT FORMS

Chapter **Section**

13. AASHTO T 168
    Sampling Bituminous Paving Mixtures

14. AASHTO R 47
    Reducing Samples of Asphalt Mixtures to Testing Size

15. AASHTO T 329
    Moisture Content of Asphalt Mixtures by Oven Method

16. AASHTO T 308
    Determining the Asphalt Binder Content of Hot Mix Asphalt (HMA) by the Ignition Method

17. AASHTO T 209
    Theoretical Maximum Specific Gravity (G_{mm}) and Density of Hot Mix Asphalt (HMA) Paving Mixtures

18. AASHTO T 166
    Bulk Specific Gravity (G_{mb}) of Compacted Hot-Mix Asphalt (HMA) Mixtures Using Saturated Surface-Dry Specimens

19. AASHTO R 66
    Sampling Asphalt Materials

20. AASHTO T 30
    Mechanical Analysis of Extracted Aggregate

21. AASHTO T 312
    Asphalt Mixtures Specimens by Means of the Superpave Gyratory Compactor

22. WAQTC TM 13
    Volumetric Properties of Hot Mix Asphalt (HMA)

23. AASHTO T 255
    Total Evaporable Moisture Content of Aggregate by Drying

SAMPLING OF BITUMINOUS PAVING MIXTURES
FOP FOR AASHTO T 168

Scope

This procedure covers the sampling of bituminous paving mixtures from HMA plants, haul units, and roadways in accordance with AASHTO T 168-03. Sampling is as important as testing, and every precaution must be taken to obtain a truly representative sample.

Apparatus

- Shovel
- Sample containers: such as cardboard boxes, metal cans, stainless steel bowls, or other agency-approved containers
- Scoops, trowels, or other equipment to obtain mix
- Sampling plate: Thick metal plate, minimum 8 gauge, sized to accommodate sample requirements, with a wire attached to one corner long enough to reach from the center of the paver to the outside of the farthest auger extension. Holes ¼ in. in diameter should be provided in each corner.
- Cookie cutter sampling device: Formed steel angle with two 100 mm by 150 mm by 9 mm (4 in. by 6 in. by 3/8 in.) handles, sized to accommodate sample requirements. Minimum 2 in. smaller than the sampling plate when used together.

  Example: Sampling plate 380 mm (15 in.) square and a cookie cutter sampling device 330 mm (13 in.) square.
- Mechanical sampling device

Sample Size

Sample size depends on the test methods specified by the agency for acceptance. Check agency requirement for the size required.

Sampling

General

- The material shall be tested to determine variations. The supplier/contractor shall provide equipment for safe and appropriate sampling, including sampling devices on plants when required.

- For dense graded mixture samples use cardboard boxes, stainless steel bowls or other agency-approved containers.

- For hot open graded mixture samples use stainless steel bowls. Do not put open graded mixture samples in boxes until they have cooled to the point that bituminous material will not migrate from the aggregate.

Attached Sampling Devices

Some agencies require mechanical sampling devices for hot mix asphalt (HMA) and cold feed aggregate on some projects. These are normally permanently attached devices that allow a sample container to pass perpendicularly through the entire stream of material or divert the entire stream of material into the container. Operation may be hydraulic, pneumatic, or manual and allows the sample container to pass through the stream twice, once in each direction, without overfilling. Special caution is necessary with manually operated systems since a consistent speed is difficult to maintain and non-representative samples may result. Check agency requirements for the specifics of required sampling systems.

1. Lightly coat the container attached to the sampling device with an agency-approved release agent or preheat it, or both, to approximately the same discharge temperature of the mix.

2. Pass the container twice through the material perpendicularly without overfilling the container.

3. Repeat until proper sample size has been obtained.

4. Transfer the HMA to an agency-approved container without loss of material.

Sampling from Haul Units

1. Visually divide the haul unit into approximately four equal quadrants.

2. Identify one sampling location in each quadrant.

3. Dig down and remove approximately 0.3 m (1 ft.) of material to avoid surface segregation. Obtain each increment from below this level.

4. Combine the increments to form a sample of the required size.

Sampling from Roadway Prior to Compaction (Plate Method)

Plate method using the “cookie cutter” sampling device.

There are two conditions that will be encountered when sampling hot mix asphalt (HMA) from the roadway prior to compaction. The two conditions are:

- Laying HMA on grade or untreated base material requires Method 1.

- Laying HMA on existing asphalt or laying a second lift of HMA requires Method 2.

SAFETY:

Sampling is performed behind the paving machine and in front of the breakdown roller. For safety, the roller must remain at least 3 m (10 ft.) behind the sampling operation until the sample has been taken and the hole filled with loose HMA.

Method 1 requires a plate to be placed in the roadway in front of the paving operation and therefore there is always concern with moving, operating equipment. It is safest to stop the paving train while a plate is installed in front of the paver. When this is not possible the following safety rules must be followed.

1. The plate placing operation must be at least 3 m (10 ft.) in front of the paver or pickup device. The technician placing the plate must have eye contact and communication with the paving machine operator. If eye contact cannot be maintained at all time, a third person must be present to provide communication between the operator and the technician.

2. No technician is to be between the asphalt supply trucks and the paving machine. The exception to this rule is if the supply truck is moving forward creating a windrow, in which case the technician must be at least 3 m (10 ft.) behind the truck.

If at any time the Engineer feels that the sampling technique is creating an unsafe condition, the operation is to be halted until it is made safe or the paving operation will be stopped while the plate is being placed.

Method 1 - Obtaining a Sample on Untreated Base:

1. Following the safety rules detailed above, the technician is to:

    a. Smooth out a location in front of the paver at least 0.5 m (2 ft.) inside the edge of the mat.

    b. Lay the plate down diagonally with the direction of travel, keeping it flat and tight to the base with the lead corner facing the paving machine.

2. Secure the plate in place by driving a nail through the hole in the lead corner of the plate.

3. Pull the wire, attached to the outside corner of the plate, taut past the edge of the HMA mat and secure with a nail.

4. Let the paving operation proceed over the plate and wire. Immediately proceed with the sampling.

5. Using the exposed end of the wire, pull the wire up through the fresh HMA to locate the corner of the plate. Place the "cookie cutter" sample device, just inside the end of the wire; align the cutter over the plate. Press "cookie cutter" device down through the HMA to the plate.

6. Using a small square tipped shovel or scoop, or both, carefully remove all the HMA from inside of the cutter and place in a sample container. Care shall be taken to prevent contamination of bituminous mixes by dust or other foreign matter, and to avoid segregation of aggregate and bituminous materials.

7. Remove the sample cutter and the plate from the roadway. The hole made from the sampling must be filled by the contractor with loose HMA.

Method 2 - Obtaining a Sample on Asphalt Surface:

1. After the paving machine has passed the sampling point, immediately place the "cookie cutter" sampling device on the location to be sampled. Push the cutter down through the HMA until it is flat against the underlying asphalt mat.

2. Using a small square tipped shovel or scoop, or both, carefully remove all the HMA from inside of the cutter and place in a sample container. The hole made from the sampling must be filled by the contractor with loose HMA.

Identification and Shipping

1. Identify sample containers as required by the agency.

2. Ship samples in containers that will prevent loss, contamination, or damage.

Report

- On forms approved by the agency
- Sample ID
- Date
- Time
- Location
- Quantity represented

REDUCING SAMPLES OF HOT MIX ASPHALT (HMA) TO TESTING SIZE FOP FOR AASHTO R 47

Scope

This procedure covers sample reduction of Hot Mix Asphalt (HMA) to testing size in accordance with AASHTO R 47-14. The reduced portion is to be representative of the original sample.

Apparatus

- Thermostatically controlled oven capable of maintaining a temperature of at least 110°C (230°F) or high enough to heat the material to a pliable condition for splitting.

- Non-contact temperature measuring device.

- Metal spatulas, trowels, metal straightedges, or drywall taping knives, or a combination thereof; for removing HMA samples from the quartering device, cleaning surfaces used for splitting, etc.

- Square-tipped, flat-bottom scoop, shovel or trowel for mixing HMA prior to quartering.

- Miscellaneous equipment including hot plate, non-asbestos heat-resistant gloves or mittens, pans, buckets, and cans.

- Sheeting: Non-stick heavy paper, heat-resistant plastic, or other material as approved by the agency.

- Agency-approved release agent, free of solvent or petroleum-based material that could affect asphalt binder.

- Mechanical Splitter Type A (Quartermaster): having four equal-width chutes discharging into four appropriately sized sample receptacles. Splitter is to be equipped with a receiving hopper that will hold the sample until the release lever is activated with four sample receptacles of sufficient capacity to accommodate the reduced portion of the HMA sample from the mechanical splitter. Refer to AASHTO R 47, Figures 1 through 3, for configuration and required dimensions of the mechanical splitter.

- Mechanical Splitter Type B (Riffle): having a minimum of eight equal-width chutes discharging alternately to each side with a minimum chute width of at least 50% larger than the largest particle size. A hopper or straight-edged pan with a width equal to or slightly smaller than the assembly of chutes in the riffle splitter to permit uniform discharge of the HMA through the chutes without segregation or loss of material. Sample receptacles of sufficient width and capacity to receive the reduced portions of HMA from the riffle splitter without loss of material.

- Quartering Template: formed in the shape of a cross with equal length sides at right angles to each other. Template shall be manufactured of metal that will withstand heat and use without deforming. The sides of the quartering template should be sized so that the length exceeds the diameter of the flattened cone of HMA by an amount allowing complete separation of the quartered sample. Height of the sides must exceed the thickness of the flattened cone of HMA.

- Non-stick mixing surface that is hard, heat-resistant, clean, level, and large enough to permit HMA samples to be mixed without contamination or loss of material.

Sampling

Obtain samples according to the FOP for AASHTO T 168.

Sample Preparation

The sample must be warm enough to separate. If not, warm in an oven until it is sufficiently soft to mix and separate easily. Do not exceed either the temperature or time limits specified in the test method(s) to be performed.

Selection of Procedure (Method)

Refer to agency requirements when determining the appropriate method(s) of sample reduction. In general, the selection of a particular method to reduce a sample depends on the initial size of the sample vs. the size of the sample needed for the specific test to be performed. It is recommended that, for large amounts of material, the initial reduction be performed using a mechanical splitter. This decreases the time needed for reduction and minimizes temperature loss. Further reduction of the remaining HMA may be performed by a combination of the following methods, as approved by the agency. The methods for reduction are:

- Mechanical Splitter Method
  - Type A (Quartermaster)
  - Type B (Riffle Splitter)
- Quartering Method
  - Full Quartering
  - By Apex
- Incremental Method

Procedure

Mechanical Splitter Type A (Quartermaster)

1. Clean the splitter and apply a light coating of approved release agent to the surfaces that will contact HMA.

2. Close and secure hopper gates.

3. Place the four sample receptacles in the splitter so that there is no loss of material.

4. Remove the sample from the agency-approved container(s) and place in the mechanical splitter hopper. Avoid segregation, loss of HMA or the accidental addition of foreign material.

5. Release the handle, allowing the HMA to drop through the divider chutes and discharge into the four receptacles.

6. Any HMA that is retained on the surface of the splitter shall be removed and placed into the appropriate receptacle.

7. Close and secure the hopper gates.

8. Reduce the remaining HMA as needed by this method or a combination of the following methods as approved by the agency.

9. Combine the material contained in the receptacles from opposite corners and repeat the splitting process until an appropriate sample size is obtained.

10. Retain and properly identify the remaining unused portion of the HMA sample for further testing if required by the agency.

Mechanical Splitter Type B (Riffle)

1. When heating of the testing equipment is desired, it shall be heated to a temperature not to exceed 110ºC (230ºF).

2. Clean the splitter and apply a light coating of approved release agent to the surfaces that will come in contact with HMA (hopper or straight-edged pan, chutes, receptacles).

3. Place two empty receptacles under the splitter.

4. Carefully empty the HMA from the agency-approved container(s) into the hopper or straight-edged pan without loss of material. Uniformly distribute from side to side of the hopper or pan.

5. Discharge the HMA at a uniform rate, allowing it to flow freely through the chutes.

6. Any HMA that is retained on the surface of the splitter shall be removed and placed into the appropriate receptacle.

7. Reduce the remaining HMA as needed by this method or a combination of the following methods as approved by the agency.

8. Using one of the two receptacles containing HMA, repeat the reduction process until the HMA contained in one of the two receptacles is the appropriate size for the required test.

9. After each split, remember to clean the splitter hopper and chute surfaces if needed.

10. Retain and properly identify the remaining unused HMA sample for further testing if required by the agency.

Quartering Method

1. When heating of the testing equipment is desired, it shall be heated to a temperature not to exceed the mix temperature.

2. If needed, apply a light coating of release agent to quartering template.

3. Dump the sample from the agency approved container(s) into a conical pile on a hard, “non-stick,” clean, level surface where there will be neither a loss of material nor the accidental addition of foreign material. The surface can be made non-stick by the application of an approved asphalt release agent, or sheeting.

4. Mix the material thoroughly by turning the entire sample over a minimum of four times with a flat-bottom scoop; or by alternately lifting each corner of the sheeting and pulling it over the sample diagonally toward the opposite corner, causing the material to be rolled. Create a conical pile by either depositing each scoop or shovelful of the last turning on top of the preceding one, or lifting both opposite corners.

5. Flatten the conical pile to a uniform diameter and thickness where the diameter is four to eight times the thickness. Make a visual observation to ensure that the material is homogeneous.

6. Divide the flattened cone into four equal quarters using the quartering template. Press the template down until it is in complete contact with the surface on which the sample has been placed, assuring complete separation.

   Note 1: Straightedges may be used in lieu of the quartering device to completely separate the material in approximately equal quarters.

7. Reduce the sample by quartering the sample completely or by removing the sample from the apex.

8. Full Quartering

    8a. Remove two diagonally opposite quarters, including all of the fine material.

    8b. Remove the quartering template and combine the remaining quarters, again forming a conical pile.

    8c. Repeat steps 4, 5, 6, 8a, and 8b until a sample of the required size has been obtained. The final sample must consist of the two remaining diagonally opposite quarters.

    8d. Retain and properly identify the remaining unused portion of the HMA sample for further testing if required by the agency.

9. By Apex

    9a. Using a straightedge, slice through a quarter of the HMA from the center point to the outer edge of the quarter.

    9b. Pull or drag the material from the quarter with two straight edges or hold one edge of the straightedge in contact with quartering device.

    9c. Remove an equal portion from the opposite quarter and combine these increments to create the required sample size.

    9d. Continue using the apex method with the unused portion of the HMA until samples have been obtained for all required tests.

    9e. Retain and properly identify the remaining unused portion of the HMA sample for further testing if required by the agency.

Incremental Method

1. Cover a hard, clean, level surface with sheeting. This surface shall be large enough that there will be neither a loss of material nor the accidental addition of foreign material.

2. Place the sample from the agency approved container(s) into a conical pile on that surface.

3. Mix the material thoroughly by turning the entire sample over a minimum of four times with a flat-bottom scoop; or by alternately lifting each corner of the sheeting and pulling it over the sample diagonally toward the opposite corner, causing the material to be rolled. Create a conical pile by either depositing each scoop or shovelful of the last turning on top of the preceding one, or lifting both opposite corners.

4. Grasp the sheeting and roll the conical pile into a cylinder (loaf), then flatten the top. Make a visual observation to determine that the material is homogenous.

5. Pull the sheeting so at least ¼ of the length of the loaf is off the edge of the counter. Allow this material to drop into a container to be saved. As an alternate, using a straightedge, slice off approximately ¼ of the length of the loaf and place in a container to be saved.

6. Pull material off the edge of the counter and drop into an appropriate size sample pan or container for the test to be performed. Continue removing material from the loaf until the proper size sample has been acquired. As an alternate, using a straightedge, slice off an appropriate size sample from the length of the loaf and place in a sample pan or container.

7. Repeat step 6 until all the samples for testing have been obtained.

   Note 2: When reducing the sample to test size it is advisable to take several small increments, determining the mass each time until the proper minimum size is achieved. Unless the sample size is grossly in excess of the minimum or exceeds the maximum test size, use the sample as reduced for the test.

8. Retain and properly identify the remaining unused portion of the HMA sample for further testing if required by the agency.

MOISTURE CONTENT OF ASPHALT MIXTURES BY OVEN METHOD FOP FOR AASHTO T 329

Scope

This procedure covers the determination of moisture content of asphalt mixtures in accordance with AASHTO T 329-15.

Overview

Moisture content is determined by comparing the wet mass of a sample and the mass of the sample after drying to constant mass. The term constant mass is used to define when a sample is dry.

Constant mass – the state at which a mass does not change more than a given percent, after additional drying for a defined time interval, at a required temperature.

Apparatus

- Balance or scale: 2 kg capacity, readable to 0.1 g and conforming to AASHTO M 231.
- Forced draft, ventilated, or convection oven: Capable of maintaining the temperature surrounding the sample at 163 ±14°C (325 ±25°F).
- Sample Container: Clean, dry, not affected by heat and of sufficient size to contain a test sample without danger of spilling.
- Thermometer or other suitable device with a temperature range of 10-260°C (50-500°F).

Sample

The test sample shall be obtained in accordance with the FOP for AASHTO T 168, and reduced in accordance with the FOP for AASHTO R 47. The size of the test sample shall be a minimum of 1000 g.

Procedure

1. Preheat the oven to the Job Mix Formula (JMF) mixing temperature range. If the mixing temperature is not supplied, a temperature of 163 ±14ºC (325 ±25ºF) is to be used.

   Note 1: For repeatability between laboratories, the preferred practice is to dry the sample at no less than 9° C (15° F) below the JMF mixing temperature.

2. Determine and record the mass of the sample container, including release media, to the nearest 0.1 g.

   Note 2: When using paper or other absorptive material to line the sample container ensure it is dry before determining initial mass of sample container.

3. Place the test sample in the sample container.

4. Determine and record the temperature of the test sample.

5. Determine and record the total mass of the sample container and test sample to the nearest 0.1 g.

6. Calculate the initial, moist mass (M_i) of the test sample by subtracting the mass of the sample container as determined in Step 2 from the total mass of the sample container and the test sample as determined in Step 5.

7. The test sample shall be initially dried for 90 ±5 minutes, and its mass determined. Then it shall be dried at 30 ±5 min intervals until further drying does not alter the mass by more than 0.05 percent.

8. Cool the sample container and test sample to ±9°C (±15°F) of the temperature determined in Step 4.

9. Determine and record the total mass of the sample container and test sample to the nearest 0.1 g.

   Note 3: Do not attempt to remove the test sample from the sample container for the purposes of determining mass.

10. Calculate the final, dry mass (M_f) of the test sample by subtracting the mass of the sample container as determined in Step 2 from the total mass of the sample container and the test sample as determined in Step 9.

    Note 4: Moisture content and the number of samples in the oven will affect the rate of drying at any given time. Placing wet samples in the oven with nearly dry samples could affect the drying process.

Calculations

Constant Mass:

Calculate constant mass using the following formula:

$$\%Change = \frac{M_p - M_n}{M_p} \times 100$$

Where: M_p = previous mass measurement

M_n = new mass measurement

Example:

Mass of container: 232.6 g

Mass of container and sample after first drying cycle: 1361.8 g

Mass, M_p, of possibly dry sample: 1361.8 g – 232.6 g = 1129.2 g

Mass of container and possibly dry sample after second drying cycle: 1360.4 g

Mass, M_n, of possibly dry sample: 1360.4 g – 232.6 g = 1127.8 g

$$\frac{1129.2\ g - 1127.8\ g}{1129.2\ g} \times 100 = 0.12\%$$

0.12 percent is not less than 0.05 percent, so continue drying the sample.

Mass of container and possibly dry sample after third drying cycle: 1359.9 g

Mass, M_n, of dry sample: 1359.9 g – 232.6 g = 1127.3 g

$$\frac{1127.8\ g - 1127.3\ g}{1127.8\ g} \times 100 = 0.04\%$$

0.04 percent is less than 0.05 percent, so constant mass has been reached.

Moisture Content:

Calculate the moisture content, as a percent, using the following formula.

$$Moisture\ Content = \frac{M_i - M_f}{M_f} \times 100$$

Where:

M_i = initial, moist mass

M_f = final, dry mass

Example:

M_i = 1134.9 g

M_f = 1127.3 g

$$Moisture\ Content = \frac{1134.9\ g - 1127.3\ g}{1127.3\ g} \times 100 = 0.674, \text{say } 0.67\%$$

Report

- Results on forms approved by the agency
- Sample ID
- Moisture content to 0.01 percent

DETERMINING THE ASPHALT BINDER CONTENT OF HOT MIX ASPHALT (HMA) BY THE IGNITION METHOD
FOP FOR AASHTO T 308

Scope

This procedure covers the determination of asphalt binder content of hot mix asphalt (HMA) by ignition of the binder in accordance with AASHTO T 308-16.

Overview

The sample is heated in a furnace at 538°C (1000°F) or less; samples may be heated by convection or direct infrared irradiation (IR). The aggregate remaining after burning can be used for sieve analysis using the FOP for AASHTO T 30.

Some agencies allow the use of recycled HMA. When using recycled HMA, check with the agency for specific correction procedures.

Asphalt binder in the HMA is ignited in a furnace. Asphalt binder content is calculated as the percentage difference between the initial mass of the HMA and the mass of the residual aggregate, with the asphalt binder correction factor, and moisture content subtracted. The asphalt binder content is expressed as percent of moisture-free mix mass.

Two methods, A and B, are presented.

Apparatus

Note 1: The apparatus must be calibrated for the specific mix design. See "Correction Factors" at the end of this FOP.

There are two methods – A and B. The apparatus for the two methods are the same except that the furnace for Method A has an internal balance.

- Ignition Furnace: A forced-air ignition furnace that heats the specimens by either the convection or direct IR irradiation method. The convection-type furnace must be capable of maintaining the temperature at 538 ± 5°C (1000 ± 9°F).

  For Method A, the furnace will be equipped with an internal scale thermally isolated from the furnace chamber and accurate to 0.1 g. The scale shall be capable of determining the mass of a 3500 g sample in addition to the sample baskets. A data collection system will be included so that mass can be automatically determined and displayed during the test. The furnace shall have a built-in computer program to calculate the change in mass of the sample baskets and provide for the input of a correction factor for aggregate loss. The furnace shall provide a printed ticket with the initial specimen mass, specimen mass loss, temperature compensation, correction factor, corrected binder content, test time, and test temperature. The furnace shall provide an

audible alarm and indicator light when the sample mass loss does not exceed 0.01 percent of the total sample mass for three consecutive minutes.

Note 2: The furnace shall be designed to permit the operator to change the ending mass loss percentage from 0.01 percent to 0.02 percent.

For both Method A and Method B, the furnace chamber dimensions shall be adequate to accommodate a 3500 g sample. The furnace door shall be equipped so that it cannot be opened during the ignition test. A method for reducing furnace emissions shall be provided and the furnace shall be vented so that no emissions escape into the laboratory. The furnace shall have a fan to pull air through the furnace to expedite the test and to eliminate the escape of smoke into the laboratory.

- Sample Basket Assembly: consisting of sample basket(s), catch pan, and basket guards. Sample basket(s) will be of appropriate size allowing samples to be thinly spread and allowing air to flow through and around the sample particles. Sets of two or more baskets shall be nested. A catch pan: of sufficient size to hold the sample basket(s) so that aggregate particles and melting binder falling through the screen mesh are caught. Basket guards will completely enclose the basket and be made of screen mesh, perforated stainless steel plate, or other suitable material.

- Thermometer, or other temperature measuring device, with a temperature range of 10 - 260°C (50-500°F).

- Oven capable of maintaining 110 ±5°C (230 ±9°F).

- Balance or scale: Capacity sufficient for the sample mass and conforming to the requirements of M 231, Class G2.

- **Safety equipment**: Safety glasses or face shield, high temperature gloves, long sleeved jacket, a heat resistant surface capable of withstanding 650°C (1202°F), a protective cage capable of surrounding the sample baskets during the cooling period, and a particle mask for use during removal of the sample from the basket assembly.

- Miscellaneous equipment: A pan larger than the sample basket(s) for transferring sample after ignition, spatulas, bowls, and wire brushes.

Sampling

1. Obtain samples of HMA in accordance with the FOP for AASHTO T 168.

2. Reduce HMA samples in accordance with the FOP for AASHTO R 47.

3. If the mixture is not sufficiently soft to separate with a spatula or trowel, place it in a large flat pan in an oven at 110 ±5°C (230 ±9°F) until soft enough.

4. Test sample size shall conform to the mass requirement shown in Table 1.

Note 3: When the mass of the test specimen exceeds the capacity of the equipment used or for large samples of fine mixes, the test specimen may be divided into suitable increments, tested, and the results appropriately combined through a weighted average for calculation of the binder content.

Table 1

Nominal Maximum Aggregate Size* mm (in.)	Minimum Mass Specimen g	Maximum Mass Specimen g
37.5 (1 ½)	4000	4500
25.0 (1)	3000	3500
19.0 (3/4)	2000	2500
12.5 (1/2)	1500	2000
9.5 (3/8)	1200	1700
4.75 (No. 4)	1200	1700

* One sieve larger than the first sieve to retain more than 10 percent of the material using an agency specified set of sieves based on cumulative percent retained. Where large gaps in specification sieves exist, intermediate sieve(s) may be inserted to determine nominal maximum size.

Procedure – Method A (Internal Balance)

1. For the convection-type furnace, preheat the ignition furnace to 538 ± 5°C (1000 ± 9°F) or to the temperature determined in the "Correction Factor" section, Step 9 of this method. Manually record the furnace temperature (set point) prior to the initiation of the test if the furnace does not record automatically. For the direct IR irradiation-type furnace, use the same burn profile as used during the correction factor determination.

2. Dry the sample to constant mass, according to the FOP for AASHTO T 329; or determine the moisture content of a companion sample in accordance with the FOP for AASHTO T 329.

3. Determine and record the mass to the nearest 0.1 g of the sample basket assembly.

4. Evenly distribute the sample in the sample basket assembly, taking care to keep the material away from the edges of the basket. Use a spatula or trowel to level the sample.

5. Determine and record the total mass of the sample and sample basket assembly to the nearest 0.1 g. Calculate and record the initial mass of the sample (total mass minus the mass of the sample basket assembly) to the nearest 0.1 g. Designate this mass as (M_i).

6. Record the correction factor or input into the furnace controller for the specific HMA.

7. Input the initial mass of the sample (M_i) into the ignition furnace controller. Verify that the correct mass has been entered.

CAUTION: Operator should wear safety equipment – high temperature gloves, face shield, fire-retardant shop coat – when opening the door to load or unload the sample.

8. Open the chamber door and gently set the sample basket assembly in the furnace. Carefully position the sample basket assembly so it is not in contact with the furnace wall. Close the chamber door and verify that the sample mass displayed on the furnace scale equals the total mass of the sample and sample basket assembly recorded in Step 5 within ±5 g.

   Note 4: Furnace temperature will drop below the set point when the door is opened, but will recover when the door is closed and ignition begins. Sample ignition typically increases the temperature well above the set point – relative to sample size and binder content.

9. Initiate the test by pressing the start button. This will lock the sample chamber and start the combustion blower.

   Safety note: Do not attempt to open the furnace door until the asphalt binder has been completely burned off.

10. Allow the test to continue until the stable light and audible stable indicator indicate that the change in mass does not exceed 0.01 percent for three consecutive minutes. Press the stop button. This will unlock the sample chamber and cause the printer to print out the test results.

    Note 5: An ending mass loss percentage of 0.02 may be used, if allowed by the agency, when aggregate that exhibits an excessive amount of loss during ignition testing is used.

11. Open the chamber door, remove the sample basket assembly, and place on the cooling plate or block. Place the protective cage over the sample basket assembly and allow it to cool to room temperature (approximately 30 minutes).

12. Determine and record the total after ignition mass to the nearest 0.1 g. Calculate and record the mass of the sample, after ignition (total after ignition mass minus the mass of the sample basket assembly) to the nearest 0.1 g. Designate this mass as Mf.

13. Use the asphalt binder content percentage from the printed ticket. Subtract the moisture content from the printed ticket asphalt binder content and report the difference as the corrected asphalt binder content.

    Asphalt binder content percentage can also be calculated using the formula from “Method B” Step 16.

Calculation

Corrected asphalt binder content:

$$P_b = BC - MC - C_f$$

(if not input in the furnace controller)

where:

P_b = the corrected asphalt binder content as a percent by mass of the HMA

BC = asphalt binder content shown on printed ticket

MC = moisture content of the companion HMA sample, percent, as determined by the FOP for AASHTO T 329 (if the specimen was oven-dried prior to initiating the procedure, MC=0)

C_f = correction factor as a percent by mass of the HMA sample

Procedure – Method B (External Balance)

1. Preheat the ignition furnace to 538 ± 5°C (1000 ± 9°F) or to the temperature determined in the "Correction Factor" section, Step 9 of this method. Manually record the furnace temperature (set point) prior to the initiation of the test if the furnace does not record automatically.

2. Dry the sample to constant mass, according to the FOP for AASHTO T 329; or determine the moisture content of a companion sample in accordance with the FOP for AASHTO T 329.

3. Determine and record the mass of the sample basket assembly to the nearest 0.1 g.

4. Place the sample basket(s) in the catch pan. Evenly distribute the sample in the sample basket(s), taking care to keep the material away from the edges of the basket. Use a spatula or trowel to level the sample.

5. Determine and record the total mass of the sample and sample basket assembly to the nearest 0.1 g. Calculate and record the initial mass of the sample (total mass minus the mass of the sample basket assembly) to the nearest 0.1 g. Designate this mass as (M_i).

6. Record the correction factor for the specific HMA.

7. Open the chamber door and gently set the sample basket assembly in the furnace. Carefully position the sample basket assembly so it is not in contact with the furnace wall. Burn the HMA sample in the furnace for 45 minutes or the length of time determined in the "Correction Factors" section.

8. Open the chamber door, remove the sample basket assembly, and place on the cooling plate or block. Place the protective cage over the sample and allow it to cool to room temperature (approximately 30 min).

9. Determine and record the total after ignition mass to the nearest 0.1 g. Calculate and record the mass of the sample, after ignition (total after ignition mass minus the mass of the sample basket assembly) to the nearest 0.1 g.

10. Place the sample basket assembly back into the furnace.

11. Burn the sample for at least 15 minutes after the furnace reaches the set temperature.

12. Open the chamber door, remove the sample basket assembly, and place on the cooling plate or block. Place the protective cage over the sample basket assembly and allow it to cool to room temperature (approximately 30 min.).

13. Determine and record the total after ignition mass to the nearest 0.1 g. Calculate and record the mass of the sample, after ignition (total after ignition mass minus the mass of the sample basket assembly) to the nearest 0.1 g.

14. Repeat Steps 10 through 13 until the change in measured mass of the sample after ignition does not exceed 0.01 percent of the previous sample mass after ignition.

    Note 6: An ending mass loss percentage of 0.02 may be used, if allowed by the agency, when aggregate that exhibits an excessive amount of loss during ignition testing is used.

15. Determine and record the total after ignition mass to the nearest 0.1 g. Calculate and record the mass of the sample, after ignition (total after ignition mass minus the mass of the sample basket assembly) to the nearest 0.1 g. Designate this mass as Mf.

16. Calculate the asphalt binder content of the sample.

Calculations

Calculate the asphalt binder content of the sample as follows:

$$P_b = \frac{M_i - M_f}{M_i} \times 100 - MC - C_f$$

where:

P_b = the corrected asphalt binder content as a percent by mass of the HMA sample

M_f = the final mass of aggregate remaining after ignition

M_i = the initial mass of the HMA sample prior to ignition

MC= moisture content of the companion HMA sample, percent, as determined by the FOP for AASHTO T 329 (if the specimen was oven-dried prior to initiating the procedure, MC=0).

C_f = correction factor as a percent by mass of the HMA sample

Example

Correction Factor	= 0.42%
Moisture Content	= 0.04%
Initial Mass of Sample and Basket	= 5292.7 g
Mass of Basket Assembly	= 2931.5 g
M_i	= 2361.2 g
Total Mass after First ignition + basket	= 5154.4 g
Sample Mass after First ignition	= 2222.9 g
Sample Mass after additional 15 min ignition	= 2222.7 g

$$\frac{2222.9\ g - 2222.7\ g}{2222.9\ g} \times 100 = 0.009\%$$

Not greater than 0.01 percent, so $\mathbf{M_f}$ = 2222.7 g

$$P_b = \frac{2361.2\ g - 2222.7\ g}{2361.2\ g} \times 100 - 0.42\% - 0.04\% = 5.41\%$$

P_b= 5.41%

Gradation

1. Empty contents of the basket(s) into a flat pan, being careful to capture all material. Use a small wire brush to ensure all residual fines are removed from the baskets.

   Note 7: Particle masks are a recommended safety precaution.

2. Perform the gradation analysis in accordance with the FOP for AASHTO T 30.

Report

- Results on forms approved by the agency
- Sample ID
- Method of test (A or B)
- Corrected asphalt binder content, P_b, per agency standard
- Correction factor, C_f , to 0.01 percent
- Temperature compensation factor (if applicable)
- Total percent loss
- Sample mass
- Moisture content to 0.01%
- Test temperature

Attach the original printed ticket with all intermediate values (continuous tape) to the report for furnaces with internal balances.

Annex – Correction Factors

(Mandatory Information)

Asphalt Binder and Aggregate

Asphalt binder content results may be affected by the type of aggregate in the mixture and by the ignition furnace. Asphalt binder and aggregate correction factors must, therefore, be established by testing a set of correction specimens for each Job Mix Formula (JMF) mix design. Each ignition furnace will have its own unique correction factor determined in the location where testing will be performed.

This procedure must be performed before any acceptance testing is completed, and repeated each time there is a change in the mix ingredients or design. Any changes greater than 5 percent in stockpiled aggregate proportions should require a new correction factor.

Historical data or scientific studies may be used to determine the correction factor(s) in lieu of using this testing procedure if the testing agency provides reference to the studies/data. All correction samples will be prepared by a central / regional laboratory unless otherwise directed.

Asphalt binder correction factor: A correction factor must be established by testing a set of correction specimens for each Job Mix Formula (JMF). Certain aggregate types may result in unusually high correction factors (> 1.00 percent). Such mixes should be corrected and tested at a lower temperature as described below.

Aggregate correction factor: Due to potential aggregate breakdown during the ignition process, a correction factor will need to be determined for the following conditions:

a. Aggregates that have a proven history of excessive breakdown

b. Aggregate from an unknown source.

This correction factor will be used to adjust the acceptance gradation test results obtained according to the FOP for AASHTO T 30.

Procedure

1. Obtain samples of aggregate in accordance with the FOP for AASHTO T 2.

2. Obtain samples of asphalt binder in accordance with the FOP for AASHTO R 66.

   Note 8: Include other additives that may be required by the JMF.

3. Prepare an initial, or “butter,” mix at the design asphalt binder content. Mix and discard the butter mix prior to mixing any of the correction specimens to ensure accurate asphalt content.

4. Prepare two correction specimens at the JMF design asphalt binder content. Aggregate used for correction specimens shall be sampled from material designated for use on the project. An agency approved method will be used to combine aggregate. An additional "blank" specimen shall be batched and tested for aggregate gradation in accordance with the FOP for AASHTO T 30. The gradation from the "blank" shall fall within the agency specified mix design tolerances.

5. Place the freshly mixed specimens directly into the sample basket assembly. If mixed specimens are allowed to cool prior to placement in the sample basket assembly, the specimens must be dried to constant mass according to the FOP for AASHTO T 329. Do not preheat the sample basket assembly.

6. Test the specimens in accordance with Method A or Method B of the procedure.

7. Once both of the correction specimens have been burned, determine the asphalt binder content for each specimen by calculation or from the printed oven tickets, if available.

8. If the difference between the asphalt binder contents of the two specimens exceeds 0.15 percent, repeat with two more specimens and, from the four results, discard the high and low result. Determine the correction factor from the two original or remaining results, as appropriate. Calculate the difference between the actual and measured asphalt binder contents for each specimen to 0.01 percent. The asphalt binder correction factor, C_f, is the average of the differences expressed as a percent by mass of HMA.

9. If the asphalt binder correction factor exceeds 1.00 percent, the test temperature must be lowered to 482 ± 5°C (900 ± 9°F) and new samples must be burned. The temperature for determining the asphalt binder content of HMA samples by this procedure shall be the same temperature determined for the correction samples.

10. For the direct IR irradiation-type burn furnaces, the **default** burn profile should be used for most materials. The operator may select burn-profile Option 1 or Option 2 to optimize the burn cycle. The burn profile for testing HMA samples shall be the same burn profile selected for correction samples.

    Option 1 is designed for aggregate that requires a large asphalt binder correction factor (greater than 1.00 percent) – typically very soft aggregate (such as dolomite).

    Option 2 is designed for samples that may not burn completely using the **default** burn profile.

11. Perform a gradation analysis on the residual aggregate in accordance with the FOP for AASHTO T 30, if required. The results will be utilized in developing an "Aggregate Correction Factor" and should be calculated and reported to 0.1 percent.

12. From the gradation results subtract the percent passing for each sieve, for each sample, from the percent passing each sieve of the "Blank" specimen gradation results from Step 4.

13. Determine the average difference of the two values. If the difference for any single sieve exceeds the allowable difference of that sieve as listed in Table 2, then aggregate gradation correction factors (equal to the resultant average differences) for all sieves shall be applied to all acceptance gradation test results determined by the FOP for AASHTO T 30. If the 75 µm (No. 200) is the only sieve outside the limits in Table 2, apply the aggregate correction factor to only the 75 µm (No. 200) sieve.

Table 2
Permitted Sieving Difference

Sieve	Allowable Difference
Sizes larger than or equal to 2.36 mm (No.8)	± 5.0%
Sizes larger than to 75 µm (No.200) and smaller than 2.36 mm (No.8)	± 3.0%
Sizes 75 µm (No.200) and smaller	± 0.5%

Examples:

Sieve Size mm (in.)	Correction Factor Blank Sample % Passing	Correction Factor Sample #1 % Passing	Correction Factor Sample #2 % Passing	Difference 1 / 2	Avg. Diff.	Sieves to adjust
19.0 (3/4)	100	100	100	0/0	0.0	
12.5 (1/2)	86.3	87.4	86.4	-1.1/-0.1	-0.6	
9.5 (3/8)	77.4	76.5	78.8	+0.9/-1.4	-0.2	
4.75 (No. 4)	51.5	53.6	55.9	-2.1/-4.4	-3.2	
2.36 (No. 8)	34.7	36.1	37.2	-1.4/-2.5	-2.0	
01.18 (No. 16)	23.3	25.0	23.9	-1.7/-0.6	-1.2	
0.600 (No. 30)	16.4	19.2	18.1	-2.8/-1.7	-2.2	
0.300 (No. 50)	12.0	11.1	12.7	+0.9/-0.7	+0.1	
0.150 (No. 100)	8.1	9.9	6.3	-1.8/+1.8	0.0	
75 µm (No. 200)	5.5	5.9	6.2	-0.4/-0.7	-0.6	**- 0.6**

In this example, all gradation test results performed on the residual aggregate (FOP for AASHTO T 30) would have an aggregate correction factor applied to the percent passing the 75 µm (No. 200) sieve. The correction factor must be applied because the average difference on the 75 µm (No. 200) sieve is outside the tolerance from Table 2.

In the following example, aggregate correction factors would be applied to each sieve because the average difference on the 4.75 mm (No. 4) is outside the tolerance from Table 2.

Sieve Size mm (in.)	**Correction Factor Blank Sample % Passing**	**Correction Factor Sample #1 % Passing**	**Correction Factor Sample #2 % Passing**	**Difference 1 / 2**	**Avg. Diff.**	**Sieves to adjust**
19.0 (3/4)	100	100	100	0/0	0.0	0.0
12.5 (1/2)	86.3	87.4	86.4	-1.1/-0.1	-0.6	**-0.6**
9.5 (3/8)	77.4	76.5	78.8	+0.9/-1.4	-0.2	**-0.2**
4.75 (No. 4)	51.5	55.6	57.9	-4.1/-6.4	-5.2	**-5.2**
2.36 (No. 8)	34.7	36.1	37.2	-1.4/-2.5	-2.0	**-2.0**
01.18 (No. 16)	23.3	25.0	23.9	-1.7/-0.6	-1.2	**-1.2**
0.600 (No. 30)	16.4	19.2	18.1	-2.8/-1.7	-2.2	**-2.2**
0.300 (No. 50)	12.0	11.1	12.7	+0.9/-0.7	+0.1	**+0.1**
0.150 (No. 100)	8.1	9.9	6.3	-1.8/+1.8	0.0	0.0
75 µm (No. 200)	5.5	5.9	6.2	-0.4/-0.7	-0.6	**-0.6**

THEORETICAL MAXIMUM SPECIFIC GRAVITY (G_{mm}) AND DENSITY OF HOT MIX ASPHALT (HMA) PAVING MIXTURES FOP FOR AASHTO T 209

Scope

This procedure covers the determination of the maximum specific gravity (G_{mm}) of uncompacted hot mix asphalt (HMA) paving mixtures in accordance with AASHTO T 209-12. Two methods using different containers – bowl and pycnometer / volumetric flask– are covered.

Specimens prepared in the laboratory shall be cured according to agency standards.

Apparatus

- Balance or scale: 10,000 g capacity, readable to 0.1 g
- Container: A glass, metal, or plastic bowl, pycnometer or volumetric flask between 2000 and 10,000 mL as required by the minimum sample size requirements in Table 1 sample and capable of withstanding a partial vacuum
- Pycnometer / volumetric flask cover: A glass plate or a metal or plastic cover with a vented opening
- Vacuum lid: A transparent lid with a suitable vacuum connection, with a vacuum opening to be covered with a fine wire mesh
- Vacuum pump or water aspirator: Capable of evacuating air from the container to a residual pressure of 4.0 kPa (30 mm Hg)
- Residual pressure manometer or vacuum gauge: Traceable to NIST and capable of measuring residual pressure down to 4.0 kPa (30 mm Hg) or less
- Manometer or vacuum gauge: Capable of measuring the vacuum being applied at the source of the vacuum
- Water bath: A constant-temperature water bath (optional)
- Thermometers: Standardized liquid-in-glass, or electronic digital total immersion type, accurate to 0.5°C (1°F)
- Bleeder valve to adjust vacuum
- Timer

Standardization of Pycnometer or Volumetric Flask

Use a pycnometer / volumetric flask that is standardized to accurately determine the mass of water, at 25 ±0.5°C (77 ±1°F), in the pycnometer / volumetric flask. The pycnometer / volumetric flask shall be standardized periodically in conformance with procedures established by the agency.

Test Sample Preparation

1. Obtain samples in accordance with the FOP for AASHTO T 168 and reduce according to the FOP for AASHTO R 47.

2. Test sample size shall conform to the requirements of Table 1. Samples larger than the capacity of the container may be tested in two or more increments. Results will be combined and averaged. If the increments have a specific gravity difference greater than 0.014 the test must be re-run.

Table 1
Test Sample Size for G_{mm}

Nominal Maximum* Aggregate Size mm (in.)	Minimum Mass g
37.5 or greater (1 ½)	4000
19 to 25 (3/4 to1)	2500
12.5 or smaller (1/2)	1500

*Nominal maximum size: One sieve larger than the first sieve to retain more than 10 percent of the material using an agency specified set of sieves based on cumulative percent retained.

Procedure – General

Two procedures – bowl and pycnometer / volumetric flask – are covered. The first 11 steps are the same for both.

1. Separate the particles of the sample, taking care not to fracture the mineral particles, so that the particles of the fine aggregate portion are not larger than 6.3 mm (1/4 in.). If the mixture is not sufficiently soft to be separated manually, place it in a large flat pan and warm in an oven only until it is pliable enough for separation.

2. Cool the sample to room temperature.

3. Determine and record the mass of the dry container to the nearest 0.1 g.

4. Place the sample in the container.

5. Determine and record the mass of the dry container and sample to the nearest 0.1 g.

6. Determine and record the mass of the sample by subtracting the mass determined in Step 3 from the mass determined in Step 5. Designate this mass as “A”.

7. Add sufficient water at approximately 25° C (77° F) to cover the sample by about 25 mm (1 in.).

Note 1: The release of entrapped air may be facilitated by the addition of a wetting agent. Check with the agency to see if this is permitted and, if it is, for a recommended agent.

8. Place the lid on the container and attach the vacuum line. To ensure a proper seal between the container and the lid, wet the O-ring or use a petroleum gel.

9. Remove entrapped air by subjecting the contents to a partial vacuum of 3.7 ±0.3 kPa (27.5 ±2.5 mm Hg) residual pressure for 15 ±2 minutes.

10. Agitate the container and contents, either continuously by mechanical device or manually by vigorous shaking, at 2 minute intervals. This agitation facilitates the removal of air.

11. Release the vacuum, increasing the pressure to atmospheric pressure in 10 to 15 seconds, turn off the vacuum pump, and remove the lid. When performing the pycnometer / volumetric flask method, complete steps 12B through 16B within 10±1 minutes.

Procedure – Bowl

12A. Fill the water bath to overflow level with water at 25 ±1°C (77 ±2°F) and allow the water to stabilize.

13A. Zero or tare the balance with the immersion apparatus attached, ensuring that the device is not touching the sides or the bottom of the water bath.

14A. Suspend and immerse the bowl and contents in water at 25 ±1°C (77 ±2°F) for 10 ±1 minutes. The holder shall be immersed sufficiently to cover both it and the bowl.

15A. Determine and record the submerged weight of the bowl and contents to the nearest 0.1 g.

16A. Refill the water bath to overflow level.

17A. Empty and re-submerge the bowl following Step 12A to determine the submerged weight of the bowl to the nearest 0.1 g.

18A. Determine and record the submerged weight of the sample to the nearest 0.1 g by subtracting the submerged weight of the bowl from the submerged weight determined in Step 15A. Designate this submerged weight as “C”.

Procedure – Pycnometer or Volumetric Flask

12B. Immediately fill the pycnometer / volumetric flask with water without reintroducing air.

13B. Stabilize the temperature of the pycnometer / volumetric flask and contents so that the final temperature is within 25 ±1°C (77 ±2°F).

14B. Finish filling the pycnometer / volumetric flask with water that is 25 ±1°C (77 ±2°F), place the cover or a glass plate on the pycnometer / volumetric flask, and eliminate all air.

Note 2: When using a metal pycnometer and cover, place the cover on the pycnometer and push down slowly, forcing excess water out of the hole in the center of the cover. Use care when filling the pycnometer to avoid reintroducing air into the water.

15B. Towel dry the outside of the pycnometer / volumetric flask and cover.

16B. Determine and record the mass of the pycnometer / volumetric flask, cover, de-aired water, and sample to the nearest 0.1 g. within 10 ±1 minutes of completion of Step 11. Designate this mass as "E."

Procedure – Mixtures Containing Uncoated Porous Aggregate

If the pores of the aggregates are not thoroughly sealed by a bituminous film, they may become saturated with water during the vacuuming procedure, resulting in an error in maximum density. To determine if this has occurred, complete the general procedure and then:

1. Carefully drain water from sample through a towel held over the top of the container to prevent loss of material.

2. Spread sample in a flat shallow pan and place before an electric fan to remove surface moisture.

3. Determine the mass of the sample when the surface moisture appears to be gone.

4. Continue drying and determine the mass of the sample at 15-minute intervals until less than a 0.5 g loss is found between determinations.

5. Record the mass as the saturated surface dry mass to the nearest 0.1 g. Designate this mass as "ASSD".

6. Calculate, as indicated below, G_{mm}, using "A" and "ASSD", and compare the two values.

Calculation

Calculate the G_{mm} to three decimal places as follows:

Bowl Procedure

$$G_{mm} = \frac{A}{A - C} \qquad or \qquad G_{mm} = \frac{A}{A_{SSD} - C}$$

(for mixes containing uncoated aggregate materials)

where:

A = mass of dry sample in air, g

A_{SSD} = Mass of saturated surface dry sample in air, g

C = submerged weight of sample in water, g

Example:

A = 1432.7 g

A_{SSD} = 1434.2 g

C = 848.6 g

$$G_{mm} = \frac{1432.7\ g}{1432.7\ g - 848.6\ g} = 2.453 \qquad or \qquad G_{mm} = \frac{1432.7\ g}{1434.2\ g - 848.6\ g} = 2.447$$

Pycnometer / Volumetric Flask Procedure

$$G_{mm} = \frac{A}{A + D - E} \qquad or \qquad G_{mm} = \frac{A}{A_{SSD} + D - E}$$

(for mixtures containing uncoated materials)

where:

A = Mass of dry sample in air, g

A_{SSD} = Mass of saturated surface-dry sample in air, g

D = Mass of pycnometer / volumetric flask filled with water at 25°C (77°F), g, determined during the Standardization of Pycnometer / Volumetric Flask procedure

E = Mass of pycnometer / volumetric flask filled with water and the test sample at test temperature, g

Example (in which two increments of a large sample are averaged):

Increment 1	Increment 2
A = 2200.3 g	A = 1960.2 g
D = 7502.5 g	D = 7525.5 g
E = 8812.0 g	E = 8690.8 g
Temperature = 26.2°C	Temperature = 25.0°C

$$G_{mm_1} = \frac{2200.3\ g}{2200.3\ g + 7502.5\ g - 8812.0\ g} = 2.470$$

$$G_{mm_2} = \frac{1960.2\ g}{1960.2\ g + 7525.5\ g - 8690.8\ g} = 2.466$$

Allowable variation is: 0.014

2.470 - 2.466 = 0.004, which is < 0.014, so they can be averaged.

Average

2.470 + 2.466 = 4.936 4.936 ÷ 2 = 2.468

Theoretical Maximum Density

To calculate the theoretical maximum density at 25°C (77°F) use one of the following formulas. The density of water at 25°C (77°F) is 997.1 in Metric units or 62.245 in English units.

Theoretical maximum density $kg/m^3 = G_{mm} \times 997.1\ kg/m^3$

$2.468 \times 997.1\ kg/m^3 = 2461\ kg/\ m^3$

or

Theoretical maximum density $lb/ft^3 = G_{mm} \times 62.245\ lb/ft^3$

$2.468 \times 62.245\ lb/ft^3 = 153.6\ lb/ft^3$

Report

- Results on forms approved by the agency
- Sample ID
- G_{mm} to three decimal places
- Theoretical maximum density to1 kg/m^3 (0.1 lb/ft^3)

BULK SPECIFIC GRAVITY (G_{mb}) OF COMPACTED HOT MIX ASPHALT (HMA) USING SATURATED SURFACE-DRY SPECIMENS FOP FOR AASHTO T 166

Scope

This procedure covers the determination of bulk specific gravity (G_{mb}) of compacted hot mix asphalt (HMA) using three methods – A, B, and C – in accordance with AASHTO T 166-16. This FOP is for use on specimens not having open or interconnecting voids or absorbing more than 2.00 percent water by volume, or both. When specimens have open or interconnecting voids or absorbing more than 2.00 percent water by volume, or both, AASHTO T 275 or AASHTO T 331 should be performed.

Overview

- Method A: Suspension
- Method B: Volumeter
- Method C: Rapid test for A or B

Test Specimens

Test specimens may be either laboratory-molded or from HMA pavement. For specimens it is recommended that the diameter be equal to four times the maximum size of the aggregate and the thickness be at least one and one half times the maximum size.

Test specimens from HMA pavement will be sampled according to AASHTO R 67.

Terminology

Constant Mass: The state at which a mass does not change more than a given percent, after additional drying for a defined time interval, at a required temperature.

Apparatus - Method A (Suspension)

Balance or scale: 5 kg capacity, readable to 0.1 g, and fitted with a suitable suspension apparatus and holder to permit weighing the specimen while suspended in water, conforming to AASHTO M 231.

- Suspension apparatus: Wire of the smallest practical size and constructed to permit the container to be fully immersed.
- Water bath: For immersing the specimen in water while suspended under the balance or scale, and equipped with an overflow outlet for maintaining a constant water level.

- Towel: Damp cloth towel used for surface drying specimens.
- Oven: Capable of maintaining a temperature of 110 ±5°C (230 ±9°F) for drying the specimens to a constant mass.
- Pan: Pan or other suitable container of known mass, large enough to hold a sample for drying in oven.
- Thermometer: Having a range of 19 to 27°C (66 to 80°F), graduated in 0.1°C (0.2°F) subdivisions.

Procedure - Method A (Suspension)

Recently molded laboratory samples that have not been exposed to moisture do not need drying.

1. Dry the specimen to constant mass, if required.

   a. Initially dry overnight at 52 ±3°C (125 ±5°F).

   b. Determine and record the mass of the specimen (M_p).

   c. Return the specimen to the oven for at least 2 hours.

   d. Determine and record the mass of the specimen (M_n).

   e. Determine percent change by subtracting the new mass determination (M_n) from the previous mass determination (M_p) divide by the previous mass determination (M_p) multiply by 100.

   f. Continue drying until there is less than 0.05 percent change in specimen mass after 2-hour drying intervals (constant mass).

   g. Constant mass has been achieved, sample is defined as dry.

   Note 1: To expedite the procedure, steps 1 and 2 may be performed last. To further expedite the process, see Method C.

2. Cool the specimen in air to 25 ±5°C (77 ±9°F), and determine and record the dry mass to the nearest 0.1 g. Designate this mass as "A."

3. Fill the water bath to overflow level with water at 25 ±1°C (77 ±1.8°F) and allow the water to stabilize.

4. Zero or tare the balance with the immersion apparatus attached, ensuring that the device is not touching the sides or the bottom of the water bath.

5. Immerse the specimen shaking to remove the air bubbles. Place the specimen on its side in the suspension apparatus. Leave it immersed for 4 ±1 minutes.

6. Determine and record the submerged weight to the nearest 0.1 g. Designate this submerged weight as "C."

7. Remove the sample from the water and quickly surface dry with a damp cloth towel within 5 seconds.

8. Zero or tare the balance.

9. Immediately determine and record the mass of the SSD specimen to nearest 0.1 g. Designate this mass as "B." Any water that seeps from the specimen during the mass determination is considered part of the saturated specimen. Do not to exceed 15 seconds performing Steps 7 through 9.

Calculations - Method A (Suspension)

Constant Mass:

Calculate constant mass using the following formula:

$$\%Change = \frac{M_p - M_n}{M_p} \times 100$$

Where:

M_p = previous mass measurement, g

M_n = new mass measurement, g

Bulk specific gravity (G_{mb}) and percent water absorbed:

$$G_{mb} = \frac{A}{B - C}$$

$$Percent\ Water\ Absorbed\ (by\ volume) = \frac{B - A}{B - C} \times 100$$

where:

A = Mass of dry specimen in air, g

B = Mass of SSD specimen in air, g

C = Weight of specimen in water at 25 ±1°C (77 ±1.8°F), g

Example:

$$G_{mb} = \frac{4833.6\ g}{4842.4\ g - 2881.3\ g} = 2.465$$

$$\%\ Water\ Absorbed\ (by\ volume) = \frac{4842.4\ g - 4833.6\ g}{4842.4\ g - 2881.3\ g} \times 100 = 0.45\%$$

Apparatus - Method B (Volumeter)

- Balance or scale: 5 kg capacity, readable to 0.1 g and conforming to AASHTO M 231.
- Water bath: Thermostatically controlled to 25 ±0.5°C (77 ±0.9°F).
- Thermometer: Range of 19 to 27°C (66 to 80°F), and graduated in 0.1°C (0.2°F) subdivisions.
- Volumeter: Calibrated to 1200 mL or appropriate capacity for test sample and having a tapered lid with a capillary bore.
- Oven: Capable of maintaining a temperature of 110 ±5°C (230 ±9°F) for drying the specimens to a constant mass.
- Pan: Pan or other suitable container of known mass, large enough to hold a sample for drying in oven.
- Towel: Damp cloth towel used for surface drying specimens.

Procedure - Method B (Volumeter)

Recently molded laboratory samples that have not been exposed to moisture do not need drying.

1. Dry the specimen to constant mass, if required.
    a. Initially dry overnight at 52 ±3°C (125 ±5°F).
    b. Determine and record the mass of the specimen (M_p).
    c. Return the specimen to the oven for at least 2 hours.
    d. Determine and record the mass of the specimen (M_n).

e. Determine percent change by subtracting the new mass determination (M_n) from the previous mass determination (M_p) divide by the previous mass determination (M_p) multiply by 100.

f. Continue drying until there is less than 0.05 percent change in specimen mass after 2-hour drying intervals (constant mass).

g. Constant mass has been achieved, sample is defined as dry.

Note 1: To expedite the procedure, steps 1 and 2 may be performed last. To further expedite the process, see Method C.

2. Cool the specimen in air to 25 ±5°C (77 ±9°F), and determine and record the dry mass to the nearest 0.1 g. Designate this mass as "A."

3. Immerse the specimen in the temperature-controlled water bath for at least 10 minutes.

4. Fill the volumeter with distilled water at 25 ±1°C (77 ±1.8°F) making sure some water escapes through the capillary bore of the tapered lid. Wipe the volumeter dry. Determine the mass of the volumeter to the nearest 0.1 g. Designate this mass as "D."

5. At the end of the ten minute period, remove the specimen from the water bath and quickly surface dry with a damp cloth towel within 5 seconds.

6. Immediately determine and record the mass of the SSD specimen to the nearest 0.1 g.

7. Designate this mass as "B." Any water that seeps from the specimen during the mass determination is considered part of the saturated specimen.

8. Place the specimen in the volumeter and let stand 60 seconds.

9. Bring the temperature of the water to 25 ±1°C (77 ±1.8°F) and cover the volumeter, making sure some water escapes through the capillary bore of the tapered lid.

10. Wipe the volumeter dry.

11. Determine and record the mass of the volumeter and specimen to the nearest 0.1 g. Designate this mass as "E."

Note 2: Method B is not acceptable for use with specimens that have more than 6 percent air voids.

Calculations - Method B (Volumeter)

Constant Mass:

Calculate constant mass using the following formula:

$$\%Change = \frac{M_p - M_n}{M_p} \times 100$$

Where:

M_p = previous mass measurement, g

M_n = new mass measurement, g

Bulk specific gravity (G_{mb}) and percent water absorbed:

$$G_{mb} = \frac{A}{B + D - E}$$

$$Percent\ Water\ Absorbed\ (by\ volume) = \frac{B - A}{B + D - E} \times 100$$

where:

A = Mass of dry specimen in air, g

B = Mass of SSD specimen in air, g

D = Mass of volumeter filled with water at 25 ±1°C (77 ±1.8°F), g

E = Mass of volumeter filled with specimen and water, g

Example:

$$G_{mb} = \frac{4833.6\ g}{4842.4\ g + 2924.4\ g - 5806.0\ g} = 2.465$$

$$\%\ Water\ Absorbed\ (by\ volume) = \frac{4842.4\ g - 4833.6\ g}{4842.4\ g + 2924.4\ g - 5806.0\ g} \times 100 = 0.45\%$$

Method C (Rapid Test for Method A or B)

See Methods A or B.

Note 3: This procedure can be used for specimens that are not required to be saved and contain substantial amounts of moisture. Cores can be tested the same day as obtained by this method.

Procedure - Method C (Rapid Test for Method A or B)

1. Start on Step 3 of Method A or B, and complete that procedure, then determine dry mass, "A," as follows.

2. Determine and record mass of a large, flat-bottom container.

3. Place the specimen in the container.

4. Place in an oven at a minimum of 105°C (221°F). Do not exceed the Job Mix Formula mixing temperature.

5. Dry until the specimen can be easily separated into fine aggregate particles that are not larger than 6.3 mm (¼ in.).

6. Determine and record the mass of the specimen (M_p).

7. Return the specimen to the oven for at least 2 hours.

8. Determine and record the mass of the specimen (M_n).

9. Determine percent change by subtracting the new mass determination (M_n) from the previous mass determination (M_p) divide by the previous mass determination (M_p) multiply by 100.

10. Continue drying until there is less than 0.05 percent change in specimen mass after 2-hour drying intervals (constant mass).

11. Constant mass has been achieved, sample is defined as dry.

12. Cool in air to 25 ±5°C (77 ±9°F).

13. Determine and record the mass of the container and dry specimen to the nearest 0.1 g.

14. Determine and record the mass of the dry specimen to the nearest 0.1 g by subtracting the mass of the container from the mass determined in Step 13. Designate this mass as "A."

Calculations - Method C (Rapid Test for Method A or B)

Complete the calculations as outlined in Methods A or B, as appropriate.

Report

- Results on forms approved by the agency
- Sample ID
- G_{mb} to 0.001
- Absorption to 0.01 percent
- Method performed.

SAMPLING ASPHALT MATERIALS
FOP FOR AASHTO R 66

Scope

This procedure covers obtaining samples of liquid asphalt materials in accordance with AASHTO R 66-16. Sampling of solid and semi-solid asphalt materials – included in AASHTO R 66 – is not covered here.

Agencies may be more specific on exactly who samples, where to sample, and what type of sampling device to use.

Warning: Always use appropriate safety equipment and precautions for hot liquids.

Terminology

- Asphalt binder: Asphalt cement or modified asphalt cement that binds the aggregate particles into a dense mass.
- Asphalt emulsion: A mixture of asphalt binder and water.
- Cutback asphalt: Asphalt binder that has been modified by blending with a chemical solvent.

Procedure

1. Coordinate sampling with contractor or supplier.
2. Allow a minimum of 4 L (1 gal) to flow before obtaining a sample(s).
3. Obtain samples of:
    - Asphalt binder from hot mix asphalt (HMA) plant from the line between the storage tank and the mixing plant while the plant is in operation, or from the delivery truck.
    - Cutback and emulsified asphalt from distributor spray bar or application device; or from the delivery truck before it is pumped into the distributor. Sample emulsified asphalt at delivery or prior to dilution.

Containers

Sample containers must be new and the inside may not be washed or rinsed. The outside may be wiped with a clean, dry cloth.

All samples shall be put in 1 L (1 qt) containers and properly identified on the outside of the container with contract number, date sampled, data sheet number, brand and grade of material, and sample number. Include lot and sublot numbers when appropriate.

- Emulsified asphalt: Use wide-mouth plastic jars with screw caps. Protect the samples from freezing since water is a part of the emulsion. The sample container should be completely filled to minimize a skin formation on the sample.
- Asphalt binder and cutbacks: Use metal cans.

Note: The sample container shall not be submerged in solvent, nor shall it be wiped with a solvent saturated cloth. If cleaning is necessary, use a clean dry cloth.

Report

- On forms approved by the agency
- Sample ID
- Date
- Time
- Location
- Quantity represented

MECHANICAL ANALYSIS OF EXTRACTED AGGREGATE FOP FOR AASHTO T 30

Scope

This procedure covers mechanical analysis of aggregate recovered from bituminous mix samples in accordance with AASHTO T 30-15. This FOP utilizes the aggregate recovered from the ignition oven used in AASHTO T 308. AASHTO T 30 was developed for analysis of extracted aggregate and thus includes references to extracted bitumen and filter element, which do not apply in this FOP.

Sieve analyses determine the gradation or distribution of aggregate particles within a given sample in order to determine compliance with design and production standards.

Apparatus

- Balance or scale: Capacity sufficient for the sample mass, accurate to 0.1 percent of the sample mass or readable to 0.1 g
- Sieves
- Mechanical sieve shaker
- Mechanical Washing Apparatus (optional)
- Suitable drying equipment (see FOP for AASHTO T 255)
- Containers and utensils: A pan or vessel of a size sufficient to contain the sample covered with water and to permit vigorous agitation without loss of any part of the sample or water

Sample Sieving

- In this procedure it is required to shake the sample over nested sieves. Sieves are selected to furnish information required by specification.
- Sieves are nested in order of decreasing size from the top to the bottom and the sample, or a portion of the sample, is placed on the top sieve.
- Sieves are shaken in a mechanical shaker for approximately 10 minutes or the minimum time determined to provide complete separation for the sieve shaker being used as established by the Time Evaluation.

Time Evaluation

The minimum time requirement should be evaluated for each shaker at least annually by the following method:

1. Shake the sample over nested sieves for approximately 10 minutes.

2. Provide a snug-fitting pan and cover for each sieve, and hold in a slightly inclined position in one hand.

3. Hand-shake each sieve by striking the side of the sieve sharply and with an upward motion against the heel of the other hand at the rate of about 150 times per minute, turning the sieve about one sixth of a revolution at intervals of about 25 strokes.

If more than 0.5 percent by mass of the total sample prior to sieving passes any sieve after one minute of continuous hand sieving adjust shaker time and re-check.

In determining sieving time for sieve sizes larger than 4.75 mm (No. 4), limit the material on the sieve to a single layer of particles.

Overload Determination

- For sieves with openings smaller than 4.75 mm (No. 4), the mass retained on any sieve shall not exceed 7 kg/m^2 (4 g/in^2) of sieving surface.

- For sieves with openings 4.75 mm (No. 4) and larger, the mass (in kg) shall not exceed the product of 2.5 x (sieve opening in mm) x (effective sieving area). See Table 1.

Additional sieves may be necessary to keep from overloading the specified sieves. The sample may also be sieved in increments or sieves with a larger surface area.

TABLE 1
Maximum Allowable Mass of Material Retained on a Sieve, g
Nominal Sieve Size, mm (in.)
Exact size is smaller (see AASHTO T 27)

Sieve Size mm (in.)		203 dia (8)	305 dia (12)	305 by 305 (12 × 12)	350 by 350 (14 × 14)	372 by 580 (16 × 24)
		Sieving Area m^2				
		0.0285	0.0670	0.0929	0.1225	0.2158
90	(3 1/2)	*	15,100	20,900	27,600	48,500
75	(3)	*	12,600	17,400	23,000	40,500
63	(2 1/2)	*	10,600	14,600	19,300	34,000
50	(2)	3600	8400	11,600	15,300	27,000
37.5	(1 1/2)	2700	6300	8700	11,500	20,200
25.0	(1)	1800	4200	5800	7700	13,500
19.0	(3/4)	1400	3200	4400	5800	10,200
16.0	(5/8)	1100	2700	3700	4900	8600
12.5	(1/2)	890	2100	2900	3800	6700
9.5	(3/8)	670	1600	2200	2900	5100
6.3	(1/4)	440	1100	1500	1900	3400
4.75	(No. 4)	330	800	1100	1500	2600
-4.75	(-No. 4)	200	470	650	860	1510

Mass Verification

1. Using the aggregate sample obtained from the FOP for AASHTO T 308, determine and record the mass of the sample, $M_{(T30)}$, to 0.1 g. This mass shall agree with the mass of the aggregate remaining after ignition, M_f from T 308, within 0.10 percent. If the variation exceeds 0.10 percent the results cannot be used for acceptance.

$$\frac{M_{f\,(T308)} - M_{(T30)}}{M_{f\,(T308)}} \times 100$$

Where:

$M_{(T30)}$ = 2422.3 g
$M_{f(T308)}$ = 2422.5 g

$$\frac{2422.5\ g\ -\ 2422.3\ g}{2422.5\ g} \times\ 100\ = 0.01\%$$

Procedure

1. Nest a sieve, such as a 2.0 mm (No. 10) or 1.18 mm (No. 16), above the 75µm (No. 200) sieve.

2. Place the test sample in a container and add sufficient water to cover it. Add a detergent, dispersing agent, or other wetting solution to the water to assure a thorough separation of the material finer than the 75µm (No. 200) sieve from the coarser particles. There should be enough wetting agent to produce a small amount of suds when the sample is agitated. Excessive suds may overflow the sieves and carry material away with them.

3. Agitate vigorously to ensure complete separation of the material finer than 75µm (No. 200) from coarser particles and bring the fine material into suspension above the coarser material. When using a mechanical washing device, exercise caution to avoid degradation of the sample. Maximum agitation is 10 min.

   Note 1: When mechanical washing equipment is used, the introduction of water, agitating, and decanting may be a continuous operation. Use care not to overflow or overload the 75µm (No. 200) sieve.

4. Immediately pour the wash water containing the suspended and dissolved solids over the nested sieves, being careful not to pour out the coarser particles.

5. Add a second change of water to the sample remaining in the container, agitate, and repeat Step 5. Repeat the operation until the wash water is reasonably clear. Continue washing until the agent is removed.

6. Rinse the material on the nested sieves until water passing through the sieve is reasonably clear.

7. Remove the upper sieve, return material retained to the washed sample.

8. Rinse the material retained on the 75 µm (No. 200) sieve until water passing through the sieve is reasonably clear.

9. Return all material retained on the 75 µm (No. 200) sieve to the washed sample by flushing into the washed sample.

10. Dry the washed aggregate to constant mass in accordance with the FOP for AASHTO T 255, and then cool prior to sieving. Record the “dry mass after washing.”

11. Select sieves to furnish information required by the specifications. Nest the sieves in order of decreasing size from top to bottom and place the sample, or a portion of the sample, on the top sieve.

12. Place sieves in mechanical shaker and shake for the minimum time determined to provide complete separation for the sieve shaker being used (approximately 10 minutes).

    Note 2: Excessive shaking (more than 10 minutes) may result in degradation of the sample.

13. Determine the mass retained on each sieve (individual/cumulative) to the nearest 0.1 g. Ensure that all material trapped in full openings of the sieves are cleaned out and included in the mass retained.

    Note 3: For sieves No. 4 and larger, material trapped in less than a full opening shall be checked by sieving over a full opening. Use coarse wire brushes to clean the 600 µm (No. 30) and larger sieves, and soft bristle brushes for smaller sieves.

14. Verify the total mass of material after sieving agrees with the mass before sieving within 0.2 percent. (Check sum). When the masses before and after sieving differ by more than 0.2 percent, do not use the results for acceptance purposes.

15. Divide the masses for each sieve (individual/cumulative) by the total dry mass before washing and multiply by 100 to determine the percent retained on and passing each sieve.

16. Calculate the percent retained and passing each sieve to the nearest 0.1 percent.

17. Apply the Aggregate Correction Factor to the calculated percent passing, as required in the FOP for AASHTO T 308 "Correction Factor" Steps 10 through 12, to obtain the reported percent passing.

18. Report percentages to the nearest 1 percent except for the percent passing the 75 µm (No. 200) sieve, which shall be reported to the nearest 0.1 percent.

Calculations

$$\boldsymbol{check\ sum} = \frac{dry\ mass\ after\ washing - total\ mass\ after\ sieving}{dry\ mass\ after\ washing} \times 100$$

PERCENT RETAINED:

$$\text{IPR} = \frac{IMR}{M_{T30}} \times 100 \quad \textbf{OR} \quad \text{CPR} = \frac{CMR}{M_{T30}} \times 100$$

Where:

IPR= Individual Percent Retained

CPR= Cumulative Percent Retained

M_{T30} = Total Dry Sample mass before washing

IMR= Individual Mass Retained

CMR= Cumulative Mass Retained

PERCENT PASSING and REPORTED PERCENT PASSING:

$$PP = PCP - IPR \quad \boldsymbol{OR} \quad PP = 100 - CPR$$

$$RPP = PP + \text{Aggregate Correction Factor}$$

Where:

PP= Calculated Percent Passing

PCP= Previous Calculated Percent Passing

RPP= Reported Percent Passing

Example

Dry mass of total sample, before washing (M_{T30}): 2422.3 g

Dry mass of sample, after washing out the 75 µm (No. 200) minus: 2296.2 g

Amount of 75 µm (No. 200) minus washed out: 2422.3 g – 2296.2g = 126.1 g

Percent Retained 75 µm (No. 200):

$$\frac{63.5\ g}{2422.3\ g} \times 100 = 2.6\% \quad or \quad \frac{2289.6\ g}{2422.3\ g} \times 100 = 94.5\%$$

Percent Passing: 8.1% – 2.6% = 5.5% or 100 %– 94.5% = 5.5%

Reported Percent Passing: 5.5% + (-0.6%) = 4.9%

Gradation on All Screens

Sieve Size mm (in.)	Mass Retained (g) (MR)	Percent Retained (PR)	Cumulative Mass Retained (g) (CMR)	Cumulative Percent Retained (CPR)	Calc'd Percent Passing (PP)	Agg. Corr. Factor from T 308 (ACF)	Reported Percent Passing (RPP)
19.0 (3/4)	0.0		0.0	0	100.0		100
12.5 (1/2)	346.9	14.3	346.9	14.3	85.7		86
9.5 (3/8)	207.8	8.6	554.7	22.9	77.1		77
4.75 (No. 4)	625.4	25.8	1180.1	48.7	51.3		51
2.36 (No. 8)	416.2	17.2	1596.3	65.9	34.1		34
01.18 (No. 16)	274.2	11.3	1870.5	77.2	22.8		23
0.600 (No. 30)	152.1	6.3	2022.6	83.5	16.5		16
0.300 (No. 50)	107.1	4.4	2129.7	87.9	12.1		12
0.150 (No. 100)	96.4	4.0	2226.1	91.9	8.1		8
75 µm (No. 200)	63.5	2.6	2289.6	94.5	5.5	-0.6	4.9
Pan	5.7		2295.3				

Check sum:

$$\frac{2296.2\ g - 2295.3\ g}{2296.2\ g} \times 100 = 0.04\%$$

This is less than 0.2 percent therefore the results can be used for acceptance purposes.

Report

- Results on forms approved by the agency
- Sample ID
- Depending on the agency, this may include:
  - Individual mass retained on each sieve
  - Individual percent retained on each sieve
  - Cumulative mass retained on each sieve
  - Cumulative percent retained on each sieve
  - Aggregate Correction Factor for each sieve from AASHTO T 308
  - Calculated percent passing each sieve to 0.1 percent
- Reported percent passing to the nearest 1 percent, except 75 µm (No. 200) sieve to the nearest 0.1 percent.

ASPHALT MIXTURE SPECIMENS BY MEANS OF THE SUPERPAVE GYRATORY COMPACTOR
FOP FOR AASHTO T 312

Scope

This procedure covers preparing specimens, using samples of plant produced asphalt mixtures, for determining the mechanical and volumetric properties of asphalt mixtures in accordance with AASHTO T 312-15.

Apparatus

- Superpave Gyratory Compactor (SGC) meeting the requirements of AASHTO T 312
- Molds meeting the requirements of AASHTO T 312
- Chute, mold funnel or both (Optional)
- Scale meeting the requirements of AASHTO M 231 Class G 5
- Oven, thermostatically controlled, capable of maintaining set temperature within ±3ºC (±5ºF)
- Thermometers accurate to ±1ºC (±2°F) between 10 and 232°C (50 - 450°F)

Note 1: Non-Contact thermometers are not acceptable.

- Miscellaneous pans, spoons, spatulas, hot pads, gloves, paper discs, markers, etc.

Equipment Requirements

The calibration shall be performed on the SGC per the Manufacturer's instructions. See agency requirements for the calibration frequency.

The mold and base plate dimensions shall be checked every twelve months or 80 hours of operation to determine that they are within the tolerances listed in AASHTO T 312.

Equipment Preparation

Prepare the equipment in accordance with manufacturer's recommendations. At a minimum preparation includes:

- Warm-up gyratory compactor
- Verify machine settings
  - Internal Angle: 1.16 ±0.02°
  - Ram Pressure: 600 kPa ±18 kPa
  - Number of gyrations

Note 2: The number of gyrations (N_{des}) is obtained from the Job Mix Formula (JMF).

- Lubricate bearing surfaces
- Prepare recording device as required
- Pre-heat molds and plates at the compaction temperature range (minimum of 30 min.) or before reuse reheat (minimum of 5 min.)

Note 3: The use of multiple molds will speed up the compaction process.

- Pre-heat chute, mold funnel, spatulas, and other apparatus (not to exceed the maximum compaction temperature)

Sample Preparation

Laboratory Prepared Asphalt Mixtures

This is a sample produced during the Mix Design process using aggregate and binder that is combined in the laboratory. When designing asphalt mixtures using the gyratory compactor refer to AASHTO T 312.

Plant Produced Asphalt Mixtures

- Determine initial sample size, number of gyrations (N_{des}), and compaction temperature range from the Job Mix Formula (JMF).
- Obtain the sample in accordance with the FOP for AASHTO T 168.
- Reduce the sample in accordance with the FOP for AASHTO R 47.
- The sample size should be such that it results in a compacted specimen that is 115 ±5mm at the desired number of gyrations.

Note 4: Replicate specimens are generally prepared. Refer to agency requirements.

If the material is not in the compaction temperature range:

1. Place the appropriate sample mass into a container.
2. Spread to a depth of 1 to 2 in. for even heating of mixture.
3. Place in the oven until the material is within the compaction temperature range.

Note 5: The material properties may be altered when the times of delivery of the test sample and the placement of the material on the roadway are different.

Compaction Procedure

Follow the manufacturer's recommended loading procedure. This may require the steps below to be performed in a different order. Steps 1 through 8 must be performed before the sample and mold cools below minimum compaction temperature.

1. Remove pre-heated mold and plate(s) from the oven (verify mold and plate(s) has been cleaned if previously used).
2. Place the base plate and paper disc in bottom of mold.
3. Place the mix into the mold in a single lift (care should be taken to avoid segregation or loss of material).
4. Level the mix in the mold.
5. Place a paper disc and the heated upper plate (if required) on top of the leveled sample.
6. Load the mold into the compactor; check settings.
7. Start the compaction process.
    a. Check the pressure (600 ±18 kPa).
    b. Check the angle (1.16 ±0.02°).
8. Upon completion of the compaction process and record the number of gyrations and specimen height.

Note 6: If the specimen is not 115 ±5mm follow agency requirements.

9. Extrude the specimen from the mold; a brief cooling period may be necessary before fully extruding some specimens to ensure the specimens are not damaged.

Note 7: Clean molds after each use.

10. Carefully remove the paper discs.
11. Cool the compacted specimen to room temperature.
12. Identify the specimen with chalk or other marker.

Report

- On forms approved by the agency
- Sample ID
- Number of gyrations
- Specimen height

VOLUMETRIC PROPERTIES OF HOT MIX ASPHALT (HMA) WAQTC TM 13

Scope

This procedure covers the determination of volumetric properties of plant produced Hot Mix Asphalt, i.e., air voids (V_a), voids in mineral aggregate (VMA), voids filled with asphalt binder (VFA), effective asphalt binder content (P_{be}) and Dust to Binder Ratio ($P_{\#200}/P_{be}$). The in-production volumetric properties are then compared to agency specifications.

Definition of Terms

- G_{mm} = theoretical maximum specific gravity (Gravity $_{\text{mix max}}$)
- G_{mb} = measured bulk specific gravity (Gravity $_{\text{mix bulk}}$)
- G_{sb} = oven-dry bulk specific gravity of aggregate (Gravity $_{\text{stone bulk}}$)
- G_{sa} = apparent specific gravity of aggregate (Gravity $_{\text{stone apparent}}$)
- G_{se} = effective specific gravity of aggregate (Gravity $_{\text{stone effective}}$)
- G_b = specific gravity of the binder (Gravity $_{\text{binder}}$)
- V_a = air Voids (Voids $_{\text{air}}$)
- VMA = Voids in Mineral Aggregate
- VFA = Voids Filled with Asphalt (binder)
- V_{ba} = absorbed binder volume (Voids $_{\text{binder absorbed}}$)
- V_{be} = effective binder volume (Voids $_{\text{binder effective}}$)
- P_b = percent binder content (Percent $_{\text{binder}}$)
- P_{ba} = percent absorbed binder (Percent $_{\text{binder absorbed}}$)
- P_{be} = percent effective binder content (Percent $_{\text{binder effective}}$)
- P_s = percent of aggregate (Percent $_{\text{stone}}$)
- DP = Dust proportion to effective binder ratio ($P_{\#200}/P_{be}$)

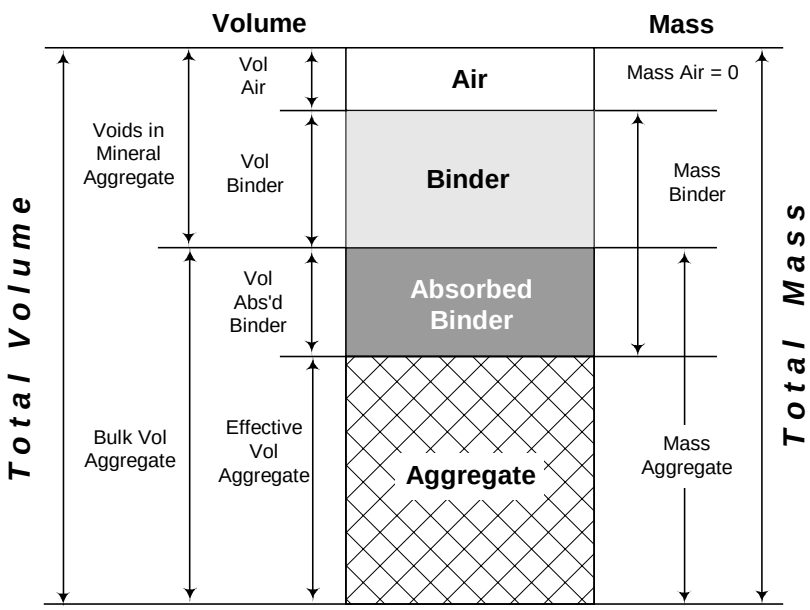
Background

Whether a mix design is developed through a Marshall, Hveem, or Superpave mix design process there are basic volumetric requirements of all. Volumetric properties are the properties of a defined material contained in a known volume. HMA Volumetric properties HMA Volumetric properties can include bulk specific gravity, theoretical maximum specific gravity, air voids, and voids in mineral aggregate.

Many agencies specify values of the volumetric properties to ensure optimum performance of the pavement. The HMA must be designed to meet these criteria. In production the HMA is evaluated to determine if the mix still meets the specifications and is consistent with the original mix design (JMF). The production HMA may vary from the mix design and may need to be modified to meet the specified volumetric criteria.

To compare the in-production volumetric properties to agency specifications and the JMF a sample of loose HMA mix is obtained in accordance with FOP for AASHTO T 168. The sample is then compacted in a gyratory compactor to simulate the in-place HMA pavement after it has been placed, compacted, and the volumetric properties of the compacted sample are determined.

HMA Phase Diagram

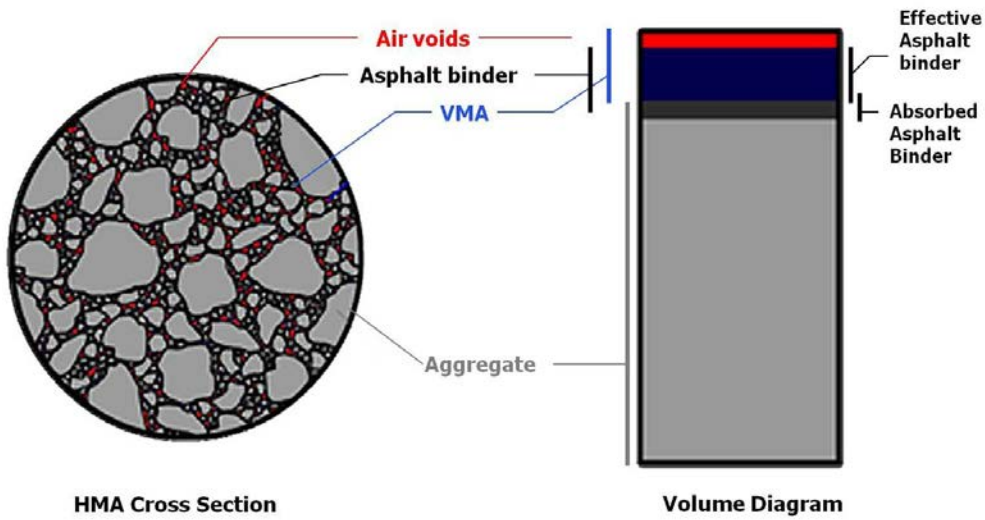


Each of the properties in the HMA phase diagram can be measured or calculated. For example: The mass of the aggregate is measured; the voids in mineral aggregate (VMA) is calculated; total asphalt binder can be measured but the amount available to act as a binder in the mix must be calculated because it is the quantity left after the aggregate has absorbed some of the asphalt binder.

The volumetric proportions of the asphalt binder and aggregate components of an asphalt mixture and their relationship to the other components are considered. The mass of the components and their specific gravities are used to determine the volumes of each of the components in the mix. The volumetric properties of a compacted HMA paving mixture: air voids (V_a), voids in mineral aggregate (VMA), voids filled with asphalt binder (VFA), and effective asphalt binder content (P_{be}) provide some indication of the mixtures probable performance.

Volumetric Properties

Volumetric Relationship of HMA Constituents



Required Values

The specific gravities listed in Table 1 and the percent by mass of each of the components in the HMA are needed to determine the volumetric properties. Other values required are also listed. Some of these values are obtained from the JMF and some are measured from a plant produced HMA sample.

Table 1

Data	Test Method	Obtained
G_{sb} - combined aggregate bulk specific gravity	AASHTO T 84 / T 85 or agency approved test method	JMF or performed at the beginning of placement
G_b – measured specific gravity of the asphalt binder	AASHTO T 228	JMF or from the supplier
G_{mm} – measured maximum specific gravity of the loose mix	FOP for AASHTO T 209	Performed on the field test sample
G_{mb} – measured bulk specific gravity of the compacted paving mix	FOP for AASHTO T 166	Performed on the field compacted specimen
P_b – percent asphalt binder	FOP for AASHTO T 308	Performed on the field test sample
$P_{-\#200}$ – aggregate passing the #200 (75 µm) sieve	FOP for AASHTO T 30	Performed on the field test sample

Air Voids (V_a)

Air voids are the total volume of the small pockets of air between the coated aggregate particles throughout a compacted paving mixture. Appropriate air voids contribute to the stability of the HMA and help the pavement withstand the combined action of environment and traffic loads. The designated percent air voids allows for thermal expansion of the asphalt binder and contributes a cushion for future compaction. Air voids are expressed as a percent of the bulk volume of the compacted mixture (G_{mb}) when compared to the maximum specific gravity (G_{mm}).

$$V_a = 100\left[\frac{(G_{mm} - G_{mb})}{G_{mm}}\right]$$

Where:

V_a = air voids in compacted mixture, percent of total volume (report to 0.1)
G_{mm} = maximum specific gravity of paving mixture (AASHTO T 209)
G_{mb} = bulk specific gravity of compacted mixture (AASHTO T 166)

Percent Aggregate (Stone) (P_s)

P_s is the percent aggregate (stone) content, expressed as a percentage of the total mass of the sample.

$$P_s = 100 - P_b$$

Where:

P_s = percent aggregate (stone) percent by total weight
P_b = asphalt binder content (AASHTO T 308)

Voids in the Mineral Aggregate (VMA)

VMA is the volume of intergranular void space between the aggregate particles of the compacted paving mixture that includes the air voids and the effective binder content, expressed as a percent of the total volume of the sample.

$$VMA = 100 - \left[\frac{(G_{mb} \times P_s)}{G_{sb}}\right]$$

Where:

VMA = voids in mineral aggregate, percent of bulk volume (report to 0.1**)**

G_{sb} = bulk specific gravity of combined aggregate (AASHTO T 85 / T 84 or agency approved method from Job Mix Formula)

G_{mb} = bulk specific gravity of compacted mixture (AASHTO T 166)

P_s = aggregate content, percent by total weight = 100 – P_b

P_b = asphalt binder content (AASHTO T 308) percent by total weight

Voids Filled with Asphalt (binder) (VFA)

VFA is the volume of space between the aggregate particles of the compacted paving mixture filled with asphalt binder, expressed as a percent of the total volume of the sample. The VFA increases as the asphalt binder content increases as it is the percent of voids that are filled with asphalt which doesn't include the absorbed asphalt.

$$VFA = 100\left[\frac{(VMA - V_a)}{VMA}\right]$$

Where:

VFA = voids filled with asphalt, percent of VMA (report to 1)
VMA = voids in mineral aggregate, percent of bulk volume
V_a = air voids in compacted mixture, percent of total volume.

Effective Specific Gravity of the Aggregate (Stone) (G_{se})

The G_{se} is used to quantify the asphalt binder absorbed into the aggregate particle. This is a calculated value based on the specific gravity of the mixture, G_{mm}, and the specific gravity of the asphalt binder, G_b This measurement includes the volume of the aggregate particle plus the void volume that becomes filled with water during the test soak period minus the volume of the voids that absorb asphalt binder. Effective specific gravity lies between apparent and bulk specific gravity.

G_{se} is formally defined as the ratio of the mass in air of a unit volume of a permeable material (excluding voids permeable to asphalt binder) at a stated temperature to the mass in air (of equal density) of an equal volume of gas-free distilled water at a stated temperature.

$$G_{se} = \frac{P_s}{\left[\left(\frac{100}{G_{mm}}\right) - \left(\frac{P_b}{G_b}\right)\right]}$$

Where:

G_{se} = effective specific gravity of combined aggregate (report to 0.001)
P_s = aggregate content, percent by total weight = 100 – P_b
G_{mm} = maximum specific gravity of mix (AASHTO T 209)
P_b = asphalt binder content (AASHTO T 308) percent by total weight
G_b = specific gravity of asphalt binder (JMF or asphalt binder supplier)

Percent of Absorbed (asphalt) Binder (P_{ba})

P_{ba} is the total percent of the asphalt binder that is absorbed into the aggregate, expressed as a percentage of the mass of aggregate rather than as a percentage of the total mass of the mixture. This portion of the asphalt binder content does not contribute to the performance of the mix.

$$P_{ba} = 100\left[\frac{(G_{se} - G_{sb})}{(G_{sb} \times G_{se})}\right]G_b$$

Where:

P_{ba} = absorbed asphalt binder (report to 0.01) percent of aggregate

G_{se} = effective specific gravity of combined aggregate
G_{sb} = bulk specific gravity of combined aggregate (AASHTO T 85 / T 84 or agency approved method from Job Mix Formula)
G_b = specific gravity of asphalt binder (JMF or asphalt binder supplier)

Percent of Effective (asphalt) Binder (P_{be})

P_{be} is the total asphalt binder content of a paving mixture minus the portion of asphalt binder that is lost by absorption into the aggregate particles, expressed as a percentage of the mass of aggregate. It is the portion of the asphalt binder content that remains as a coating on the outside of the aggregate particles. This is the asphalt content that controls the performance of the mix.

$$P_{be} = P_b - \left[\frac{P_{ba}}{100} \times P_s\right]$$

Where:

P_{be} = effective asphalt binder content (report to 0.01), percent by total weight

P_s = aggregate content, percent by total weight = 100 – P_b

P_b = asphalt binder content (AASHTO T 308) percent by total weight

P_{ba} = absorbed asphalt binder

Dust Proportion – DP (Dust to Effective (asphalt) Binder Ratio)

The DP is the percent passing the No. 200 sieve of the gradation divided by the percent of effective asphalt binder. Excessive dust reduces asphalt binder film thickness on the aggregate which reduces the durability. Insufficient dust may allow excessive asphalt binder film thickness, which may result in a tender, unstable mix.

$$DP = \frac{P_{-\#200}}{P_{be}}$$

Where:

DP = Dust Proportion, (dust-to-binder ratio) (report to 0.01)

$P_{-\#200}$ = aggregate passing the -#200 (75 µm) sieve, percent by mass of aggregate (AASHTO T 30)

P_{be} = effective asphalt binder content, percent by total weight

Mix Design and Production Values

Job Mix Formula

Table 2 includes example data required from the JMF. Some of these values are used in the example calculations.

Note: Some of the targets may change after the HMA is in production based on field test data.

Table 2

JMF Data	
Asphalt binder grade	PG 64-28
N_{values}	N_{ini} = 7 **N_{des} = 75** N_{max} = 115
G_{sb} (combined specific gravity of the aggregate)	2.678
Target P_b	4.75%
Initial sample mass for gyratory specimens	4840 grams
Mixing temperature range	306 – 312 °F
Laboratory compaction temperature range	286 – 294 °F
G_b (specific gravity of the asphalt binder)	1.020
Target gradation	
Sieve Size mm (in.)	**Percent Passing**
19.0 (3/4)	100
12.5 (1/2)	85
9.5 (3/8)	80
4.75 (No. 4)	50
2.36 (No. 8)	30
01.18 (No. 16)	25
0.600 (No. 30)	15
0.300 (No. 50)	10
0.150 (No. 100)	7
75 µm (No. 200)	5.0

Sample Test Result

Tables 3 and 4 include data from test results performed on a field sample of HMA used in the example calculations.

Table 3

Field Data		
	Test method	**Example values**
P_b	FOP for AASHTO T 308	4.60%
G_{mb}	FOP for AASHTO T 166	2.415
G_{mm}	FOP for AASHTO T 209	2.516

Table 4

Sieve Analysis FOP for AASHTO T 30	
Sieve Size **mm (in.)**	**Percent Passing**
19.0 (3/4)	100
12.5 (1/2)	86
9.5 (3/8)	77
4.75 (No. 4)	51
2.36 (No. 8)	34
01.18 (No. 16)	23
0.600 (No. 30)	16
0.300 (No. 50)	12
0.150 (No. 100)	8
75 µm (No. 200)	4.9

Sample Calculations

Air Voids (V_a)

$$V_a = 100\left[\frac{(G_{mm} - G_{mb})}{G_{mm}}\right]$$

$$V_a = 100\left[\frac{(2.516 - 2.415)}{2.516}\right] = 4.01431\%\ report\ 4.0\%$$

Given:

G_{mm} = 2.516

G_{mb} = 2.415

Percent Aggregate (Stone) (P_s)

$$P_s = 100 - P_b$$

$$P_s = 100.0 - 4.60\% = 95.40\%$$

Given:

P_b = 4.60%

Voids in the Mineral Aggregate (VMA)

$$VMA = 100 - \left[\frac{(G_{mb} \times P_s)}{G_{sb}}\right]$$

$$VMA = 100.0 - \left[\frac{2.415 \times 95.40\%)}{2.678}\right] = 13.96\%\ report\ 14.0\%$$

Given:

G_{sb} =2.678

Voids Filled with Asphalt (binder) (VFA)

$$VFA = 100\left[\frac{(VMA - V_a)}{VMA}\right]$$

$$VFA = 100\left[\frac{(14.0\% - 4.0\%)}{14.0\%}\right] = 71.4\%\ report\ 71\%$$

Effective Specific Gravity of the Aggregate (Stone) (G_{se})

$$G_{se} = \frac{P_s}{\left[\left(\frac{100}{G_{mm}}\right) - \left(\frac{P_b}{G_b}\right)\right]}$$

$$G_{se} = \frac{(100 - 4.60\%)}{\left[\left(\frac{100}{2.516}\right) - \left(\frac{4.60\%}{1.020}\right)\right]} =$$

$$G_{se} = \frac{95.40\%}{39.7456 - 4.5098} = 2.70747\ report\ 2.707$$

Given:

G_b = 1.020

Percent of Absorbed (asphalt) Binder (P_{ba})

$$P_{ba} = 100\left[\frac{(G_{se} - G_{sb})}{(G_{sb} \times G_{se})}\right] G_b$$

$$P_{ba} = 100\left[\frac{(2.707 - 2.678)}{(2.678 \times 2.707)}\right] 1.020 =$$

$$P_{ba} = 100\left[\frac{0.0290}{7.2493}\right] 1.020 = 0.40804\%\ report\ 0.41\%$$

Percent of Effective (asphalt) Binder (P_{be})

$$P_{be} = P_b - \left[\frac{P_{ba}}{100} \times P_s\right]$$

$$P_{be} = 4.60 - \left[\frac{0.41\%}{100} \times (100 - 4.60\%)\right] = 4.20886\%\ report\ 4.21\%$$

Dust Proportion – DP (Dust to Effective (asphalt) Binder Ratio)

$$DP = \frac{P_{-\#200}}{P_{be}}$$

$$DP = \frac{4.9\%}{4.21\%} = 1.16390\ report\ 1.16$$

Given:

$P_{-\#200}$ = 4.9%

Report

- Results on forms approved by the agency
- Sample ID
- Air Voids, V_a to 0.1 percent
- Voids in the Mineral Aggregate, VMA to 0.1 percent
- Voids Filled with Asphalt, VFA to nearest whole value
- Effective Specific Gravity of Aggregate (stone), G_{se} to 0.001
- Percent of Absorbed (asphalt) Binder, P_{ba} to 0.01
- Percent Effective (asphalt) Binder, P_{be} to 0.01
- Dust Proportion, DP to 0.01

Appendix - Formulas

Air Voids (V_a)

$$V_a = 100\left[\frac{(G_{mm} - G_{mb})}{G_{mm}}\right]$$

Where:

V_a = air voids in compacted mixture, percent of total volume (report to 0.1)
G_{mm} = maximum specific gravity of paving mixture (AASHTO T 209)
G_{mb} = bulk specific gravity of compacted mixture (AASHTO T 166)

Percent Aggregate (Stone) (P_s)

$$P_s = 100 - P_b$$

Where:

P_s = percent aggregate (stone) percent by total weight
P_b = asphalt binder content (AASHTO T 308)

Voids in the Mineral Aggregate (VMA)

$$VMA = 100 - \left[\frac{(G_{mb} \times P_s)}{G_{sb}}\right]$$

Where:

VMA = voids in mineral aggregate, percent of bulk volume (report to 0.1**)**

G_{sb} = bulk specific gravity of combined aggregate (AASHTO T 85 / T 84 or agency approved method from Job Mix Formula)

G_{mb} = bulk specific gravity of compacted mixture (AASHTO T 166)

P_s = aggregate content, percent by total weight = 100 – P_b

P_b = asphalt binder content (AASHTO T 308) percent by total weight

Voids Filled with Asphalt (binder) (VFA)

$$VFA = 100\left[\frac{(VMA - V_a)}{VMA}\right]$$

Where:

VFA = voids filled with asphalt, percent of VMA (report to 1)
VMA = voids in mineral aggregate, percent of bulk volume
V_a = air voids in compacted mixture, percent of total volume.

Effective Specific Gravity of the Aggregate (Stone) (G_{se})

$$G_{se} = \frac{P_s}{\left[\left(\frac{100}{G_{mm}}\right) - \left(\frac{P_b}{G_b}\right)\right]}$$

Where:

G_{se} = effective specific gravity of combined aggregate (report to 0.001)
P_s = aggregate content, percent by total weight = 100 – P_b
G_{mm} = maximum specific gravity of mix (AASHTO T 209)
P_b = asphalt binder content (AASHTO T 308) percent by total weight
G_b = specific gravity of asphalt binder (JMF or asphalt binder supplier)

Percent of Absorbed (asphalt) Binder (P_{ba})

$$P_{ba} = 100\left[\frac{(G_{se} - G_{sb})}{(G_{sb} \times G_{se})}\right]G_b$$

Where:

P_{ba} = absorbed asphalt binder (report to 0.01) percent of aggregate
G_{se} = effective specific gravity of combined aggregate
G_{sb} = bulk specific gravity of combined aggregate (AASHTO T 85 from Job Mix Formula)
G_b = specific gravity of asphalt binder (JMF or asphalt binder supplier)

Percent of Effective (asphalt) Binder (P_{be})

$$P_{be} = P_b - \left[\frac{P_{ba}}{100} \times P_s\right]$$

Where:

P_{be} = effective asphalt binder content (report to 0.01), percent by total weight

P_s = aggregate content, percent by total weight = 100 – P_b

P_b = asphalt binder content (AASHTO T 308) percent by total weight

P_{ba} = absorbed asphalt binder

Dust Proportion – DP (Dust to Effective (asphalt) Binder Ratio)

$$DP = \frac{P_{-\#200}}{P_{be}}$$

Where:

DP = Dust Proportion, (dust-to-binder ratio) (report to 0.01)

$P_{-\#200}$ = aggregate passing the -#200 (75 µm) sieve, percent by mass of aggregate (AASHTO T 30)

P_{be} = effective asphalt binder content, percent by total weight

TOTAL EVAPORABLE MOISTURE CONTENT OF AGGREGATE BY DRYING FOP FOR AASHTO T 255

Scope

This procedure covers the determination of moisture content of aggregate in accordance with AASHTO T 255-00. It may also be used for other construction materials.

Overview

Moisture content is determined by comparing the wet mass of a sample and the mass of the sample after drying to constant mass. The term constant mass is used to define when a sample is dry.

Constant mass – the state at which a mass does not change more than a given percent, after additional drying for a defined time interval, at a required temperature.

Apparatus

- Balance or scale: Capacity sufficient for the principle sample mass, accurate to 0.1 percent of sample mass or readable to 0.1 g, meeting the requirements of AASHTO M 231.
- Containers, clean, dry and capable of being sealed
- Suitable drying containers
- Microwave safe container with ventilated lids
- Heat source, controlled
  - Forced draft oven
  - Ventilated oven
  - Convection oven
- Heat source, uncontrolled
  - Infrared heater, hot plate, fry pan, or any other device/method that will dry the sample without altering the material being dried
  - Microwave oven (900 watts minimum)
- Hot pads or gloves

- Utensils such as spoons

Sample Preparation

In accordance with the FOP for AASHTO T 2 obtain a representative sample in its existing condition. The representative sample size is based on Table 1 or other information that may be specified by the agency

TABLE 1
Sample Sizes for Moisture Content of Aggregate

Nominal Maximum Size* mm (in.)	Minimum Sample Mass g (lb)
4.75 (No. 4)	500 (1.1)
9.5 (3/8)	1500 (3.3)
12.5 (1/2)	2000 (4)
19.0 (3/4)	3000 (7)
25.0 (1)	4000 (9)
37.5 (1 1/2)	6000 (13)
50 (2)	8000 (18)
63 (2 1/2)	10,000 (22)
75 (3)	13,000 (29)
90 (3 1/2)	16,000 (35)
100 (4)	25,000 (55)
150 (6)	50,000 (110)

* One sieve larger than the first sieve to retain more than 10 percent of the material using an agency specified set of sieves based on cumulative percent retained. Where large gaps in specification sieves exist, intermediate sieve(s) may be inserted to determine nominal maximum size.

Immediately seal or cover samples to prevent any change in moisture content or follow the steps in “Procedure.”

Procedure

Determine all masses to the nearest 0.1 percent of the sample mass or to the nearest 0.1 g.

When determining the mass of hot samples or containers or both, place and tare a buffer between the sample container and the balance. This will eliminate damage to or interference with the operation of the balance or scale.

1. Determine and record the mass of the container (and lid for microwave drying).

2. Place the wet sample in the container.

    a. For oven(s), hot plates, infrared heaters, etc.: Spread the sample in the container.

   b. For microwave oven: Heap sample in the container; cover with ventilated lid.

3. Determine and record the total mass of the container and wet sample.

4. Determine and record the wet mass of the sample by subtracting the container mass determined in Step 1 from the mass of the container and sample determined in Step 3.

5. Place the sample in one of the following drying apparatus :

   a. Controlled heat source (oven): at 110 ±5°C (230 ±9°F).

   b. Uncontrolled heat source (Hot plate, infrared heater, etc.): Stir frequently to avoid localized overheating.

6. Dry until sample appears moisture free.

7. Determine mass of sample and container.

8. Determine and record the mass of the sample by subtracting the container mass determined in Step 1 from the mass of the container and sample determined in Step 7.

9. Return sample and container to the heat source for additional drying.

   a. Controlled (oven): 30 minutes

   b. Uncontrolled (Hot plate, infrared heater, etc.): 10 minutes

   c. Uncontrolled (Microwave oven): 2 minutes

Caution: Some minerals in the sample may cause the aggregate to overheat, altering the aggregate gradation.

10. Determine mass of sample and container.

11. Determine and record the mass of the sample by subtracting the container mass determined in Step 1 from the mass of the container and sample determined in Step 10.

12. Determine percent change by subtracting the new mass determination (M_n) from the previous mass determination (M_p) divide by the previous mass determination (M_p) multiply by 100.

13. Continue drying, performing steps 9 through 12, until there is less than a 0.10 percent change after additional drying time.

14. Constant mass has been achieved, sample is defined as dry.

15. Allow the sample to cool. Determine and record the total mass of the container and dry sample.

16. Determine and record the dry mass of the sample by subtracting the mass of the container determined in Step 1 from the mass of the container and sample determined in Step 15.

17. Determine and record percent moisture by subtracting the final dry mass determination (M_D) from the initial wet mass determination (M_W) divide by the final dry mass determination (M_D) multiply by 100.

Table 2
Methods of Drying

Heat Source	Specific Instructions	Drying intervals to achieve constant mass (minutes)
Controlled: Forced Draft Oven (preferred), Ventilated Oven, or Convection Oven	110 ±5°C (230 ±9°F)	30
Uncontrolled:		
Hot plate, Infrared heater, etc.	Stir frequently	10
Microwave	Heap sample and cover with ventilated lid	2

Calculation

Constant Mass:

Calculate constant mass using the following formula:

$$\frac{M_p - M_n}{M_p} \times 100 = \%\ \text{Change}$$

Where:

M_p = previous mass measurement

M_n = new mass measurement

Example:

Mass of container: 1232.1 g

Mass of container after first drying cycle: 2637.2 g

Mass, M_p, of possibly dry sample: 2637.2 g - 1232.1 g = 1405.1 g

Mass of container and dry sample after second drying cycle: 2634.1 g

Mass, M_n, of dry sample: 2634.1 g - 1232.1 g = 1402.0 g

$$\frac{1405.1\text{ g} - 1402.0\text{ g}}{1405.1\text{ g}} \times 100 = 0.22\%$$

0.22 percent is not less than 0.10 percent, so continue drying

Mass of container and dry sample after third drying cycle: 2633.0 g

Mass, M_n, of dry sample: 2633.0 g - 1232.1 g = 1400.9 g

$$\frac{1402.0\text{ g} - 1400.9\text{ g}}{1402.0\text{ g}} \times 100 = 0.08\%$$

0.08 percent is less than 0.10 percent, so constant mass has been reached

Moisture Content:

Calculate the moisture content, w, as a percent, using the following formula:

$$\frac{M_W - M_D}{M_D} \times 100 = \%\ Moisture\ Content$$

where:

M_W = wet mass

M_D = dry mass

Example:

Mass of container: 1232.1 g

Mass of container and wet sample: 2764.7 g

Mass, M_W, of wet sample: 2764.7 g - 1232.1 g = 1532.6 g

Mass of container and dry sample (COOLED): 2633.0 g

Mass, M_D, of dry sample: 2633.0 g - 1232.1 g = 1400.9 g

$$w = \frac{1532.6\text{ g} - 1400.9\text{ g}}{1400.9\text{ g}} \times 100 = \frac{131.7\text{ g}}{1400.9\text{ g}} = 9.40\% \quad \text{rounded to } 9.4\%$$

Report

- Results on forms approved by the agency
- Sample ID
- M_W, wet mass
- M_D, dry mass
- w, moisture content to nearest 0.1 percent