Approved Asphalt Quality Control Technician

(ODOT Level 2 Asphalt Technician)

This is a course designed for understanding the asphalt testing requirements of Ohio Department of Transportation projects.

Course Manual
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Introduction

Level 2 Prerequisite

To be approved as an Asphalt Level 2 Technician for Ohio, you will need the following:

- A Certificate of completion from a recognized Radiation Safety Training Program.
  - Completion of this Radiation training is not required before taking this class or for the Hands-On Practical testing.
  - This class only includes classroom training of the Nuclear AC Gauge
  - The Practical test will only include use of the control panel and the chamber that contains the Nuclear Source.
  - However, Radiation Safety training must be completed and the Certificate must remain on file with the Asphalt Materials Section at the ODOT Central Lab in Columbus before a technician may be Level 2 approved.

- Successful completion of the Level 2 written examination.

- Successful completion of the hands-on practical examination (details to be announced).

- Note:
  - Written and Practical exams will be held a maximum of 2 months pending receipt of the radiation safety certification.
  - Should you not pass the written examination, then it should be retaken within a maximum of 3 weeks.
  - The hands-on practical examination must be completed within 1 month of successfully completing the written exam. Should this time elapse, then the tests will be discarded and the exams will need to be retaken in its entirety.
Asphalt Level 2
Testing Information and Directions

Written exam results will be e-mailed to you within one week.

Please provide the e-mail address that you would like your test results sent to. There is an area on the front cover of your test booklet. ODOT employees will automatically have an e-mail sent to their ODOT e-mail address if no other address is listed. District HT coordinators will be notified of your results as well. If you do not have access to an e-mail address you may contact by phone No sooner than 1:00 pm on the Thursday following the test day. In the event you do not receive an e-mail by 1:00 pm on the Thursday following the test day or you have any questions please contact us at one of the numbers listed below.

Steve McAvoy – 614-275-1379  steven.mcavoy@dot.state.oh.us
Tim Selby – 614-275-1338  tim.selby@dot.state.oh.us

Those who successfully pass the written exam will then be scheduled for the hands on practical (details to be announced). Those who do not pass the written portion of the exam may schedule a review and retake at the ODOT Central Lab in Columbus, Ohio on a first come basis, depending on the availability of the Test Lab staff.

ODOT Central Test Lab: 1600 W. Broad Street, Columbus, Ohio 43223.

Testing will take place on the second floor of the Lab in room 2015.

Directions to the Lab:

From I-70 Westbound: Exit at #97 W Broad St. Continue straight through the traffic light at the end of the ramp like you are getting back on I-70 West. Veer right into the ODOT complex. Our building (1600) Materials Management is the first building on the right.

From I-70 Eastbound: Exit at #97 W Broad St. Turn left onto W. Broad St and pass under the bridge and turn Left at the first traffic light, like you are getting back on I-70 West. Veer right into the ODOT complex. Our building (1600) Materials Management is the first building on the right.
Level 2 Technician Training and Approval – What is this all about?

The Level 2 training in this class provides the minimum skills and resources needed to get started on the road to becoming an experienced and competent asphalt lab testing technician. The Level 2 Approval enables you to perform QC and QA tests whether you are a HMA contractor/producer employee, consultant employee or Ohio DOT employee. The Level 3 Approval allows you to perform and submit asphalt mix designs for Ohio DOT approval.

The Ohio DOT typically uses up to 5 million tons of HMA (hot mix asphalt) in a year. The material and placement cost for Ohio HMA is over $350,000,000.00. The vast majority of this material is produced by HMA contractors and producers who design, produce, test and place the HMA. Testing of the HMA by the HMA contractor/producer is called QC (quality control).

The Ohio DOT performs testing also. Ohio DOT testing and review that validate HMA contractor/producer QC is called monitoring. Ohio DOT tests that are used for payment of the HMA contractor/producer are called acceptance. Both monitoring and acceptance are called QA (quality assurance). The HMA contractor/producer QC along with Ohio DOT QA, makeup what is called the QC/QA program for asphalt.

All general HMA contractor/producer QC/QA requirements are found in Ohio DOT C&MS sections 403, 441 and/or 442. General mix and placement requirements are found in Ohio DOT C&MS section 401. Ohio DOT acceptance requirements are found in 403, 448 or 446.

A Level 2 technician should have all the documents needed to fully understand what is expected of the job he/she is working on. This includes the Ohio DOT C&MS specification book, Ohio DOT supplemental specifications, proposal notes if applicable, copies of all worksheets and forms submitted to the Ohio DOT, and copies of JMF (Job Mix Formula) approval letters. Ohio DOT monitoring checks on HMA contractor/producer QC, including the Level 2 technician practices.

The Ohio DOT C&MS specification book, supplemental specifications and proposal notes can be viewed online at:
http://www.dot.state.oh.us/construction/OCA/Specs/default.htm
However, since most labs do not have internet access it is in the Level 2 technicians best interest to obtain hard copies for their personal use.

Finally, the Level 2 technician is responsible for maintaining their approval with the Ohio DOT by contacting the Office of Materials Management when their approval is up.
1041.01 Scope

A. This supplement outlines the requirements for Contractor's employees:

1. to perform asphalt concrete quality control testing under the Asphalt Quality Control Technician Level 2 approval program.

2. to perform asphalt concrete mix designs under the Asphalt Concrete Mix Design Level 3 approval program.

3. to perform supervision of asphalt concrete placement under the asphalt Field Quality Control Supervisor (FQCS) approval program.

B. This supplement outlines the requirements for a Contractor's or consultant’s laboratory to be equipped with:

1. the proper equipment to perform asphalt concrete quality control testing in accordance with 403, 441 and 442 (approved Level 2 Laboratory).

2. the proper equipment to perform asphalt concrete mix designs and quality control testing (approved Level 3 Laboratory).

1041.02 Administration

A. The Division of Construction Management is responsible for the administration of the asphalt approval programs. The Division of Construction Management Control Group will consist of the following Department personnel:

1. Deputy Director, Division of Construction Management
2. Administrator, Office of Construction Administration
3. Administrator, Office of Materials Management

B. A complaint submitted by a District of an approved contractor employee will be reviewed. This review will consist of a hearing and recommendation by the Approval
Program Review Group. The Approval Program Review Group will consist of the Asphalt Materials Engineer, Office of Materials Management, Pavements Engineer, Office of Construction Administration, one District representative and one industry representative. The Approval Program Review Group will make recommendation to the Division of Construction Management Control Group.

C. The administration of the daily activities of the asphalt approval programs will be performed by the Asphalt Materials Engineer, Office of Materials Management.

1041.03 Personnel Approval

A. Asphalt Quality Control Technician Level 2

1. The Department will approve quality control personnel upon satisfactory completion of the Level 2 Examination.

2. Eligibility requirements for the examination are the submission of proof of successful completion of a Department approved asphalt concrete quality control course.

B. Asphalt Concrete Mix Design Technician Level 3

1. The Department will approve mix design personnel upon satisfactory completion of the Level 3 Examination.

2. Eligibility requirements for the examination are the submission of proof of successful completion of a Department approved asphalt concrete mix design course.

C. Field Quality Control Supervisor

1. The Department will approve FQCS personnel upon satisfactory completion of a Department approved FQCS course and verified minimum two years experience with asphalt placement operations on Department projects.

D. Removal from Work

1. Contractors and their employees are subject to the provisions of 108.05.

2. Any incident or problem will be investigated by the DET and/or DCE who will in turn send documentation of a complaint to the Asphalt Materials Engineer and the Flexible Pavements Engineer for review by the Approval Program Review Group. A criterion for review, will be, but is not limited to, evidence of failure to meaningfully respond to deficiencies as outlined in ODOT C&MS. Lack of meaningful response is defined as a failure to respond to single event items that are major and obvious, or multiple event items that are recurring and minor in nature. Appropriate response is expected even if not directed by ODOT personnel.
The Approval Program Review Group will make a written recommendation to the Control Group. The final decision will be made by the Control Group in written form.

1041.04 Laboratory Approval

A. Level 2

1. A Level 2 Laboratory will contain the following equipment:

   a. an Asphalt Content Nuclear Gauge (AC Gauge). This AC Gauge shall be a Troxler 3241-C with a 100mCi ± 10 percent Am-241; Be neutron source or an equivalent gauge, approved by the Laboratory, with a 100mCi ± 10 percent source and the capability of transferring its calibration data in accordance with Supplement 1043 to a Troxler gauge meeting the above requirements. The AC Gauge shall be located in the Level 2 Laboratory such that it is at least 10 feet from the nearest variable hydrogen source. This includes haul roads, asphalt binder or emulsion tanks, water storage tanks, etc.

   b. a minimum 10,000 g digital balance which reads to the nearest 0.1 g

   c. a minimum of eight (8) AC Gauge pans

   d. an AC Gauge printer

   e. mechanical convection oven capable of maintaining a constant temperature of 355 ± 20°F (180 ± 10 °C) for moisture testing

   f. mechanical convection oven(s) capable of maintaining 200 -320 °F (93-160°C) and with sufficient space for all required samples and equipment without delaying any testing.

   g. ignition oven meeting Supplement 1054 when required by specification.

   h. muffle furnace capable of maintaining 500 - 600°C (932-1112 °F) or an ignition oven meeting the requirements of Supplement 1054.

   i. mechanical shaker for 8.00 in (203 mm) or 12.00 in (305 mm) sieves for gradation analysis

   j. set of 8 inch (200 mm) diameter or 12 inch (300 mm) diameter sieves meeting the requirements of ASTM E11, "Specification for Wire-Cloth and Sieves for Testing Purposes" and of the proper size to ensure conformance to the appropriate gradation specifications.

   k. balances that meet the appropriate specifications
l. 3000 g electrical centrifuge meeting the requirements of ASTM D 2172

m. non-corrosive flat pan 12.00 in x 8.00 in x 1.00 in (305 mm x 203 mm x 25 mm) deep.

n. hot plate

o. 1000 ml graduate

p. crucible suitable for ash determination

q. Bunsen burner or approved equal

r. water bath with clean water meeting the requirements of Supplement 1036 and including a switched suitable heater and switched circulator wired to a properly 3 functioning ground fault interrupt outlet.

s. Minimum 4000 ml glass flask or metal pycnometer meeting AASHTO T 209. A table top mechanical vibration device designed specifically for the MSG test operating on 120 volts AC and capable of holding the above metal pycnometer. Ensure devices are approved by the Laboratory.

t. vacuum pump or water aspirator capable of evacuating air from the container to a residual pressure in accordance with AASHTO T 209

u. thermometers will be Type 17 C meeting the requirements of ASTM E 1

v. laboratory style timer with audible warning and visible timing (do not use devices such as watches, cell phones etc.)

w. automatic, calibrated Marshall specimen compactor and extractor meeting the requirements of AASHTO T 245

x. when 442 is specified, an automatic, calibrated gyratory specimen compactor meeting the requirements of AASHTO T 312. Include in the calibration internal angle validation per AASHTO TP-71. At a minimum calibrate the internal angle annually and when requested by the District for poor comparison. Measure and record the external angle at each internal angle validation and verify the external angle when a gyratory is moved (if possible for the model in question, otherwise calibrate the internal angle). Place a sticker on the gyratory with the date of internal angle validation and values of internal and external angles measured as appropriate for the model in question. Document internal angle validation per the QCP. Do not use gyratory compactors that cannot meet T 312 and TP-71 requirements

y. miscellaneous equipment as required by the appropriate specification
2. Provide a Level 2 Laboratory with a minimum floor area of 250 square feet (18.6 m²). Provide in the lab a desk or similar space for both a technician and monitor to perform paperwork.

3. Maintain the condition of the lab equipment according to the contractor Quality Control Program (403.03). Maintain orderliness and cleanliness of the lab according to the contractor Quality Control Program (403.03). Maintain the inside temperature of a Level 2 Laboratory at 68 to 86 °F (20 to 30 °C) during working hours.

4. Level 2 Laboratories will be inspected at the time of the asphalt plant inspection by Department personnel. There is no maximum number of times a laboratory may be inspected.

5. Level 2 Laboratories are required to participate in the Department's Reference Testing Program.

B. Level 3

1. A Level 3 Laboratory will meet all the equipment and size requirements of a Level 2 Laboratory and will have the following equipment:

   a. heated water bath capable of maintaining 140 ± 2 °F (60 ± 1.0 °C)
   b. Marshall test apparatus meeting the requirements of AASHTO T 245
   c. all apparatus for meeting AASHTO T 283.
   d. miscellaneous equipment as required by the appropriate specifications

2. An asphalt ignition oven is not required for a Level 3 Laboratory.

3. A computer with Microsoft Office, internet access and ability to email attachments is required.

4. Level 3 Laboratories will be inspected a minimum of once every two years by Department personnel. There is no maximum number of times a laboratory may be inspected.

5. Level 3 Laboratories are required to participate in the Department's Reference Testing Program.

C. Loss of Approval

1. Failure to maintain required equipment in good condition may result in loss of approval of a laboratory. Loss of approval can be invoked, in written form, by the District Engineer of Tests or the Asphalt Materials Engineer. Re-approval will be granted once the deficiencies have been corrected.
2. Chronic failure to maintain required equipment in good condition may result in loss of approval of a Level 3 approved person to perform work per Section 1041.03.
Definitions

1. **AASHTO** - American Association of State Highway & Transportation Officials

2. **AC Gauge** - Asphalt Content Gauge

3. **Air Voids** - Pockets of air between the coated aggregate particles.

4. **ASTM** - American Society for Testing & Materials

5. **Asphalt Binder** - Liquid asphalt derived from crude oil.

6. **Asphalt Concrete or H.M.A.** - Hot Mix Asphalt

7. **BSG** - Bulk Specific Gravity - Test performed on compacted hot mix asphalt.

8. **Density** - The mass of a cubic meter of material at 25° C.

9. **F/A - Fines / Asphalt Ratio** - The value calculated to the nearest (0.1) one-tenth of the fines to asphalt (F/A) ratio, which is the percentage of aggregate passing the No. 200 (75 μm) sieve divided by the percentage of asphalt binder.

10. **F-T : Fifty - Thirty Value** – The value which is calculated to the nearest whole percentage point of the Fifty to Thirty (F-T) value, which is the percent of total aggregate retained between the No.50 (300 μm) and No. 30 (600 μm) sieves, minus the percent of total aggregate retained between the No. 30 (600 μm) and 16 (1.18mm)sieves.

11. **Hot Mix Asphalt Plants:**
    a) **Batch Plant** - A manufacturing facility for producing bituminous paving mixtures that proportions the aggregate and bituminous constituents into the mix by weighed batches, adds bituminous material by either weight or volume, and mixes the blend.

    b) **Drum Mix Plant** - A manufacturing facility for producing bituminous paving mixtures that continuously proportions aggregate, heats and dries in a rotating drum and simultaneously mixes them with a controlled amount of bituminous material. The same plant may produce cold-mix paving mixtures without heating and drying the aggregate.
12. **J.M.F. – Job Mix Formula** – It is an Asphalt Concrete Mix Design made up of a percentage of Aggregate and a percentage of Asphalt Binder blended to meet a mix types pre-determined design criteria.

13. **MSG - Maximum Specific Gravity** - Test performed on loose hot mix asphalt, commonly known as RICE test.

14. **Maximum Size Aggregate** - One sieve larger than the nominal maximum size.

15. **Nominal Maximum Size Aggregate** - One sieve size larger than the first sieve to retain more than 10 percent.

16. **PG - Performance Graded Asphalt (eg. PG 64 -22)** - Using the 64 -22 as an example the binder must meet high temperature physical property requirements at least up to a temperature of 64° C and low temperature physical property requirements at least down to -22° C.

17. **QA - Quality Assurance**

18. **QC - Quality Control**

19. **QCP - Quality Control Program**

20. **Specific Gravity** - Ratio of the mass of the given volume of material to the mass of an equal volume of water at the same temperature (25° C or 77° F)

   **NOTE:** Specific Gravity has NO SPECIFIC UNITS.

21. **Optimum Asphalt Content – Design Asphalt Content** – The asphalt content that best fits the blended materials chosen to be utilized in the design asphalt mix. This asphalt content is chosen by utilizing the volumetric properties of a mix design.

22. **D.E.T.** – This abbreviation stands for the **District Engineer of Tests**. This person is responsible for the quality of the materials being used on ODOT projects in their district. There are twelve (12) districts in the State of Ohio.

23. **D.C.E.** - This abbreviation stands for the **District Construction Engineer**. This person is responsible for the quality of the construction practices being used on ODOT projects in their district.
**ODOT Accepted Rounding off Procedure for Level 2 and 3 Asphalt Approval**

Note:
If the last number your using to round off is a 5:
You will round up to the next number:

**EXAMPLES:**

**Rounding to the Whole number:**

38.5 = 39  
38.501 or greater = 39

39.5 = 40  
39.501 or greater = 40

**********************************************************

**Rounding to the nearest 0.1:**

3.85 = 3.9  
3.8501 or greater = 3.9

3.95 = 4.0  
3.9501 or greater = 4.0

**********************************************************

**Rounding to the nearest 0.01:**

1.374 = 1.37  
1.385 = 1.39

1.375 = 1.38  
1.395 = 1.40

**********************************************************

**Rounding to the nearest 0.001:**

1.3774 = 1.377  
1.3785 = 1.379

1.3775 = 1.378  
1.37851 = 1.379
ODOT ROUNDING  
(Practice Problem)

When the number following the place holder is exactly 5 – **Round Up**

When the place holder is higher than 5 – **Round Up**

When the place holder is less than 5 – **Round Down**

**Examples:**

When rounding to the nearest whole number:

- 4.5000 rounds to 5.0
- 4.4999 rounds to 4.0
- 4.5001 rounds to 5.0

**Round to nearest whole number (1):**

- 6.4 _____
- 6.5 _____
- 6.51 _____
- 5.6 _____
- 6.501 _____
- 5.5 _____

**Round to the nearest tenth (0.1):**

- 7.450 _____
- 6.649 _____
- 6.651 _____

**Round to the nearest thousandth (0.001):**

- 7.9905 _____
- 6.7445 _____
- 2.6499 _____
- 2.3354 _____
- 7.002500001 _____
- 2.999500000 _____
AGGREGATE MOISTURE CALCULATIONS

Used at all Drum Mix Plants and Batch Plants where RAP is introduced at Hot Elevator

Formula:

Aggregate Wet Weight - Aggregate Dry Weight = Aggregate Moisture

\[(\text{Aggregate Moisture} ÷ \text{Aggregate Dry Weight}) \times 100 = \% \text{ Moisture}\]

Example:

\[
\begin{align*}
\text{Agg. Wet Wt.} & - \text{Agg. Dry Wt.} = \text{Wt. of Moisture} \\
1000 \text{ Grams} & - \ 965 \text{ Grams} = \ 35 \text{ Grams of Moisture} \\
(\text{Agg. Moisture} ÷ \text{Agg. Dry Wt}) \times 100 & = \% \text{ Moisture} \\
(35 \text{ Grams} ÷ \ 965 \text{ Grams}) \times 100 & = 3.6 \% \text{ Moisture}
\end{align*}
\]

Using the formula listed below Calculate the % Moisture for each Aggregate and then combine the answers to obtain the % of Total Moisture.

\[
\begin{align*}
\% \text{ Moisture in Agg. # 1} & \times \% \text{ Agg. # 1 used in mix (per JMF) (made into decimal)} \\
+ \% \text{ Moisture in Agg. # 2} & \times \% \text{ Agg. # 2 used in mix (per JMF) (made into decimal)} \\
+ \% \text{ Moisture in Agg. # 3} & \times \% \text{ Agg. # 3 used in mix (per JMF) (made into decimal)} \\
= \text{Total Moisture of Aggregates for this JMF.}
\end{align*}
\]

Given:

\[
\begin{align*}
\text{Agg. # 1} & - 40\% \text{ in JMF} \quad \text{Moisture Agg. # 1} = 3.6\% \\
\text{Agg. # 2} & - 20\% \text{ in JMF} \quad \text{Moisture Agg. # 2} = 3.0\% \\
\text{Agg. # 3} & - 40\% \text{ in JMF} \quad \text{Moisture Agg. # 3} = 4.0\%
\end{align*}
\]

\[
\begin{align*}
\text{Agg. # 1} & = 3.6 \times 0.40 = 1.4 \% \\
\text{Agg. # 2} & = 3.0 \times 0.20 = + 0.6 \% \\
\text{Agg. # 3} & = 4.0 \times 0.40 = + 1.6 \%
\end{align*}
\]

\[\text{Total Moisture} = 3.6 \%\]

NOTE: Round off to nearest 0.1 %
Moisture Practice Problem

Given the following information from a JMF:

(1) - Calculate the Moisture Content percentages for each Aggregate Size along with the Rap that is being utilized in this Job Mix Formula composition.

After completion of those calculations:

(2) - Calculate the Total Moisture percentage for the entire Job Mix Formula.

<table>
<thead>
<tr>
<th>Aggregate</th>
<th>Size</th>
<th>Used (%)</th>
<th>Wet Weight</th>
<th>Dry Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agg. 1</td>
<td># 57's</td>
<td>37</td>
<td>1000 grams</td>
<td>965 grams</td>
</tr>
<tr>
<td>Agg. 2</td>
<td># 8's</td>
<td>16</td>
<td>1000 grams</td>
<td>963 grams</td>
</tr>
<tr>
<td>Agg. 3</td>
<td>SAND</td>
<td>32</td>
<td>1000 grams</td>
<td>953 grams</td>
</tr>
<tr>
<td>Agg. 4</td>
<td>RAP</td>
<td>15</td>
<td>1000 grams</td>
<td>959 grams</td>
</tr>
</tbody>
</table>

Show all Calculations:

% Moisture for Agg. # 1
+% Moisture for Agg. # 2
+% Moisture for Agg. # 3
+% Moisture for Rap # 4

% Total Moisture =
Moisture Practice Problem
(Answer Sheet)

Given the following information from a JMF:

(1) - Calculate the Moisture Content percentages for each Aggregate Size along with the Rap that is being utilized in this Job Mix Formula composition.

After completion of those calculations:

(2) - Calculate the Total Moisture percentage for the entire Job Mix Formula.

Agg. # 1 — # 57's — 37 % used — Wet Wt. = 1000 grams — Dry Wt. = 965 grams
Agg. # 2 — # 8's — 16 % used — Wet Wt. = 1000 grams — Dry Wt. = 963 grams
Agg. # 3 — SAND — 32 % used — Wet Wt. = 1000 grams — Dry Wt. = 953 grams
Agg. # 4 — RAP — 15 % used — Wet Wt. = 1000 grams — Dry Wt. = 959 grams

Show all Calculations:

Agg. # 1  
1000 – 965 = 35 / 965 X 100 = 3.6 % x .37 = 1.3 %

Agg. # 2  
1000 – 963 = 37 / 963 X 100 = 3.8 % x .16 = 0.6 %

Agg. # 3  
1000 – 953 = 47 / 953 X 100 = 4.9 % x .32 = 1.6 %

Agg. # 4  
1000 – 959 = 41 / 959 X 100 = 4.3 % x .15 = 0.6 %

Total = 1.3 % + 0.6 % + 1.6 % + 0.6 % = 4.1 % Total Moisture

% Moisture for Agg. # 1 — 1.3 %
+ % Moisture for Agg. # 2 — 0.6 %
+ % Moisture for Agg. # 3 — 1.6 %
+ % Moisture for Rap # 4 — 0.6 %

% Total Moisture = 4.1 %
Formulas for Extraction / Gradation Worksheet Calculations

*The following information would be obtained through testing:*

- **Nuclear Gauge AC** — **Effluent** — **Ash per 100 ML**
- **Sample Gross** — **Extracted Aggregates** — **Grams (Sieves)**

**Formulas:**

1) **Mineral in Effluent (Grams)** = Effluent \( \div \ 100 \times \text{Ash per 100 ML} \) (Whole Number)

2) **Net Wt. of Agg. (Grams)** = Extracted Agg. + Mineral (From Calculation # 1)

3) **% Passing (Sieves)** = Grams \( \div \) Net Wt. of Agg. \( \times \) 100 – 100

(Round to the Whole Number except the 200 Sieve as it rounds to the 0.1 %)

4) **Corrected Bitumen (Grams)** = Sample Gross – Net Wt. of Agg. (Whole Number)

5) **Corrected Bitumen %** = Corrected Bitumen \( \div \) Sample Gross \( \times \) 100 (0.1 %)

**To Calculate the Composite: Follow these Steps:**

1) Add the Sample Gross Weights of each Sample Increment.

2) Add the Net Weights of Aggregate of each Sample Increment.

3) Add the Sieve Weights for each sieve size of each Sample Increment.

4) Add the Corrected Bitumen Weights of each sample Increment.

5) To Calculate the % Passing of each Sieve in the Composite – use #3 under Formulas

6) To Calculate the % Bitumen in the Composite – use #5 under Formulas

***NOTE: Do Not Average The Composite, This can give False Information.***

7) Calculate the **F / A Ratio** and the **F - T Value**

**F / A = % Passing the 200 \( \div \) Nuclear Gauge AC** (Report to the tenth)

* F - T = (P30 – P50) – (P16 – P30) (Round to the Whole Number and report as + or - number)
Utilizing the following Data given from this Laboratory Extraction and Gradation analysis along with the Nuclear Asphalt Content Gauge reading:

A. Calculate the corrected gradation percentage and the corrected bitumen content of each sample increment.

B. Combine the increments arithmetically to form the composite sample result.

C. Calculate the Fines / Asphalt Ratio and the Fifty / Thirty Value for the composite.

<table>
<thead>
<tr>
<th>Individual Bowls</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>Composite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncorrected Bitumen</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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F / A Ratio___________  F - T Value____________
F/A & F-T Practice Problem

Given the following Test Results:

Calculate the F/A Ratio and the F-T Value.

% Passing  1/2  72 %
% Passing  3/8  58 %
% Passing  # 4  44 %
% Passing  # 8  36 %
% Passing  # 16 29 %
% Passing  # 30 21 %
% Passing  # 50  8 %
% Passing  # 100 3 %
% Passing  # 200 1.9 %

Extracted AC  5.3 %

Nuclear Gauge AC  5.7 %

Show All Calculations:

F/A__________                    F-T__________
Practice Problem

Given the following Test Results:

(A) Calculate the % Moisture Correction:

(B) Adjust the % PG Binder Content:

(C) Calculate the Fines to Asphalt Ratio:

Nuclear AC 5.9 %

Extracted AC 5.4 %

Mix Wt. Before Dry Back 2500 grams

Mix Wt. After Dry Back 2493 grams

% Passing # 200 Sieve 4.7 %

Moisture %

Adjusted AC %

Fines to Asphalt Ratio
## Practice Problem

Utilizing the following Data given from this Laboratory Extraction and Gradation analysis along with the Nuclear Asphalt Content Gauge reading:

A. Calculate the corrected gradation percentage and the corrected bitumen content of each sample increment.

B. Combine the increments arithmetically to form the composite sample result.

C. Calculate the Fines / Asphalt Ratio and the Fifty / Thirty Value for the composite.

<table>
<thead>
<tr>
<th>Individual Bowls</th>
<th>A</th>
<th>B</th>
<th>C</th>
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<th>Composite</th>
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**F / A Ratio**__________  **F - T Value**__________
**Practice Problem**  
(Answer Sheet)

Utilizing the following Data given from this Laboratory Extraction and Gradation analysis along with the Nuclear Asphalt Content Gauge reading:

A. Calculate the corrected gradation percentage and the corrected bitumen content of each sample increment.

B. Combine the increments arithmetically to form the composite sample result.

C. Calculate the Fines / Asphalt Ratio and the Fifty / Thirty Value for the composite.

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| Corrected Bitumen | 136 | 134 | 4.4 | 96 | 4.8 | 366 | 4.6 |

F / A Ratio **1.1**  
F - T Value **+4**
Effective Asphalt Content and F/A Calculation
Ohio DOT  Ver4/2011

This worksheet is used only when, according to specification, the calculation of the F/A ratio requires the use of the effective asphalt content. The fines portion of the F/A ratio always requires the use of the P200 from a washed gradation (or dry adjusted P200 from correction between previous dry and washed gradation noted on 189).

Date ___________________  JMF No_________________________  Mix sample ID ____________

Step 1  Determine asphalt absorption

\[ P_{ba} = \text{asphalt absorption, \% by mass of aggregate} \]
\[ G_{se} = \text{bulk specific gravity of aggregate (from mix design)} = \_\_\_\_\_\_\_\_\_\_\_ \]
\[ G_b = \text{specific gravity of binder (from mix design)} = \_\_\_\_\_\_\_\_\_\_\_ \]
\[ G_{se} = \text{effective specific gravity of aggregate (calculated)}: \]
\[ \frac{P_{mn}}{P_{mm}} - \frac{P_b}{P_b} \quad G_{mn} = \text{maximum specific gravity (from mix test)} = \_\_\_\_\_\_\_\_\_\_\_ \]
\[ G_{mn} - \frac{P_b}{G_b} \quad P_{mn} = 100 \]
\[ \frac{G_{mn}}{G_b} \quad P_b = \text{asphalt content (from mix test)} = \_\_\_\_\_\_\_\_\_\_\_ \]
\[ G_b = \text{specific gravity of binder (from mix design)} = \_\_\_\_\_\_\_\_\_\_\_ \]
\[ G_{se} = \_\_\_\_\_\_\_\_\_\_\_ \quad \text{Show work:} \]

\[ P_{ba} = 100 \times \frac{G_{se} - G_{eb}}{G_{eb} G_{se}} \times G_b = \_\_\_\_\_\_\_\_\_\_\_\_ \quad \text{Show work:} \]

Note: \( G_{se} \) should always be higher than \( G_{eb} \), if not don’t continue until the problem is corrected.

Step 2  Determine effective asphalt content

\[ P_{ba} = \text{effective asphalt content, \% by total mass of mix} \]
\[ P_b = \text{asphalt content, \% by total mass of mix (from mix test)} = \_\_\_\_\_\_\_\_\_\_\_ \]
\[ P_{be} = \text{absorbed asphalt, \% by mass of aggregate (from above)} = \_\_\_\_\_\_\_\_\_\_\_ \]
\[ P_e = \text{aggregate content, \% by total mass of mix (100 - P_b)} = \_\_\_\_\_\_\_\_\_\_\_ \]

\[ P_{be} = P_b - \frac{P_{ba} \times P_e}{100} = \_\_\_\_\_\_\_\_\_\_\_\_ \quad \text{Show work:} \]

Step 3  Determine fines to asphalt ratio (F/A)

\[ F = \text{washed or corrected dry P200 (attach gradation worksheet)} = \_\_\_\_\_\_\_\_\_\_\_\_ \]
\[ A = \text{effective asphalt content (P_{be} from above)} = \_\_\_\_\_\_\_\_\_\_\_\_ \]

\[ F/A = \_\_\_\_\_\_\_\_\_\_\_\_ \quad \text{ephasph2011} \]
Maximum Specific Gravity (Rice)

Practice Problem # 1

Given the following Test Results:

Calculate the Maximum Theoretical Specific Gravity:

A = Dry Weight of Mix --------------------------------------------- 1818.0 grams

A* = S.S.D. Wt. of Sample ----------------------------------------- 1920.3 grams

B = Weight of Flask, Mix and Water ------------------------------- 7292.7 grams

C = Weight of Flask and Water (Constant) ------------------------- 6331.9 grams

D = B – C

E = A* – D

F = A ÷ E

(Show all Calculations)

ANSWER ____________________
Maximum Specific Gravity (Rice)
Practice Problem # 2

Given the following Test Results:

Calculate the Maximum Theoretical Specific Gravity:

\[ A = \frac{\text{Dry Weight of Mix}}{} = 1620.0 \text{ grams} \]
\[ A^* = \frac{\text{S.S.D. Wt. of Sample}}{} = 1686.0 \text{ grams} \]
\[ B = \frac{\text{Weight of Flask, Mix and Water}}{} = 7193.9 \text{ grams} \]
\[ C = \frac{\text{Weight of Flask and Water (Constant)}}{} = 6228.1 \text{ grams} \]
\[ D = B - C \]
\[ E = A^* - D \]
\[ F = A ÷ E \]

(Show all Calculations)

ANSWER ____________________
Maximum Specific Gravity (Rice)

Practice Problem # 3
(Test Format)

Given the following information:

Calculate the Maximum Theoretical Specific Gravity:

Dry Weight of Mix --------------------------------------------- 1997.3 grams
S.S.D. Wt. of Sample ------------------------------------------ 1999.5 grams
Weight of Flask, Mix and Water ------------------------------- 7289.1 grams
Weight of Flask and Water (Constant) ------------------------- 6120.9 grams
Temperature of Water ---------------------------------------- 25 Degrees C
PG Binder % ---------------------------------------------------- 5.5%

(Show all Calculations)

ANSWER ____________________
BULK SPECIFIC GRAVITY

Example Calculation Worksheet for a Set of (3) Marshall Specimen(s)

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<tr>
<th>Compacton Temperature</th>
<th>Weight in Air (A)</th>
<th>SSD Weight (B)</th>
<th>Weight in Water (C)</th>
<th>Volume, cc (D)</th>
<th>Actual Specific Gravity (E)</th>
<th>Max Theo. Specific Gravity (F)</th>
<th>% Air Voids</th>
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Water Temp. is 21°C

Avg. Specific Gravity = 2.318

Corrected Avg. Specific Gravity = 2.320

% Air Voids = 4.3%

* Formula for Calculating % Air Voids:

\[
\frac{(E \div F \times 100 - 100)}{100} = \% \text{ AIR VOIDS}
\]

\[
2.320 \div 2.425 \times 100 - 100 = 4.3\%
\]

Conversion Chart:

Absolute Density of Water and Conversion Factor (K) for Various Water Temperatures

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<thead>
<tr>
<th>Temperature C</th>
<th>Correction Factor (K)</th>
<th>Temperature C</th>
<th>Correction Factor (K)</th>
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</thead>
<tbody>
<tr>
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<td>1.002661</td>
<td>21</td>
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<td>1.002567</td>
<td>22</td>
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<td>1.002458</td>
<td>23</td>
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<td>13</td>
<td>1.002338</td>
<td>24</td>
<td>1.000253</td>
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<td>1.002204</td>
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<td>0.999000</td>
</tr>
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<td>15</td>
<td>1.002060</td>
<td>26</td>
<td>0.999738</td>
</tr>
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<td>16</td>
<td>1.001903</td>
<td>27</td>
<td>0.999467</td>
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<td>0.999187</td>
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<td>29</td>
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</tr>
<tr>
<td>19</td>
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<td>30</td>
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</tr>
<tr>
<td>20</td>
<td>1.001162</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Formula for Correcting Water Bath Temperature:

\[
\text{Correction Factor (K) } \times \text{ Avg. Bulk Specific Gravity} = \text{ Corrected Avg. Specific Gravity}
\]

Example for above Test: 1.000950 \times 2.318 = 2.320
Bulk Specific Gravity and % Air Voids

Practice Problem # 1

Given the Following Test Results:

1) Calculate the Bulk Specific Gravity (BSG):

2) Adjust the BSG for Water Bath Temperature:

3) Calculate the % Air Voids:

Dry Weight in Air ---------------------------------- 1147.5 Grams
S.S.D. Weight -------------------------------------- 1148.9 Grams
Weight in Water ---------------------------------- 640.9 Grams
Temperature of Water Bath -------------------------- 27 Degrees C.
Maximum Theoretical Specific Gravity (MSG) --------- 2.396

(Show all Work)

Answers:

1) Bulk Specific Gravity (BSG) ____________

2) BSG Corrected for Water Bath Temperature ____________

3) % Air Voids __________
Bulk Specific Gravity and % Air Voids

Practice Problem # 2

Given the Following Test Results:

1) Calculate the Bulk Specific Gravity (BSG):

2) Adjust the BSG for Water Bath Temperature:

3) Calculate the % Air Voids:

Dry Weight in Air ------------------------------- 1151.5 Grams

S.S.D. Weight ---------------------------------- 1152.7 Grams

Weight in Water ------------------------------ 652.0 Grams

Temperature of Water Bath ------------------ 21 Degrees C.

Maximum Theoretical Specific Gravity (MSG) ------ 2.396

(Show all Work)

Answers:

1) Bulk Specific Gravity (BSG) _____________

2) BSG Corrected for Water bath Temperature ______________

3) % Air Voids __________
# BULK SPECIFIC GRAVITY and % AIR VOID

(Practice Problem #3)

## Problem (A)

<table>
<thead>
<tr>
<th>Compaction Temperature</th>
<th>Weight in Air (A)</th>
<th>SSD Weight (B)</th>
<th>Weight in Water (C)</th>
<th>Volume cc (D)</th>
<th>Actual Specific Gravity (E)</th>
<th>Max Theo. Specific Gravity (F)</th>
<th>% Air Voids</th>
</tr>
</thead>
<tbody>
<tr>
<td>290</td>
<td>1318.0</td>
<td>1319.5</td>
<td>755.5</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>290</td>
<td>1183.9</td>
<td>1184.9</td>
<td>679.5</td>
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<td></td>
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</tr>
<tr>
<td>290</td>
<td>1350.8</td>
<td>1351.7</td>
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<td></td>
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Water Temperature is 28 C

Avg. Specific Gravity

Corrected Avg. B.S.G. 2.443

## Problem (B)

<table>
<thead>
<tr>
<th>Compaction Temperature</th>
<th>Weight in Air (A)</th>
<th>SSD Weight (B)</th>
<th>Weight in Water (C)</th>
<th>Volume cc (D)</th>
<th>Actual Specific Gravity (E)</th>
<th>Max Theo. Specific Gravity (F)</th>
<th>% Air Voids</th>
</tr>
</thead>
<tbody>
<tr>
<td>290</td>
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<tr>
<td>290</td>
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<td>1294.8</td>
<td>735.6</td>
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<tr>
<td>290</td>
<td>1244.2</td>
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<td>707.7</td>
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</tr>
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Water Temperature is 25 C

Avg. Specific Gravity

Corrected Avg. B.S.G. 2.405

## Problem (C)

<table>
<thead>
<tr>
<th>Compaction Temperature</th>
<th>Weight in Air (A)</th>
<th>SSD Weight (B)</th>
<th>Weight in Water (C)</th>
<th>Volume cc (D)</th>
<th>Actual Specific Gravity (E)</th>
<th>Max Theo. Specific Gravity (F)</th>
<th>% Air Voids</th>
</tr>
</thead>
<tbody>
<tr>
<td>290</td>
<td>1202.2</td>
<td>1203.8</td>
<td>693.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>290</td>
<td>1201.3</td>
<td>1201.9</td>
<td>690.8</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>290</td>
<td>1205.8</td>
<td>1207.8</td>
<td>685.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Water Temperature is 19 C

Avg. Specific Gravity

Corrected Avg. B.S.G. 2.438
## BULK SPECIFIC GRAVITY and % AIR VOID

(Practice Problem # 3 - Answer Sheet)

### Problem (A)

<table>
<thead>
<tr>
<th>Compaction Temperature</th>
<th>Weight in Air (A)</th>
<th>SSD Weight (B)</th>
<th>Weight in Water (C)</th>
<th>Volume cc (D)</th>
<th>Actual Specific Gravity (E)</th>
<th>Max Theo. Specific Gravity (F)</th>
<th>% Air Voids</th>
</tr>
</thead>
<tbody>
<tr>
<td>290</td>
<td>1318.0</td>
<td>1319.5</td>
<td>755.5</td>
<td>564.0</td>
<td>2.337</td>
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<td></td>
</tr>
<tr>
<td>290</td>
<td>1183.9</td>
<td>1184.9</td>
<td>679.5</td>
<td>505.4</td>
<td>2.343</td>
<td></td>
<td></td>
</tr>
<tr>
<td>290</td>
<td>1350.8</td>
<td>1351.7</td>
<td>775.3</td>
<td>576.4</td>
<td>2.344</td>
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<td></td>
</tr>
</tbody>
</table>

Water Temperature – 28 C  
Avg. Specific Gravity 2.341  
Corrected Avg. B.S.G. 2.339 2.443 4.3

### Problem (B)

<table>
<thead>
<tr>
<th>Compaction Temperature</th>
<th>Weight in Air (A)</th>
<th>SSD Weight (B)</th>
<th>Weight in Water (C)</th>
<th>Volume cc (D)</th>
<th>Actual Specific Gravity (E)</th>
<th>Max Theo. Specific Gravity (F)</th>
<th>% Air Voids</th>
</tr>
</thead>
<tbody>
<tr>
<td>290</td>
<td>1232.5</td>
<td>1233.0</td>
<td>702.8</td>
<td>530.2</td>
<td>2.325</td>
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<td></td>
</tr>
<tr>
<td>290</td>
<td>1293.8</td>
<td>1294.8</td>
<td>735.6</td>
<td>559.2</td>
<td>2.314</td>
<td></td>
<td></td>
</tr>
<tr>
<td>290</td>
<td>1244.2</td>
<td>1244.8</td>
<td>707.7</td>
<td>537.1</td>
<td>2.317</td>
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Water Temperature – 25 C  
Avg. Specific Gravity 2.319  
Corrected Avg. B.S.G. 2.319 2.405 3.6

### Problem (C)

<table>
<thead>
<tr>
<th>Compaction Temperature</th>
<th>Weight in Air (A)</th>
<th>SSD Weight (B)</th>
<th>Weight in Water (C)</th>
<th>Volume cc (D)</th>
<th>Actual Specific Gravity (E)</th>
<th>Max Theo. Specific Gravity (F)</th>
<th>% Air Voids</th>
</tr>
</thead>
<tbody>
<tr>
<td>290</td>
<td>1202.2</td>
<td>1203.8</td>
<td>693.9</td>
<td>509.9</td>
<td>2.358</td>
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</tr>
<tr>
<td>290</td>
<td>1201.3</td>
<td>1201.9</td>
<td>690.8</td>
<td>511.1</td>
<td>2.350</td>
<td></td>
<td></td>
</tr>
<tr>
<td>290</td>
<td>1205.8</td>
<td>1207.8</td>
<td>685.9</td>
<td>521.9</td>
<td>2.310</td>
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</tbody>
</table>

Water Temperature – 19 C  
Avg. Specific Gravity 2.339  
Corrected Avg. B.S.G. 2.342 2.438 3.9
### Field Test Worksheet

#### Extraction, Dust Correction & Gradation

<table>
<thead>
<tr>
<th>SIEVE #</th>
<th>WEIGHT RETAINED</th>
<th>% PASSING</th>
<th>(A) DRY WT. OF MIX</th>
<th>1561.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>2&quot;</td>
<td>SOLVENT 3040</td>
<td></td>
<td>(A*) SSD WT. OF MIX</td>
<td></td>
</tr>
<tr>
<td>1.5&quot;</td>
<td>DISH &amp; ASH 85.50</td>
<td></td>
<td>(B) CONT. OF MIX &amp; WATER</td>
<td>8428.1</td>
</tr>
<tr>
<td>1.0&quot;</td>
<td>DISH 84.62</td>
<td></td>
<td>(C) CONT. OF WATER (CONST)</td>
<td>7501.1</td>
</tr>
<tr>
<td>3/4&quot;</td>
<td>300</td>
<td></td>
<td>(B - C) = (D)</td>
<td></td>
</tr>
<tr>
<td>½&quot;</td>
<td>1220</td>
<td></td>
<td>(A* - D) = (E)</td>
<td></td>
</tr>
<tr>
<td>3/8&quot;</td>
<td>1449</td>
<td></td>
<td>(A + E) = (F)</td>
<td></td>
</tr>
</tbody>
</table>

#### Rice Test

<table>
<thead>
<tr>
<th>amaño</th>
<th>WT. OF ASH</th>
<th>MIN. in EFF.</th>
<th>PAN WT.</th>
<th>479.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>#4</td>
<td>1514</td>
<td></td>
<td>ORIG. WT.</td>
<td>3000</td>
</tr>
<tr>
<td>#8</td>
<td>1644</td>
<td></td>
<td>EXT. WT.</td>
<td>2844</td>
</tr>
<tr>
<td>#16</td>
<td>1793</td>
<td></td>
<td>NET WT.</td>
<td>2045.0</td>
</tr>
<tr>
<td>#30</td>
<td>2024</td>
<td></td>
<td>BIT WT.</td>
<td>2043.1</td>
</tr>
<tr>
<td>#50</td>
<td>2343</td>
<td>% AC</td>
<td>2041.3</td>
<td></td>
</tr>
<tr>
<td>#100</td>
<td>2748</td>
<td></td>
<td>2041.1</td>
<td></td>
</tr>
<tr>
<td>#200</td>
<td>2784</td>
<td>Uncorrected Gauge AC%</td>
<td>4.6</td>
<td></td>
</tr>
<tr>
<td>PAN</td>
<td>2843</td>
<td>% Moisture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSD Weight</td>
<td></td>
<td>Corrected Gauge AC%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Mix & PAN WT.

Mix & PAN WT. | 2986 | DRY Mix & PAN WT. | 2979 |

#### F/T Value

F/T Value - | F/A Ratio -

#### Pills

<table>
<thead>
<tr>
<th></th>
<th>DRY WEIGHT (A)</th>
<th>SSD WEIGHT (B)</th>
<th>WT. IN WATER (C)</th>
<th>B - C (D)</th>
<th>A + D (E)</th>
<th>MSG (RICE)</th>
<th>% AIR VOID</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1208.7</td>
<td>1209.7</td>
<td>701.0</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1181.2</td>
<td>1182.4</td>
<td>681.9</td>
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<td></td>
<td></td>
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<tr>
<td>3</td>
<td>1216.0</td>
<td>1216.7</td>
<td>708.5</td>
<td></td>
<td></td>
<td>MSG (RICE)</td>
<td></td>
</tr>
</tbody>
</table>

Water Bath Temperature = 26 C

**Avg. BSG**

**Corr. BSG**

---

38
### Field Test Worksheets (Answer Sheet)

<table>
<thead>
<tr>
<th>SIEVE #</th>
<th>WEIGHT RETAINED</th>
<th>% PASSING</th>
<th>(A) DRY WT.. OF MIX</th>
<th>(A*) SSD WT. OF MIX</th>
<th>(B) CONT. OF MIX &amp; WATER</th>
<th>(C) CONT. OF WATER (CONST)</th>
<th>(B - C) = (D)</th>
<th>(A* - D ) = (E)</th>
<th>(A + E) = (F)</th>
<th>PAN WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2&quot;</td>
<td>SOLVENT</td>
<td>3040</td>
<td>1561.1</td>
<td>1561.9</td>
<td>8428.1</td>
<td>7501.1</td>
<td>927.0</td>
<td>634.9</td>
<td>2.459</td>
<td>479.2</td>
</tr>
<tr>
<td>1.5&quot;</td>
<td>DISH &amp; ASH</td>
<td>85.50</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>1.0&quot;</td>
<td>DISH</td>
<td>84.62</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3/4&quot;</td>
<td>300</td>
<td>90</td>
<td>WT. OF ASH</td>
<td>0.88</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>½&quot;</td>
<td>1220</td>
<td>58</td>
<td>MIN. in EFF.</td>
<td>27</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
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### Field Test Worksheets (Answer Sheet)

<table>
<thead>
<tr>
<th>#4</th>
<th>1514</th>
<th>47</th>
<th>ORIG. WT.</th>
<th>3000</th>
<th>TIME</th>
<th>WEIGHT</th>
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</thead>
<tbody>
<tr>
<td>#8</td>
<td>1644</td>
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<td>EXT. WT.</td>
<td>2844</td>
<td>10:30</td>
<td>2045.0</td>
</tr>
<tr>
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<td>1793</td>
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<td>10:45</td>
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<tr>
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<td>2024</td>
<td>30</td>
<td>BIT WT.</td>
<td>129</td>
<td>11:00</td>
<td>2041.3</td>
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<tr>
<td>#50</td>
<td>2343</td>
<td>18</td>
<td>% AC</td>
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<td>11:15</td>
<td>2041.1</td>
</tr>
<tr>
<td>#100</td>
<td>2748</td>
<td>4</td>
<td>SSD Weight</td>
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<td></td>
</tr>
<tr>
<td>#200</td>
<td>2784</td>
<td>3.0</td>
<td>Uncorrected Gauge AC%</td>
<td>4.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PAN</td>
<td>2843</td>
<td></td>
<td>% Moisture</td>
<td>0.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Corrected Gauge AC %</td>
<td>4.3</td>
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</tr>
</tbody>
</table>

**MIX & PAN WT.** 2986 **DRY MIX & PAN WT.** 2979

**PAN WT.** 483 **% MOISTURE** 0.3

F/T Value +4 F/A Ratio 0.7

### PILLS

<table>
<thead>
<tr>
<th>DRY WEIGHT (A)</th>
<th>SSD WEIGHT (B)</th>
<th>WT. IN WATER (C)</th>
<th>B - C (D)</th>
<th>A ÷ D (E)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 1208.7</td>
<td>1209.7</td>
<td>701.0</td>
<td>508.7</td>
<td>2.376</td>
</tr>
<tr>
<td>2 1181.2</td>
<td>1182.4</td>
<td>681.9</td>
<td>500.5</td>
<td>2.360</td>
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<td>3 1216.0</td>
<td>1216.7</td>
<td>708.5</td>
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<td>2.393</td>
</tr>
</tbody>
</table>

WATER BATH TEMPERATURE = 26 C

<table>
<thead>
<tr>
<th>AVG. BSG</th>
<th>CORR. BSG</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.376</td>
<td>2.375</td>
</tr>
</tbody>
</table>

% AIR VOID: 3.4
441.10 Control Charts.

Maintain up to date control charts showing each individual test result and also the moving accumulative range as follows:

A. Plot tests showing the percent passing for the 1/2 inch (12.5 mm), No. 4 (4.75 mm), No. 8 (2.36 mm), and No. 200 (75 µm) sieves the percent asphalt binder content, the MSG and the percent air voids. Round all percentages to the nearest whole percent; except, round asphalt binder content, the No. 200 (75 µm) sieve, and air voids to the nearest 0.1 percent.

B. Show the out of specification limits specified in Table 441.10-1 and QCP Warning Band Limits on the control charts.

C. Label each control chart to identify the project, mix type and producer.

D. Record the moving accumulative range for three tests under each test point on the chart for air voids and asphalt binder content. Accumulative range is defined as the positive total of the individual ranges of two consecutive tests in three consecutive tests regardless of the up or down direction tests take. If more than the minimum required testing (i.e. two tests per production day or night, 441.09 first paragraph) is performed do not include the result in accumulative range calculations.

Stop production and immediately notify the Monitoring Team when either A or B occurs:

A. Any two tests in a row or any two tests in two days are outside OF the specification limits of Table 441.10-1.

B. Any four consecutive moving accumulative ranges greater than specification limits of 2.50 percent for air voids or 0.60 percent for asphalt binder content occur. Any mixture sent to the paving site without stopping production and notifying the Monitoring Team when required by this specification will be considered non-specification material.

Do not restart production until an adequate correction to remedy problems is in place and the Monitoring Team is satisfied. Following a shutdown restart production in a manner acceptable to the DET. When production problems cannot be solved within one day after a plant shut down a Contractor’s representative holding a Level 3 Asphalt Department approval is required to be at the asphalt plant until a full production day is achieved with results satisfactory to the Monitoring Team.
<table>
<thead>
<tr>
<th>Mix Characteristic</th>
<th>Out of Specification Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt Binder Content[1]</td>
<td>-0.3% to 0.3%</td>
</tr>
<tr>
<td>1/2 inch (12.5 mm) sieve[1]</td>
<td>-6.0% to 6.0%</td>
</tr>
<tr>
<td>No. 4 (4.75 mm) sieve[1]</td>
<td>-5.0% to 5.0%</td>
</tr>
<tr>
<td>No. 8 (2.36 mm) sieve[1]</td>
<td>-4.0% to 4.0%</td>
</tr>
<tr>
<td>No. 200 (75 mm) sieve[1]</td>
<td>-2.0% to 2.0%</td>
</tr>
<tr>
<td>Air Voids[2]</td>
<td>2.5 to 4.5</td>
</tr>
<tr>
<td>Air Voids[3]</td>
<td>3.0 to 5.0</td>
</tr>
<tr>
<td>MSG[4]</td>
<td>-0.012 to 0.012</td>
</tr>
</tbody>
</table>

[1] deviation from the JMF
[2] for Design Air Voids of 3.5%
[3] for Design Air Voids of 4.0%
[4] deviation from the MTD
***When producing Asphalt Hot Mix for an ODOT project which is governed under ODOT’s 441.10, you must plot each Individual Test Result and record the accumulative range (for AV and AC only) on a Control Chart.

Using the Test Results Provided below:
(1) Set up your control chart to include the Specification Band Limit and the QCP Warning Band Limit of (-3.2% to 4.8%) for plotting Air Void test results.

(2) After setting up your Control Chart, Plot each of the Individual Test Results and calculate the accumulative range results for the following Air Void Tests.

**This is a 4.0% Air Void Designed Mix:**

The First Air Void test result shows a 4.6%

The Second Air Void test result shows a 5.2%

The Third Air Void test result shows a 4.8%

The Fourth Air Void test result shows a 4.1%

The Fifth Air Void test result shows a 6.2%

The Sixth Air Void test result shows a 6.1%

<table>
<thead>
<tr>
<th>Test Result</th>
<th>Air Void %</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td>4.6</td>
</tr>
<tr>
<td>Second</td>
<td>5.2</td>
</tr>
<tr>
<td>Third</td>
<td>4.8</td>
</tr>
<tr>
<td>Fourth</td>
<td>4.1</td>
</tr>
<tr>
<td>Fifth</td>
<td>6.2</td>
</tr>
<tr>
<td>Sixth</td>
<td>6.1</td>
</tr>
</tbody>
</table>
***When producing Asphalt Hot Mix for an ODOT project which is governed under ODOT’s 441.10, you must plot each Individual Test Result and record the accumulative range (for AV and AC only) on a Control Chart.

Using the Test Results Provided below:

(1) Set up your control chart to include the Specification Band Limit and the QCP Warning Band Limit of (-0.2% to 0.2%) for plotting Asphalt Content test results.

(2) After setting up your Control Chart, Plot each of the Individual Test Results and calculate the accumulative range results for the following Asphalt Contest Tests.

The JMF Asphalt Content is a 5.8%

The First Asphalt Content test result shows a 6.1%

The Second Asphalt Content test result shows a 6.1%

The Third Asphalt Content test result shows a 5.8%

The Forth Asphalt Content test result shows a 5.6%

The Fifth Asphalt Content test result shows a 5.5%

The Sixth Asphalt Content test result shows a 5.9%
### MOVING RANGE EXAMPLE – AC%

<table>
<thead>
<tr>
<th>AC%</th>
<th>6.0</th>
<th>5.4</th>
<th>6.3</th>
<th>6.0</th>
<th>5.8</th>
<th>6.2</th>
<th>6.0</th>
<th>6.1</th>
<th>5.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diff.</td>
<td>-</td>
<td>0.6</td>
<td>0.9</td>
<td>0.3</td>
<td>0.2</td>
<td>0.4</td>
<td>0.2</td>
<td>0.1</td>
<td>0.6</td>
</tr>
<tr>
<td>Range</td>
<td>-</td>
<td>-</td>
<td>1.5</td>
<td>1.2</td>
<td>0.5</td>
<td>0.6</td>
<td>0.6</td>
<td>0.3</td>
<td>0.7</td>
</tr>
</tbody>
</table>

### MOVING RANGE LIMITS*

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Voids</td>
<td></td>
<td>2.50%</td>
</tr>
<tr>
<td>AC</td>
<td></td>
<td>0.60%</td>
</tr>
</tbody>
</table>

*For four consecutive ranges

Notes:
- Used only for Air Voids and AC Graphs
- Only use the results obtained from the minimum, randomly selected, two QC tests/day

\[
\begin{align*}
AC &= 6.0-5.4=\textbf{0.6} \\
&\quad 5.4-6.9=\textbf{0.9} \\
&\quad 6.3-6.0=\textbf{0.3} \\
&\quad 6.0-5.8=\textbf{0.2} \\
&\quad 5.8-6.2=\textbf{0.4} \\
&\quad 6.2-6.0=\textbf{0.2} \\
\end{align*}
\]

\[
\begin{align*}
6.0-6.1=&\textbf{0.1} \\
6.1-5.5=&\textbf{0.6} \\
AC\ on\ two\ test\ and\ the\ difference \\
\end{align*}
\]

Range = 1\textsuperscript{st} Test=1.5  \ 2\textsuperscript{nd} Test=1.2  \ 3\textsuperscript{rd} Test=0.5  \ 4\textsuperscript{th} Test=0.6  \ 5\textsuperscript{th} Test=0.6  \ 6\textsuperscript{th} Test=0.3  \ 7\textsuperscript{th} Test=0.7
Sampling Hot Mix Asphalt

A. Sampling – General

1. Importance of Sampling

a. Sampling helps determine quality of material accepted by ODOT

b. Sampling helps determine proper payment to the contractor

(1) Incentive pay above bid price
(2) Full pay
(3) Reduced pay

c. Critical variables in construction

(1) Materials
(2) Production process
(3) Sampling
(4) Testing
(5) Construction operations

d. Deficiency in any of these is detrimental to achieving a quality pavement

2. Importance of Sampling HMA

a. Proper sampling of HMA is critical to determining specification compliance

b. Correct procedure at all levels is essential

(1) Components of HMA are sampled or certified prior to production of HMA
(2) HMA mixture is sampled at production facility and at project
(3) Sampling is performed by both contractor and ODOT personnel

The ODOT Sampling and Testing Manual provides guidance on sampling and testing requirements for ODOT personnel

B. Sampling Procedure
1. Concept of Sampling Procedure

   a. For many years, one sample was thought to be sufficient to represent a large quantity of material

   b. In the late 1970s, ODOT introduced the emerging concept of statistically-oriented specifications, which used the principles of:

      (1) Random sampling
      (2) Using the average of multiple samples
      (3) Sampling from lots and sublots of material

2. Proper Sampling Procedure

   a. A sample is properly taken if it is....

      (1) Representative of the material
      (2) Properly randomized and in conformance with agency procedures

   b. An improperly taken sample can skew the results of the QC and acceptance procedure by indicating that....

      (1) Bad material is acceptable
      (2) Good material is not-approved

3. Value of Proper Sampling

   a. The material represented by a sample of HMA can have a value of up to $50,000

   b. A sample taken improperly can result in....

      (1) ODOT accepting non-specification material
      (2) The contractor receiving reduced pay for material which meets specifications
      (3) The contractor having to remove and replace material which meets specifications

4. Sampling Before Production

   a. Approvals are responsibility of ODOT Office of Materials Management (Central Lab) in cooperation with District Testing Offices
b. Coarse and fine aggregates are certified by producer and sampled by District Testing personnel at aggregate plants and HMA facilities

c. Asphalt binder is certified by producer and check sampled by ODOT Central Lab

5. Sampling During Production at the HMA Plant

a. Most sampling at HMA plant is performed by contractor's plant technician as part of quality control function

b. ODOT personnel (Monitoring Team) observe sampling and testing at HMA plant and take samples as part of verification acceptance process

6. Sampling at the Project

a. ODOT personnel participate in acceptance sampling procedure at the project by determining location of random samples for 446 and taking samples of 448 when required

   (1) 446 sample core locations determined by random number calculation
   (2) 448 mix is sampled from road or hopper if construction or plant QC problems occur

C. Sampling HMA Specification Items

1. Sampling 301 and 302

   a. Sampled at HMA plant from truck selected at random by contractor's QC technician

   b. Monitoring team picks up "split samples" for testing by District Lab

2. Sampling 448

   a. Contractor's technician randomly selects truck, takes and tests samples for quality control at HMA plant

   b. Contractor's QC technician takes and splits sublot acceptance samples from truck selected at random by Monitoring Team

   c. Monitoring Team picks up split samples for testing at District Lab
d. If problems arise placing mix at project, such as segregation, or if QC problems persist at HMA plant, Monitoring Team may require that acceptance samples be taken from paver hopper or from behind paver at locations selected randomly by project personnel.

3. Sampling 446

a. Contractor is responsible for cutting cores from completed pavement at random locations determined by ODOT personnel.

b. ODOT personnel are responsible for calculating random sampling locations and for making information available to contractor in a timely manner.

c. ODOT personnel are responsible for carefully handling cores cut from pavement to prevent damage.

d. Cores are to be delivered to District Lab for testing as soon as possible.

D. Sampling Materials

1. Sampling Aggregate

a. Aggregate can be sampled at

(1) Project  
(2) HMA plant  
(3) Aggregate plant

b. Aggregate can be sampled from

(1) Roadway  
(2) Stockpile  
(3) Bin  
(4) Belt

c. The proper sampling tools for taking an aggregate sample are:

(1) A shovel with turned-up edges  
(2) A bag, bucket, or other suitable container  
(3) Material for identifying the sample and attaching it to the container

2. Sampling Asphalt Binder
a. Asphalt binder can be sampled from
   (1) HMA plant
   (2) Asphalt terminal

b. Proper equipment
   (1) Metal quart can
   (2) Gloves
   (3) Identification material

c. Proper procedure
   (1) Let material flow before filling sample container

3. Sampling Tack and Prime

a. Liquid asphalt for 407 Tack Coat and 408 Prime Coat shall be certified when delivered to project

b. One sample per project of each is required
   unless amount used is a "small quantity"

c. Sample from distributor or storage tank on project
   (1) One quart in plastic screw top container
      for tack (asphalt emulsion)
   (2) One quart in metal screw top container
      for prime (cutback asphalt)

4. Sampling HMA

a. HMA is usually sampled from trucks at the HMA plant selected randomly
b. Proper equipment
   (1) Shovel or scoop with turned-up edges
   (2) Sturdy metal container
   (3) Thermometer
   (4) Identification material

c. HMA can be sampled at the project from the paver hopper or pavement behind the paver
d. It is sampled at random locations and in accordance with Supplement 1035
e. Proper equipment
   (1) Sampling tube for hopper
   (2) Plate sampler for pavement
   (3) Suitable metal container
(4) Spatula, trowel, and nails
(5) Identification material

E. Goal of Sampling

1. The goal of a sampling program is to provide a true representation of the materials used, and in that way contribute to building quality pavements.

2. ODOT and contractor personnel can achieve this goal by the following:
   a. Familiarity with construction materials
   b. Knowledge of sampling requirements
   c. Adherence to proper sampling methods
   d. Care in taking and processing samples
1035.01 General. Field samples of asphalt concrete will be selected by a stratified random sampling procedure and taken from the mat behind the paver. If the mat thickness is less than 1.25 inch (32 mm) the samples will be taken from the paver hopper. A sample form for determining and documenting the location of material in each subplot to be sampled is attached.

1035.02 Equipment. The equipment required for taking samples includes:
1. Spatula or scraping device
2. Clean sample pan
3. Asphalt concrete mix sampling tube
4. Clean metal plates, Three 10" x 10" (250 mm x 250 mm) for mat thickness of
   1.25 to 2 inches (32 to 50 mm)
5. Nails
6. Trowel or other form of lifting device

1035.03 Random Selection of Sample. Obtain four random samples, taken from within four sublots or partial lots, to represent each specified lot. Determine the particular location of material to be sampled by applying a random percent number, as obtained from the random number table, to the total tonnage in the sublot or partial lot. The location of production material selected shall be anticipated in its particular truck and in the first, second, or last third fraction of that load. When the approximate location of material is being placed, the sample shall be taken.

1035.04 Taking Samples

1. Mat - Place the plate in the path of the paver so the sample will be obtained when the desired ton is fed into the spreading screws. Determine where the plate will be located transversely from the edge of pavement by applying a second random percent number to the total width of the mat. If the transverse location selected is in imminent conflict with the paving equipment, the plate shall be moved laterally to the nearest suitable location within the mat width. Nails should be used to prevent the plate from sliding. Mark the location of the plate so that after the paver has passed, the plate may be found by probing the mat with a trowel. The trowel may then be used to lift the plate and sample from the mat. The plate and sample should be placed into the sample pan.
2. **Paver hopper** - Samples are taken alternately from over right and left flight feeders when the desired ton is in the hopper. With the loading interrupted and the truck pulled away from the paver, the correct size of sampler is sunk into the mix to collect a proper sample. Material is deposited from the sampler into the sample pan. Fine materials are scraped from inside the sampler, placed in the pan, and the spatula is scraped on the side of the pan. Sample size shall not be less than 22 lbs (10 kg).

**1035.05 Identification and Shipment** The sample data card (TE-10) is completed, placed in an envelope and wrapped up with the pan. The sample no will also be created in CMS; the information completed in CMS; and a copy of the sample screen submitted with the sample. The wrapped sample shall be tagged and shipped to the District Testing Engineer.
OHIO DEPARTMENT OF TRANSPORTATION
RANDOM SELECTION OF ASPHALT CONCRETE FIELD SAMPLES

Project No. ________________  Item Type ________________
Reference No. ________________  Lot No. ________________

<table>
<thead>
<tr>
<th>SUBLOT</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
</tr>
<tr>
<td>B</td>
</tr>
<tr>
<td>C</td>
</tr>
<tr>
<td>D</td>
</tr>
</tbody>
</table>

1. Initial accumulative total of weight laid
2. Sublot size or partial estimate
3. Random percentage number from table
4. Location in sublot to be sampled (2 X 3)
5. Accumulative weight at sample location (1 + 4)
6. Initial accumulative total for next sublot (1 + 2)
7. Station where sample taken
8. Lane
9. Width of mat
10. Random percentage number from table
11. Distance from edge (right or left) or pavement (9 X 10)
12. Location of sublot
13. Dates Placed

*Used when taking mat samples.
**Random Sampling Procedure**

The Inspector in charge of sampling shall determine four (4), random two (2) digit numbers, from an approved table for each lot. These four (4), two (2) digit numbers shall be entered on the Bituminous Concrete Sampling Sheets. To determine the four (4) random numbers, start at a random point by placing a pencil aimlessly on the approved table of random digits.

**Example 1:** The pencil point picks digit 8, it’s in row 28 column 75. The digit 8 plus the next the next three (3) digits 541 gives row 85, column 41. In row 85 and column 41 find the digit 0 plus the next seven (7) digits to the right, they are 5405472.

These eight (8) digits give the four (4) random numbers 05, 40, 54, and 72.

Using these numbers as percentages, the random ton to be sampled is determined by multiplying the percentage number times the sub-lot or partial sub-lot size. If a lot is not a full lot and consists of maybe 2700 tons, then sublots A, B, & C would be 750 tons and sublot D (partial) would be 450 tons.

**Example Calculation of the Random Ton to be sampled for the Above Lot Size would be:**

\[
\begin{align*}
\text{Sublot A} &= (0.05 \times 750) = 37.5 \text{ tons} + 0 \text{ tons accumulative} = 37.5 \text{ tons} \\
\text{Sublot B} &= (0.40 \times 750) = 300 \text{ tons} + 750 \text{ tons accumulative} = 1050 \text{ tons} \\
\text{Sublot C} &= (0.54 \times 750) = 405 \text{ tons} + 1500 \text{ tons accumulative} = 1905 \text{ tons} \\
\text{Sublot D} &= (0.72 \times 450) = 324 \text{ tons} + 2250 \text{ tons accumulative} = 2574 \text{ tons}
\end{align*}
\]

**If you needed a second set of random numbers for the width of the mat (see below)**

Get these numbers the same way as outlined in Example 1: New Numbers 09, 50, 67, and 75.

\[
\begin{align*}
\text{Sublot A} &= (0.09 \times 12) = 1.0 \text{ foot from edge of mat} \\
\text{Sublot B} &= (0.50 \times 12) = 6.0 \text{ feet from edge of mat} \\
\text{Sublot C} &= (0.67 \times 12) = 8.0 \text{ feet from edge of mat} \\
\text{Sublot D} &= (0.75 \times 12) = 9.0 \text{ feet from edge of mat}
\end{align*}
\]

**Example 2:** If our pencil point picks the 3 at row 49, column 68, and our next 3 digits are 395. From here we go to row 33 column 95 and find the digit 3. To the right there are less than 7 digits on the table, so we must use the 7 digits to the left. They are 3205497. So the random numbers using this example would be 32, 05, 49, and 73.

55
101.03
On pages 6-10, **Revise** the definitions as follows:

**Claims.** Disputes that are not settled through Steps 1 and 2 of the Dispute Resolution and Administrative Claim Process. The Dispute becomes a Claim when the Contractor submits a Notice of Intent to File a Claim.

**Construction Limits.** These limits must encompass all Work. This includes removals, room for construction equipment to complete work, site access, etc.

**Disputes.** Disagreements, matters in question and differences of opinion between the Department’s personnel and the Contractor.

**Partnering.** A collaborative process for project cooperation and communication meant to achieve effective and efficient contract performance and completion of the Project within budget, on schedule, safely and with requisite quality in accordance with the contract.

**Project Limits.** Project limits are points on the mainline centerline of construction where the proposed improvement, as described in the project description on the Title Sheet (excluding incidental construction), begins and ends

**Work Limits.** Work Limits are the extreme limits of the contractor’s responsibility on a project, including all temporary and incidental construction, with the exception of work zone traffic control devices required for maintenance of traffic.

104.05
On pages 19-24, **Delete** the entire subsection **104.05 Partnering and Dispute Resolution.** (See new section **108.02 Partnering**)

105.16
On page 29, **Replace** the first sentence of the third paragraph with the following:

Perform all engineering, including any field investigation, necessary to ensure long term stability of all side slopes and foundations of all borrow and waste areas.

105.19 **Value Engineering Change Proposals.**
On page 31 and 32, **Replace** the entire section with the following:

The Department will Partner with the Contractor by considering the Contractor’s submission of a Value Engineering Change Proposal (VECP) which will reduce construction costs and possibly time on projects that do not contain Design Build provisions or incentive provisions based on time.
On page 170, Replace section 401.04 Reclaimed Asphalt Concrete Pavement with the following:

401.04 Reclaimed Asphalt Concrete Pavement and Reclaimed Asphalt Shingles.

Provide reclaimed asphalt concrete pavement (RAP) and/or reclaimed asphalt shingles (RAS) per the following requirements when choosing to use them in a mix. Failure to follow these requirements will result in a rejection of the Contractor QCP (403.03); restriction of any RAP or RAS use at the facility; and/or a change to Unconditional Acceptance at the facility.

**Job Mix Formula.** The Contractor may use a blend of new materials in combination with RAP obtained from verifiable Department or Ohio Turnpike Commission projects and/or RAS obtained from unused manufactured shingle waste or used roofing tear-off shingles as listed in Tables 401.04-1 and 401.04-2 and as follows. If the RAP is not from the above sources or the source is unknown, process and blend the RAP into a single uniform stockpile, test according to Level 3 Asphalt Mix Design requirements and obtain District approval for use. Obtain written Laboratory approval for use of unusually large, old RAP stockpiles of unknown content and/or age. Include approved methods in the QCP for ongoing processing and testing of these piles. Ensure no foreign or deleterious material (703.04, 703.05) is present in RAP. All RAS suppliers must meet the requirements of Supplemental Specification 1116.

Ensure that the JMF falls within the specified limits of the required mix item. Ensure the JMF submittal includes the percentages of RAP, RAS, virgin aggregates, and virgin asphalt binder required for the mix item. Report all RAP and RAS test results, including binder blend analysis, in the JMF submittal. Identify the RAP in the JMF submittal as to project origin and mix type(s). Identify the manufactured shingle waste manufacturer source or the approved tear-off RAS processor in the JMF submittal.

Determine RAP properties and uniformity as follows. Determine the final RAP gradation and asphalt binder content on a minimum of four separate stockpile (or roadway for concurrent grinding) samples all agreeing within a range of 0.4 percent for asphalt binder content and 5 percent passing the No. 4 (4.75 mm) sieve. If fractionated RAP is used use a suitable sieve for determining gradation uniformity.

Determine RAS properties and usage as follows. Use no more than 5.0% RAS by dry weight of mix. For design assume 18.0% available RAS binder. Determine gradation and specific gravity per AASHTO PP 53-09, Section 5 or subsequent AASHTO applicable standard. Provide the required certification forms in the JMF submittal documenting that the RAS meets AASHTO MP 15-09, sections 3.2 or 3.3 and that RAS from roofing tearoffs conforms to the EPA’s NESHAP, 40 CFR 61 Subpart M, and other applicable agency requirements for asbestos.

**RAP and RAS Usage Limits and Requirements.** Process and use RAP and RAS as follows.

Process and use RAP by one of the following two methods. Note on the JMF submittal RAP page which of Method 1 or Method 2 methods described below apply to the RAP.

1) **Method 1 Standard RAP.** Include RAP in a JMF submittal per the Standard RAP/RAS Limits Table 401.04-1 unless specified differently in the applicable mix specification. For mixes that will contain up to 10 percent RAP the JMF submittal is not required to include the RAP except when a virgin polymer asphalt binder is used in a surface course. For surface course JMFs having polymer asphalt binder only submit at 0 or 10% RAP. If greater than 20 percent RAP is used in a JMF submittal include an analysis of the recovered asphalt binder and blend per Level 3 Mix Design procedures to determine the grade of virgin asphalt binder to use.
### TABLE 401.04-1
#### METHOD 1 – STANDARD RAP/RAS LIMITS

<table>
<thead>
<tr>
<th>Asphalt Mix Application</th>
<th>Percent RAP by Dry Weight of Mix, Max.</th>
<th>RAS Usage*</th>
<th>Total Virgin Asphalt Binder Content, Min.</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy Traffic Polymer Surface Course</td>
<td>10</td>
<td>None</td>
<td>5.2</td>
<td>Polymerized binder is virgin. (For non-polymer virgin binder allow 20% max RAP and 5.0 min. virgin.)</td>
</tr>
<tr>
<td>Medium Traffic Surface Course</td>
<td>20</td>
<td>Manufacturing waste only</td>
<td>5.0</td>
<td>Polymer or non-polymer virgin.</td>
</tr>
<tr>
<td>Light Traffic Surface Course</td>
<td>35</td>
<td>Manufacturing waste only</td>
<td>5.2</td>
<td></td>
</tr>
<tr>
<td>Intermediate Course</td>
<td>50</td>
<td>Manufacturing waste and tear-offs</td>
<td>3.0</td>
<td>Any mix type used as an intermediate course.</td>
</tr>
<tr>
<td>Base Course 301</td>
<td>40 (30)</td>
<td>Manufacturing waste and tear-offs</td>
<td>2.7</td>
<td>The Laboratory will establish the asphalt binder content.</td>
</tr>
<tr>
<td>Base Course 302</td>
<td></td>
<td>Manufacturing waste and tear-offs</td>
<td>2.0</td>
<td>A lower RAP limit of 30 percent will be required if poor production mixing or coating is evident.</td>
</tr>
</tbody>
</table>

* No more than 5.0% RAS by dry weight of mix

**RAP Processing for Table 401.04-1 Method 1-Standard RAP.** For surface courses process RAP to less than 0.75 inch (19 mm) and place a 0.75 inch (19 mm) screen on the cold feed. For other courses place a 2-inch (50 mm) screen on the cold feed. Ensure that the RAP is the proper size to allow for complete breakdown in the plant. If mixing is incomplete, place a smaller screen on the cold feed.

2) **Method 2 Extended RAP.** Include RAP in a JMF submittal per the Extended RAP/RAS Limits Table 401.04-2 unless specified differently in the applicable mix specification. Only use Method 2 with counter flow drum plants or mini-drum batch plant configurations meeting 402. For mixes that will contain up to 15 percent RAP the JMF submittal is not required to include the RAP unless a virgin polymer asphalt binder is used in a surface course. For JMFs having polymer asphalt binder do not submit at 1 through 9% RAP.

If greater than 25 percent RAP is used in a JMF submittal include an analysis of the recovered asphalt binder and blend per Level 3 Mix Design procedures to determine the grade of virgin asphalt binder to use. If the blending shows a grade change is required use a PG64-28 for heavy intermediate courses or PG 58-28 or 64-28 for medium intermediate or base courses. No grade change is required with RAP at 26% to 40% if Warm Mix Asphalt (WMA) technology is used in a manner to maintain the mix temperature below 275 ºF (135°C). Use WMA technology meeting 402.09. Other WMA technologies must be approved by the Laboratory. If desired, WMA may be used to control plant temperatures when producing mixes using RAP above 40%, but a grade change is required if shown necessary by the blending index.
**TABLE 401.04-2**

**METHOD 2-EXTENDED RAP/RAS LIMITS**

<table>
<thead>
<tr>
<th>Asphalt Mix Application</th>
<th>Percent RAP by Dry Weight of Mix, max.</th>
<th>RAS Usage*</th>
<th>Total Virgin Asphalt Binder Content, min.</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy Traffic Polymer Surface Course</td>
<td>15</td>
<td>None</td>
<td>5.0</td>
<td>Polymerized binder is virgin. (For non-polymer virgin binder allow 25% max RAP and 4.6 min virgin.)</td>
</tr>
<tr>
<td>Medium Traffic Surface Course</td>
<td>25</td>
<td>Manufacturing waste only</td>
<td>4.8</td>
<td>Polymer or non-polymer virgin.</td>
</tr>
<tr>
<td>Light Traffic Surface Course</td>
<td>25</td>
<td>Manufacturing waste only</td>
<td>5.0</td>
<td>Any mix type used as an intermediate course.</td>
</tr>
<tr>
<td>Intermediate Course</td>
<td>40</td>
<td>Manufacturing waste and tear-offs</td>
<td>3.0</td>
<td>The Laboratory will establish the asphalt binder content.</td>
</tr>
<tr>
<td>Base Course 301</td>
<td>55</td>
<td>Manufacturing waste and tear-offs</td>
<td>2.5</td>
<td>A lower limit of 35 percent will be required if poor coating is evident. The virgin requirement of 302.02 does not apply.</td>
</tr>
<tr>
<td>Base Course 302</td>
<td>45 (35)</td>
<td>Manufacturing waste and tear-offs</td>
<td>1.8</td>
<td></td>
</tr>
</tbody>
</table>

* No more than 5.0% RAS by dry weight of mix

**RAP Processing for Table 401.04-2 Method 2-Extended RAP.** Process RAP by means of fractionation or by additional in line processing. Include in the QCP additional methods and procedures to dictate how this is to be accomplished at plants. Specify documentation method for RAP measurement. Fractionation is the process of creating separate piles of RAP from one pile when split over a specific sieve or sieves. Test fractionated piles to show uniformity. For additional in line processing only process RAP from a uniform, tested and approved stockpile by passing the RAP over a double deck screen placed in-line between the RAP cold feed bin and the mixer. Use a 9/16 inch (14.3 mm) screen for surface and intermediate mixes and a 1.5 inch screen for base mixes. Do not use concurrent project RAP in a stream process.

3) **RAS Processing and Usage.** Include RAS in a JMF submittal per the Standard RAP/RAS Limits Table 401.04-1 or Extended RAP/RAS Limits Table 401.04-2 unless specified differently in the applicable mix specification.

Ensure RAS is processed to have 100 percent passing the ½ inch sieve and at least 85 percent passing the No. 4 sieve. Ensure RAS has less than 1.0 percent deleterious materials and 0.1 percent metals by weight. Do not blend RAS from manufacturing waste and RAS from roofing tearoffs.

Ensure the approved QCP includes RAS usage methods before using RAS. Include in the contractor QCP what contractor requirements apply to the RAS processor.

Introduce and control RAS in asphalt plants in the same manner as RAP is introduced and controlled. RAS for base courses may be preblended with RAP if using rate control equipment to ensure uniformity of blending and if satisfactory blend and production is achieved. RAS may be preblended with a small amount of virgin aggregate meeting 703.05 to minimize stockpile agglomeration. Include in the contractor QCP blending equipment type and operation and uniformity testing requirements for preblended RAP and RAS or RAS and virgin aggregate. Other methods must be approved by the Laboratory.
**RAP and RAS QC and Management Requirements.** Maintain as part of the QC records the signed certification forms as required in Supplemental Specification 1116.

Always note on the daily quality control report how much RAP and RAS is actually being used. Apply a tolerance of +/-5.0% on the amount of RAP used if needed for a quality control adjustment but do not exceed the limits of Table 401.04-1 or Table 401.01-2, whichever applies. If this adjustment is not adequate for maintaining control of the mix submit a new JMF for approval. Do not apply this tolerance to RAS.

Include in the QCP methods to be used to meet Method 1 and Method 2 requirements above and the following requirements:

Provide enough space for meeting all RAP and RAS handling requirements at a hot mix facility. Provide a clean, graded base for stockpiles that does not collect water. Test blended RAP and RAS stockpiles to assure uniform gradation and asphalt binder content. Ensure uniform stockpile properties match the JMF submitted RAP and RAS properties unless the uniform stockpile will be processed into the asphalt plant using plant cold feed in line processing.

If the uniform stockpile will be processed into the asphalt plant using plant cold feed in line processing determine the processed RAP properties for use in the mix design. Record in the JMF submittal both the uniform stockpile and in line processed RAP properties.

If desired, when applying Method 1 Standard RAP requirements, use concurrent Department project RAP in a stream process in place of stockpiling and testing for uniformity but do so in the following manner. Concurrent project RAP must be taken from one existing mix type on the concurrent project or two existing mix types if both mix types are taken at the same time in one pass of the milling machine. Submit a new JMF for each existing mix type on the project (or each milling pass of two types) desired for use as concurrent project RAP. Include in the QCP methods of validating RAP properties when using concurrent project RAP. If these requirements are not met blend and test for uniformity and apply the stockpile requirements of this specification.

Maintain in the plant lab and control room an up to date and dated site map of all tested and untested RAP and RAS stockpiles. Give each stockpile a unique identification and identify if RAS piles are from unused manufactured shingle waste or used roofing tear-off shingles. Provide in the plant lab RAP and RAS properties for each uniform, blended stockpile cross referenced with its identification. In addition, provide the date the stockpile processing was completed and the stockpile estimated size in tons. The DET may require RAP and RAS pile staking for failure to maintain the above. Do not add to a stockpile once it is tested for uniformity. Provide signage at all uniform stockpiles to inform haulers that uniform piles are not to be added to.

Stockpiles and processing methods are subject to inspection and approval by the DET at any time. Rejection of stockpiles can occur for the presence of foreign or deleterious materials, lack of uniformity, incomplete mixing in the asphalt mixture, adding to piles, or moving RAP or RAS in a way not traceable through the QCP records and methods. The Laboratory will resolve disputes over acceptability of RAP or RAS.

401.05

On page 173, in the 1st paragraph of this section, Add after the 1st sentence the following sentences:

Schedule a date with the Department for approval inspection to be at least 1 week before mix production. Do not produce mixtures for projects from unapproved plants.

On page 178, Replace the third paragraph with the following:

Spread and finish the mixture using approved equipment or methods such that compaction can follow immediately. Preheat screeds and extensions before placing any asphalt concrete. Use side plates sufficient to contain the mixture laterally during spreading. Use only screed extensions, rigid
or extendable, having the same features as the main screed including, but not limited to, vibration, heating, pre-strikeoffs, and tamping bars. When using front-mounted hydraulically extendable screeds at a fixed paving width use full width auger extensions and full tunnel extensions. When using fixed screed extensions use full width auger extensions and full tunnel extensions. Do not allow a buildup of excess material in front of any extended screed. Where excessive buildup of material is not controlled in front of the extended screed, the Engineer will require paver changes to correct the problem. The Contractor may use strike-off plates/strike-off extensions on irregular areas such as mailbox turnouts, driveway turnouts, and other irregular non-travelled roadway areas. The Engineer may approve the use of strike-off plates/extensions on variable width shoulders if the use of a standard extendable screed extension with the same features as the main screed is not practicable. Perform supplemental hand forming and tamping where irregularities develop and where placing the mixture by hand methods.

On page 178 after the 3rd paragraph in this section, Add the following paragraph:

Ensure the paver operation, screed, screed extension, and, or, mix design provide a mat, prior to compaction, that is free of texture inconsistencies, shadowing, streaking, tearing, pulling, or other deficiencies. Take immediate action to correct the paver operation, screed, screed extensions, or, mix design. The Engineer may stop placement until corrections are completed.

On page 179, Replace the 3rd, 4th, and 5th full paragraphs with the following:

When the total project includes more than one continuous lane mile (including bridges) of surface course paving in combination with night paving, provide a Material Transfer Vehicle (MTV) with paver hopper insert; a Material Transfer Device (MTD) with paver hopper insert; or a remixing paver specifically manufactured to eliminate segregation.

Provide equipment that:

a. Includes a mixer/agitator mechanism that consists of either segmented, anti-segregation, re-mixing augers or two full-length longitudinal paddle mixers specifically designed for the specific purpose of re-mixing. The longitudinal paddle mixers shall be located in the paver hopper insert.

b. Eliminates segregation, and provides a uniform temperature throughout the mixture;

c. Limits temperature differentials to less than 25 °F (14 °C).

Use the equipment on all mainline lanes of the traveled way including express lanes, collector-distributor lanes, continuous center turn lanes, acceleration/deceleration lanes, and ramp lanes.

Use paver hopper inserts with a minimum capacity of 14 tons. Remixing may be done by the MTV or MTD, in the paver hopper insert, or by the remixing paver.

Demonstrate to the Engineer that the selected equipment eliminates physical segregation and limits the temperature differential of the mat surface measured transversely to 25 °F (14 °C). Provide a method before the start of paving that ensures non-segregation and thermal differential requirements are met, continuously during placement operations.

Remove equipment that does not consistently eliminate physical segregation and, or, does not meet the temperature differential requirement.

401.16

On page 180, Section 401.16 Compaction, Replace the 6th paragraph with the following:

For surface courses using a polymer modified asphalt binder give a copy of the JMF approval letter containing the design compaction temperature to the Engineer before any mix is placed. Unless otherwise specified ensure that the mix temperature immediately before rolling is not less than 290 °F (145 °C) if placing hot mix asphalt, and not less than 250 °F (121 °C) if placing warm mix asphalt according to 402.09. Do not compact polymer asphalt concrete surface courses with pneumatic tire rollers.
On page 180, Section 401.16 Compaction, Add the following new paragraph after paragraph 8:

When using pneumatic tire rollers, ensure for any mix, that surface deviations and deformations caused by the tires are removed with steel wheel rollers. Do not use pneumatic tire rollers if any resultant surface deformations cannot be removed.

401.17
On page 181, Section Joints, Replace paragraph 6 with the following:

Seal all cold longitudinal construction joints by coating the entire face of the cold joint with a certified 702.01 PG binder or 702.13 SBR Asphalt Emulsion to provide 100 percent coverage of the joint. Overlap the joint edges by at least 1/2 inch (13 mm). Seal all cold transverse construction joints with a certified 702.01 PG binder or 702.13 SBR Asphalt Emulsion to provide 100 percent coverage of the joint or with a certified 702.04 asphalt material applied at a rate of 0.25 gallon per square yard (1 L/m²).

401.19
On Page 182, Paragraph 6, Delete paragraph 6 of 401.19 and replace with the following paragraph:

Check the surface course for variations in slope or surface at locations where bumps are suspected when directed by the Engineer.

402
On page 183 Replace the entire section with the following:

ITEM 402 ASPHALT CONCRETE MIXING PLANTS

402.01 Description. This specification consists of the minimum requirements for an asphalt concrete mixing plant to produce asphalt concrete mixes according to Department specifications.

Ensure asphalt concrete mixing plants conform to the requirements of Supplement 1101 in addition to the following.

402.02 Calibration. Ensure the plant is calibrated according to Supplement 1101 when producing any asphalt concrete for the Department. Ensure that the calibration is accurate within 1.0 percent. When performing a complete calibration for ODOT projects notify the ODOT district 24 hours in advance of the calibration.

402.03 Polymer Binders. If an asphalt binder is modified by SBR at an asphalt concrete mixing plant, equip the plant with an automated SBR flow control and monitoring system. Obtain the Department’s approval of the system before operating and demonstrate the system calibration to the District. If the District waives the demonstration, provide a letter documenting calibration data for the flow system to the
DET for each project. Obtain written approval from the Laboratory for the use of SBR and ensure the QCP contains methods for properly controlling SBR.

For drum mix plants, introduce the SBR directly into the asphalt binder line through means of an in-line motionless blender or other device approved by the Laboratory which is able to provide a homogeneous blend. Locate a sampling valve between the in-line blender and the plant drum.

For batch plants, add the SBR after the aggregate has been completely coated with asphalt binder. Continue mixing for a minimum of 20 seconds after SBR is added and long enough to provide a uniform mixture.

Ensure the SBR pumping and metering system is capable of adding the SBR within the limits of 702.01. For drum plants ensure the SBR pump is automatically controlled by an independent computer and interfaced with the asphalt binder flow to automatically maintain the SBR flow within specification limits. Produce asphalt mixtures for placement in automatic SBR control mode only.

Ensure the SBR meter is accurate to +/- 2.0 percent over a flow rate typical of that used at the asphalt plant (typically 0.8 to 12 gpm at drum plants and 10 to 25 gpm at batch plants). Ensure the SBR meter is a magnetic flow meter consisting of a metering flow tube which utilizes Faraday’s Law of Induction to measure the flow and includes a transmitter to transmit the flow signal to a totalizer located in the control room of the asphalt plant. Locate the SBR meter downstream of any recirculation lines. Provide a means for removing the SBR line at the in-line blender to be able to obtain a sample of the SBR for calibration purposes.

Obtain Laboratory approval for use of any other type of SBR meter. Ensure the totalizer displays total volume measured and flow rate in standard engineering units. Ensure the totalizer is interfaced with a data logger which produces printouts of the logged data every five minutes for a drum plant or every batch for a batch plant. Ensure the logged data includes time, date, flow rate, and flow total except flow rate is not necessary for batch plant production.

Balling or wadding of SBR or uncoated aggregate indicates improper mixing; cease production immediately and until corrected to District satisfaction.

402.04 Water Injection System for Warm Mix Asphalt When allowed by specification use a Department-approved water injection system for the purpose of foaming the asphalt binder and lowering the mixture temperature. Only use equipment that has been proven stable and effective through project use on non-ODOT projects. Ensure equipment for water injection meets the following requirements:

1. Injection equipment computer controls are in the plant control room and are tied to the plant computer metering.
2. Injection equipment has variable water injection control controlled by the plant operation rate and the water injection can never exceed 1.8% by weight of asphalt binder.
3. Water injection rate cannot be manually overridden by the plant operator once in the computer.
4. Injection equipment stops water flow when a control or equipment failure in the injection system occurs.
5. The water injects into the asphalt binder flow before the asphalt binder spray hits aggregate. Do not allow water to touch aggregate before the binder spray.
6. Injection equipment includes water storage and pump control tied to the injection computer controls.
7. Water storage low water alarm installed in the control room.
8. Provide a PG binder sampling valve between the last piping tee on the tank side of the line and the injection equipment to sample PG binder before water is injected.
403.03
On page 188, Replace the 3rd sentence of the 1st Paragraph, with the following:
A minimum of 3 weeks before mix production, but no later than February 28, submit a hard copy of the proposed QCP to the Laboratory for review and approval.

On page 188, Replace the 2nd paragraph with the following:
Send a hard copy and a digital copy (if available) of the approval letter and approved QCP to the DET in every District in which work is performed. Keep copies of the approval letter and the approved QCP in each Contractor plant laboratory and plant operation control room. Digital copies of the approved QCP and approval letter in pdf format are allowed in each Contractor plant laboratory and plant operation control room with the following requirements: The file icon must be appropriately labeled and be on the computer desktop of a computer in each area, the QCP must contain a Table of Contents inside the front cover locating all sections by page number and the QCP must be page numbered, and out of date QCPs must be removed from the computer desktop.

403.03. A
On page 188, Replace sentence 5 of the current Subsection A with the following:
Assign Level 2 technicians for all Level 2 QC testing duties, and provide a list designating their responsibilities and expected actions.

On page 188, Insert a new sentence 7 in the current Subsection A as follows:
Define in the QCP who is responsible at plants and specific methods for assuring haul vehicles meet all requirements and proper bed release products are used.

403.03. C
On page 188, Delete the following words in the 1st sentence of the current Subsection C:
“when tests are outside warning band limits of the QCP”

403.03. D
On page 189, Replace the current Subsection D with the following:
D. Methods to maintain all worksheets, including all handwritten records, and other test records for the duration of the contract or 5 years, whichever is longer. Define the test record process. Define company records retention requirements. Provide copies of all test reports and forms used in the quality control process.

403.03. E
On page 189, Replace the current Subsection E with the following:
E. Procedures for equipment calibration and documentation for Level 2 lab equipment. Provide documentation that all Level 2 lab equipment has been calibrated at the time of the Level 2 lab approval inspection. Procedures for calibration record storage.

403.03. H
On page 189, Replace entire paragraph with the following:
H. All procedures to meet the processing, testing and documentation requirements for RAP and RAS in 401.04 including test forms, record keeping, technician responsibilities, etc.

403.06
On page 190, Replace the 1st paragraph with the following:
The Department will perform VA. If the random Department sampling and testing verifies the accompanying Contractor tests, the results of all the Contractor’s quality control tests for each day (for Basic mix), the Contractor’s tests for each Lot (for 448 mix), or daily average MSG (446 mix) will be used to determine acceptance.

403.06. A
On page 191 Replace paragraphs 3 and 4 with the following paragraphs:
Provide a clean area of sufficient size and a hard surface to perform sample splitting. Split samples by
quartering and recombining according only as described in to AASHTO T 248, Method B for hard surfaces and recombining for the Department and Contractor’s sample. The Department split sample size required is generally 22 to 27 pounds (10,000 to 12,000 g). A mechanical quartering device approved by the Laboratory may be used in lieu of the above but only split according to the procedure outlined in the Contractor QCP. Ensure that every quality control or Item 448 Sublot sample taken by the technician has a labeled split for the Department. Wrap and label the Department split samples as to Lot or Sublot, time, location (tonnage), and accompanying Contractor test identification. The Monitoring Team will pick up all Department split samples within 4 workdays. Sample mishandling (careless identification, changing sample size, consistency, or pre-testing) will result in a change to Unconditional Acceptance.

For Item 448 mixes, conform to the procedures of Supplements 1035, 1038, 1039, and 1043 except take samples from a truck at the plant. If workmanship problems continue on the project (segregation, etc.) or if quality control problems persist, the Monitoring Team may require sampling on the road according to Supplement 1035. Lots will be 3000 tons (3000 metric tons), and Sublots will be 750 tons (750 metric tons). However, when production is limited to less than 3000 tons (3000 metric tons), consider the quantity produced as a partial Lot. For partial Lots of 1500 tons or less sample and test at least two sublot samples regardless of the tons produced. Split and test all Sublot sample locations, as selected by the Monitoring Team or project and taken by the Contractor. The Contractor may test a Sublot QC sample at the required Sublot sample location instead of the required random quality control test as both a QC and Sublot test provided the sample is tested in the half day in which the Sublot sample mix was produced and is tested for all required quality control properties. Test results will apply for both QC and sublot requirements. A change in the location of the Sublot sample must be approved by the District and be reasonably close to the original location. This allowance does not apply to any other samples including Department VA sample locations selected by the Monitor. Label Department split samples as Sublot or quality control samples.

When the figures to be dropped in rounding off are exactly one-half of unity in the decimal place to be retained, round the value up to the nearest number in the decimal place to be retained.

On Page 191, Add a final paragraph to the current Subsection A as follows:
For Item 446 mixes MSG VA testing will be performed by the District on a minimum of one in every four required District-sampled Daily samples.

403.06. B
On page 192, In 2nd paragraph of this section, Replace the 2nd sentence with the following:
When the figures to be dropped in rounding off are exactly one-half of unity in the decimal place to be retained, round the value up to the nearest number in the decimal place to be retained.

403.06. C
On page 192, Replace the 1st and 3rd sentences of the 1st paragraph of the current Subsection C with the following respectively:
For Basic and 448 mixes the Monitor/District will randomly choose one Department sample in a maximum of every four production days for VA testing to confirm Contractor testing and mix control.
The Department VA sample location will be chosen randomly by the Monitor, including where in the truck to take the sample, if applicable.

On page 192, Replace the 2nd sentence of the 2nd paragraph of the current Subsection C with the following:
However, if the Department tests VA samples on Contractor equipment, test a VA sample on District lab equipment a minimum of one time in 15 production days from a given plant regardless of the number of projects or JMFs tested in the Level 2 lab.

On page 193, Replace existing paragraph 3 of the current Subsection C with two new paragraphs as follows:
For Item 446 mixes MSG VA testing will be performed by the District on a minimum of one in every four required District-sampled Daily samples. This result will be compared to that days Contractor average of MSG QC test results.
For all mixes, the District may increase the number of VA testing samples if desired.

On page 193, Replace Table 403.06-1 Department Verification Acceptance and Quality Control Test Comparison with the following:

| TABLE 403.06-1 DEPARTMENT VERIFICATION ACCEPTANCE AND QUALITY CONTROL TEST COMPARISON |
|----------------------------------|---------------------------------|---------------------------------|
| Percent Asphalt Binder | Percent Passing No. 4 (4.75mm) | MSG Comparison |
| Basic | ±0.3 | ±0.4 | ±4.0 | ±5.0 |
| 448 | ±0.3 | ±0.3 | ±4.0 | ±4.0 |
| 446 | | | 0.025 |

[1] District VA mix test deviation from Contractor split.
[2] District VA mix test deviation from QC and/or lot test.

403.06 D

On page 194, Replace Table 403.06-2 Mix Acceptance with the following:

<table>
<thead>
<tr>
<th>TABLE 403.06-2 MIX ACCEPTANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mix Type</td>
</tr>
<tr>
<td>Basic Mixes (no acceptance limits stated in appropriate specification)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Basic Mixes (acceptance limits stated in appropriate specification)</td>
</tr>
<tr>
<td>448 Mixes</td>
</tr>
<tr>
<td>446 Mixes</td>
</tr>
</tbody>
</table>

403.06 E. 2

On page 195, Replace the 1st sentence of the current Subsection E. 2. with the following:
If the District tests and investigation shows lack of Contractor mix control compared to the JMF the District will test the remaining Department split or Daily samples for the days or Lots represented by the original tests.

407.06

On page 199 replace paragraphs 5 and 6 in this section with the following:

Apply the tack coat in a manner that offers the least inconvenience to traffic. Do not allow tack pick up and tracking by traffic or by construction vehicles. Take immediate steps to eliminate tack pick up and tracking. Only apply the tack coat to areas that will be covered by a pavement course during the same day unless using a lane closure lasting more than 24-hours. Obtain the Engineer's approval for the quantity, rate of application, temperature, and areas to be treated before application of the tack coat. The Engineer will determine the actual application in gallons per square yard (Liters per square meter) by a check on the project. The application is considered satisfactory when the actual rate is within ±10 percent of the required rate and the material is applied uniformly with no visible evidence of streaking or ridging. The Engineer will require repairs to equipment when ridging, streaking, or other non-uniform coverage is observed, and a subsequent test strip to demonstrate proper application.
If the application is not uniform and not corrected or there is pick up, and, or tracking the total square yardage of non-uniform application will be considered non specification material. The Engineer will determine the number of gallons (liters) for non-payment by using the approved rate of application times the total square yards (square meters) of non-uniform application, pick up, and or tracking.

421
On Page 206, Replace entire section 421.02 Materials with the following:

421.02
Use a polymer modified emulsified asphalt binder (Binder) consisting of the following materials milled together:

A. Natural SBR latex modifier or synthetic SBR latex modifier conforming to 702.14. Use only one type of latex.
B. CSS-1h or CSS-1m (as required below) emulsified asphalt conforming to 702.04, except the cement-mixing test is waived. Use only emulsion certified per Supplement 1032.
C. Other emulsifiers.

Use CSS-1mL (as defined below) if the project ADTT is less than 2000, otherwise use CSS-1hL (as defined below). Do not use port addition of the polymer to the emulsified asphalt. Provide to the Engineer certified test data and a statement from the Binder manufacturer with each load of Binder that the Binder is the same formulation as used in the mix design. Ensure the Binder meets one of the following.

CSS-1hL: Combine CSS-1h and SBR latex modified (L) to yield 3 percent SBR solids based on the weight of the asphalt binder content of the Binder. Ensure that the SBR latex modified residue conforms to the following requirements:

<table>
<thead>
<tr>
<th>Test</th>
<th>Description</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AASHTO T 59 (Note 1)</td>
<td>Residue</td>
<td>62 %</td>
</tr>
<tr>
<td>AASHTO T 53</td>
<td>Softening Point</td>
<td>60 °C minimum</td>
</tr>
<tr>
<td>AASHTO T 202</td>
<td>Absolute Viscosity @ 60 °C</td>
<td>8000 poise minimum</td>
</tr>
</tbody>
</table>

Note 1 - 24 hours at 77 °F (25 °C) in forced draft oven

CSS-1mL: Combine CSS-1m and SBR latex modifier (L) to meet the following properties.

<table>
<thead>
<tr>
<th>Tests on emulsion, ASTM D 244, unless otherwise designated:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viscosity, Saybolt Furol, ASTM D 88, at 25 °C (sec)</td>
</tr>
<tr>
<td>Storage Stability Tests, 24-hr (% difference)</td>
</tr>
<tr>
<td>Particle Charge Tests</td>
</tr>
<tr>
<td>Sieve Tests (%) (Distilled Water)</td>
</tr>
<tr>
<td>Distillation to 260 °C, % by Weight, Residue, min[1]</td>
</tr>
<tr>
<td>Tests on distillation residue:</td>
</tr>
<tr>
<td>Penetration, 25 °C, 100 g, 5 sec (dmm) ASTM D 5</td>
</tr>
<tr>
<td>Ductility, 4 °C, 5 cm/min, ASTM D 113</td>
</tr>
<tr>
<td>Elastic Recovery, 4 °C, 10 cm (%)[2]</td>
</tr>
<tr>
<td>Softening Point, Ring &amp; Ball (°C) ASTM D 36</td>
</tr>
</tbody>
</table>

[1] ASTM D 244, with modifications to include a 400 °F ± 10 °F (204 °C ± 6 °C)
maximum temperature to be held for 15 minutes.

[2] Straight molds. Hold at test temperature for 90 minutes. Place in ductilometer and elongate 10 cm at 5 cm/min. Hold for 5 minutes and cut. After 1 hour retract the broken ends to touch and measure the elongation (X) in centimeters. Use the following formula to calculate the elastic recovery:

\[
\text{Elastic Recovery (percent)} = \left( \frac{10 - X}{10} \right) \times 100
\]

Conform to 703.01 and 703.05 for aggregate, except as follows:

<table>
<thead>
<tr>
<th>Percent by weight of fractured pieces</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand Equivalence (ASTM D 2419)</td>
<td>45 minimum</td>
</tr>
</tbody>
</table>

Conform to Gradation A for the aggregate for leveling and surface courses and to Gradation B for the aggregate for rut fill courses according to the following:

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Total Percent Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>3/8 inch (9.50 mm)</td>
<td>100</td>
</tr>
<tr>
<td>No. 4 (4.75 mm)</td>
<td>85 to 100</td>
</tr>
<tr>
<td>No. 8 (2.36 mm)</td>
<td>50 to 80</td>
</tr>
<tr>
<td>No. 16 (1.18 mm)</td>
<td>40 to 65</td>
</tr>
<tr>
<td>No. 30 (600 µm)</td>
<td>25 to 45</td>
</tr>
<tr>
<td>No. 50 (300 µm)</td>
<td>13 to 25</td>
</tr>
<tr>
<td>No. 100 (150 µm)</td>
<td></td>
</tr>
<tr>
<td>No. 200 (75 µm)</td>
<td></td>
</tr>
</tbody>
</table>

Screen the aggregate for oversize material prior to use. For mineral filler, use Portland cement conforming to ASTM C 150, Type I. Use water conforming to 499.02. Use mix set additives as required.

422.02
On Page 213. Replace the 2nd paragraph with the following:
Provide cover aggregate for the chip seal Job Mix Formula (JMF) of washed limestone or dolomite meeting 703.05. Do not use an aggregate source designated with “SR” on the Aggregate Source Group list in accordance with 703.01F. Additionally the following requirements apply:

422.06
On Page 216, Replace 1st paragraph with the following
Remove all existing pavement markings 740.03 (polyester), 740.04 (thermoplastic) and 740.07(epoxy) using an abrasion method conforming to 641.10.

422.10. B
On page 218, Replace the 1st sentence of the current Subsection B with the following:

Within one hour of start of production obtain and label a binder sample from the distributor truck and give the sample to the Engineer the same day. Provide and sample the binder in one quart plastic containers with plastic screw tops. Take more samples when requested by the Engineer.

422.13
On Page 224, Replace the 2nd paragraph under the subsection with the following: The cost of removal of all existing pavement markings according to 422.06 is incidental to this item.
424.03
On page 224 Replace the 2nd paragraph in this section with the following paragraph:
Use a PG 76-22M asphalt binder; or a PG 64-22 asphalt binder modified by adding 5.0 +/- 0.3 percent by weight Styrene Butadiene Rubber (SBR) solids and meeting the requirements of PG 76-22. Provide SBR conforming to 702.14. Provide mineral filler conforming to 703.07. Provide binders conforming to 702.01.

On page 224, Replace the 1st sentence in the 3rd paragraph with the following: Ten percent reclaimed asphalt concrete pavement may be used in a Type B mix if all requirements of footnote 3 are met by the reclaimed asphalt concrete.

On page 224, (3) Fine Aggregate– After the last sentence of this section add the following sentence:
Contact the Office of Materials Management, Asphalt Materials section for guidance on submitting RAP aggregate silicon dioxide data.

On page 224, (4) Coarse Aggregate – Replace entire paragraph with the following:
(4) Coarse Aggregate - For medium mixes, for the final blend of all coarse aggregate use a minimum 10 percent two - or more fractured faces aggregate. For heavy mixes, use 100 percent two or more fractured faces aggregate. Meet the two or more fractured faces aggregates criteria of ASTM D5821 (reapproved 2006).

424.04
On page 325, Replace section 424.04 Mixing with the following:
424.04 Mixing. Ensure the mixing plant conforms to 402. Discharge the mix from the plant at temperatures between 335 °F to 370 °F (168 °C to 188 °C) for hot mix asphalt or 300 °F to 340 °F (149 °C to 171 °C) for warm mix asphalt.

441.09 Contractor Mix Design and AC, Quality Control Tests, A. Asphalt Binder Content.
On page 234 at the end of paragraph 2 in this section, add the following sentence:
Only take SBR PG-Modified Binder samples using a five gallon bucket, stirring its contents and transferring to the required sample containers.

442
On page 239 Replace Table 442.02.02 with the following:

**TABLE 442.02-2 AGGREGATE GRADATION REQUIREMENTS**

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>9.5 mm mix (% passing)</th>
<th>12.5 mm mix (% passing)</th>
<th>19 mm mix (% passing)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 1/2 inch (37.5 mm)</td>
<td></td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>3/4 inch (19 mm)</td>
<td></td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>1/2 inch (12.5 mm)</td>
<td>100</td>
<td>95 to 100</td>
<td>85 to 100</td>
</tr>
<tr>
<td>3/8 inch (9.5 mm)</td>
<td>90 to 100</td>
<td>96 max</td>
<td></td>
</tr>
<tr>
<td>No. 4 (4.75 mm)</td>
<td>70 max</td>
<td>52 min</td>
<td></td>
</tr>
<tr>
<td>No. 8 (2.36 mm)</td>
<td>34 to 52</td>
<td>34 to 45</td>
<td>28 to 45</td>
</tr>
<tr>
<td>No. 200 (75 µm)</td>
<td>2 to 8</td>
<td>2 to 8</td>
<td>2 to 6</td>
</tr>
</tbody>
</table>

442.01
On page 238, Delete the last sentence of the second paragraph that states:
1036.1 Procedure for Determining Theoretical Maximum Specific Gravity

1036.2 Procedure for Determining Bulk Specific Gravity

1036.3 Procedure for Determining Air Voids in Compacted Dense Asphalt Concrete

1036.1 Procedure for Determining Theoretical Maximum Specific Gravity

1) Condition the sample to be tested according to the specified requirement in ODOT C&MS. When determining the Maximum Theoretical Specific Gravity (MSG) in accordance with 441.09 or 442.05, this conditioning is not required when the mix is stored in a surge or storage bin for greater than 1 hour prior to sampling.

2) Determine the MSG per AASHTO T 209, Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures, (Rice Method). Do not use the “AASHTO T 209 Supplemental Procedure for Mixtures Containing Porous Aggregate” except as follows:

When creating a Job Mix Formula (JMF), if a 12.5mm surface course has air cooled blast furnace slag (No. 8 or larger) or a 19mm or Type 2 intermediate course has dolomite, air cooled blast furnace slag or limestone virgin coarse aggregate (No. 8 or larger) the Contractor may perform the ‘Supplemental Procedure for Mixtures Containing Porous Aggregate’ (SSD per the method in section 4) to determine the amount of retained water. If the retained water in the JMF is greater than 0.18% water based on the dry weight of mix apply the SSD procedure for both the JMF testing and in quality control testing. Do not apply SSD to quality control if retained water is less than 0.18% water based on the dry weight of mix. Note on the JMF submittal and TE 199 that the SSD method is being used.

If during production it is believed an approved non-SSD 12.5mm surface course having air cooled blast furnace slag (No. 8 or larger size) or an approved non-SSD intermediate course JMF having dolomite, air cooled blast furnace slag or limestone virgin coarse aggregate (No. 8 or larger) needs to have the SSD procedure performed apply the following requirements:

a) The amount of water retention in quality control must be greater than 0.18% water based on the dry weight of mix based on District confirmation testing.

b) The change must be approved by the District and the Laboratory.

c) Note the change on the TE 199.

d) Apply the SSD change to all subsequent MSG testing for the project.

3) Use the following equipment and procedures when performing the MSG test:

a) MSG Equipment:
   1. Metal pycnometers with a 4000 ml minimum volume.
2. A table top mechanical vibration device designed specifically for the MSG test operating on 120 volts AC and capable of holding the above metal pycnometer. Ensure devices are approved by the Laboratory.

3. The residual pressure manometer placed in the vacuum system per AASHTO T 209 may be a digital manometer. Obtain Laboratory approval of digital manometer models. Provide documentation for NIST traceability. Provide a connection near the vacuum pump for attaching a vacuum gauge as a check when needed. Immediately replace failed manometers with a functioning manometer before proceeding with testing.

b) MSG Procedure: Use only the submerged method. Calibrate the weight of the empty pycnometer in water weekly, or when a different technician begins testing, or when any changes to the water bath occur (changing/addition water, heating/cooling water, etc.).

4) When allowed by specification or the District and Laboratory, perform the SSD according to the following. No other SSD equipment and procedures are allowed.

   a) MSG SSD Equipment: 12 inch (305 mm) diameter ‘full height’ sieve meeting the requirements of ASTM E11, "Specification for Wire-Cloth and Sieves for Testing Purposes", No. 50 (300µm) or No. 100 (150µm) mesh. Portable 120 volt AC fan that is a minimum 12 inch (305mm) diameter.

b) MSG SSD Test Procedure:

   1. After the material has been removed from the water bath drain well.
   2. Obtain and record an empty weight of the sieve that the material will be placed in.
   3. Place the material in the sieve and pat/wipe the sieve underside with a dry towel to dry excess water. Place under the fan for 15 minutes. Ensure the fan axis is perpendicular to the sieve mesh with air flowing thru the sieve. Ensure the setup allows the air flow to readily escape the sieve bottom. Ensure the fan does not touch any sample being tested.
   4. After 15 minutes place the mix and sieve on a scale and record the weight. Subtract the weight of the empty sieve from the total weight to get the weight of the mix only. After weighing stir the entire contents of the mix by hand, especially at the corners and edges, ensuring all material is turned over to expose new surfaces to the air flow for drying. Place the mix and sieve under the operating fan for 15 minutes.
   5. Repeat the process (15 minutes under the fan, weigh and subtract the sieve from total weight and record the weight, stir and dry again).
   6. After obtaining the weight of the mix in each dry back period subtract the last two weights and record the difference. Divide the difference by the higher of the last two dry backs then multiply by 100. If the answer is 0.050 or below the material is considered SSD and the processed is finished. Use the final SSD weight in the MSG calculation.

**1036.2 Procedure for Determining Bulk Specific Gravity**

Condition the sample to be compacted according to the specific requirement in ODOT C&MS. When determining the Bulk Specific Gravity (BSG) in accordance with 441.09 or 442.05, this conditioning is not required when the mix is stored in a surge or storage bin for greater than 1 hour prior to sampling.

Determine the BSG of a compacted mixture per ASTM D 2726. If the water bath for the specimens is not maintained at 77°F (25°C), use the correction factor (K) specified in ASTM D 2726. Do not exceed 350°F (177°C) in the destructive dry back of BSG samples. It is recommended for non-destructive purposes that the BSG dry back temperature be no more than 120°F (49°C).

**1036.3 Procedure for Determining Air Voids in Compacted Dense Asphalt Concrete**

Determine percent air voids in a compacted mixture by ASTM D 3203, using the procedure for dense asphalt concrete mixtures.
1037.01 SCOPE. This method covers the procedure for the determination of voids in the mineral aggregate (VMA) in a compacted mixture.

1037.02 DEFINITION. VMA is defined as the intergranular void space between the aggregate particles in a compacted paving mixture that includes the air voids and the effective asphalt content, expressed as a percent of the total volume.

1037.03 SUMMARY OF METHOD. Determination of VMA is based on bulk specific gravity of the aggregate and is expressed as a percentage of the bulk volume of the compacted paving mixture. VMA is calculated by subtracting the volume of the aggregate determined by its bulk specific gravity from the bulk volume of the compacted paving mixture.

1037.04 CALCULATIONS. Determining VMA in mixtures containing:

1. 100% NEW MATERIAL (for mixtures incorporating recycled material, see 2. following).

\[
VMA = 100 - \frac{G_{ab} P_a}{G_{ab}}
\]

where

\[
\begin{align*}
VMA &= \text{voids in mineral aggregate (percent of bulk volume)} \\
G_{ab} &= \text{bulk specific gravity of compacted mixture (ASTM D 2726)} \\
P_a &= \text{aggregate, percent by total weight of mixture} \\
G_{sb} &= \text{bulk specific gravity of total aggregate} \\
G_{sb} &= \frac{P_1 + P_2 + \ldots + P_n}{G_1 + G_2 + \ldots + G_n} \\
\end{align*}
\]

where

\[
\begin{align*}
P_1, P_2, \ldots, P_n &= \text{percentage by weight of aggregates 1, 2, \ldots, n} \\
G_1, G_2, \ldots, G_n &= \text{bulk specific gravities of 1, 2, \ldots, n (AASHTO T 84 and T 85)}
\end{align*}
\]

2. Recycled materials.

\[
VMA = 100 - \frac{G_{ab} P_a}{G_{ab}}
\]

Where:

\[
\begin{align*}
VMA &= \text{voids in mineral aggregate (percent of bulk volume)}
\end{align*}
\]
\( G_{mb} \) = bulk specific gravity of compacted mixture (ASTM D 2726)

\( P_i \) = aggregate, percent by total weight of mixture

\( G_{sb} \) = bulk specific gravity of total aggregate

\[
G_{sb} = \frac{P_1 + P_2 + \ldots + P_n + P_{RAP}}{G_1 + G_2 + \ldots + G_n + G_{eRAP}}
\]

where
\( P_1, P_2, \ldots, P_n \) = percentage by weight of aggregates 1, 2, \ldots n
\( G_1, G_2, \ldots, G_n \) = bulk specific gravities of 1, 2, \ldots n (AASHTO T 84 and T 85)
\( P_{RAP} \) = percentage by weight of recycled aggregate
\( G_{eRAP} \) = effective specific gravity of the recycled aggregate

\[
G_{eRAP} = \frac{100 - P_b}{100 - \frac{P_b}{G_{mn}}} - \frac{P_b}{G_b}
\]

where
\( P_b \) = asphalt content of recycled material, percent by total weight
\( G_{mn} \) = theoretical maximum specific gravity of recycled material (ASTM D 2041)
\( G_b \) = specific gravity of the asphalt in recycled material
1038.01 Scope. This method covers the procedure for the quantitative determination of asphalt binder in hot-mixed asphalt mixtures and pavement samples.

1. The aggregate remaining may be used for sieve analysis according to AASHTO T 30, Mechanical Analysis of Extracted Aggregate.

Note 1: Although asphalt binder, by definition, is material soluble in carbon disulfide, other solvents are used in this method for safety and environmental reasons.

1038.02 Summary of Method.

1. The mixture is extracted with a suitable solvent using the extraction equipment. The asphalt binder content is calculated by difference between the mass of the original sample and the mass of the extracted aggregate and ash from an aliquot of the extract.

1038.03 Apparatus.

1. Oven, capable of maintaining the temperature at 230 ± 9 °F (110 ± 5 °C).

2. Pan, flat, 14 inches (350mm) long, 10 inches (250mm) wide and 2.5 inches (65mm) deep.

3. Balance: A balance conforming to the requirements of AASHTO M 231, Class D shall be provided.

4. Balance: A balance conforming to the requirements of AASHTO M 231, Class E capacity 15 kg or more.
5. Hot Plate: Electric with adjustable heating rate.


7. Ignition Dish, 120 ml capacity.

8. Balance: A balance conforming to the requirements of AASHTO M 231, Class C.

9. Muffle furnace or gas burner capable of maintaining temperatures between 500 °C and 600 °C.

**1038.04 Solvent.**

1. For ODOT lab testing use trichloroethylene or alternate solvent approved by the Laboratory. Contractors may use any solvent that is determined to perform adequately.

**1038.05 Preparation of Sample and General Requirements for weighing.**

1. Place mixture in a large flat pan and dry to constant weight in an oven at a maximum temperature of 230 °F (110 °C).

2. The test sample consists of the entire sample or the end result of splitting or quartering a large sample conforming to AASHTO T 168. The size of the test sample is governed by the nominal maximum aggregate shown in the following table.

<table>
<thead>
<tr>
<th>Nominal Maximum Aggregate Size</th>
<th>Standard (mm)</th>
<th>Alternate</th>
<th>Minimum Mass of Sample (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.75</td>
<td>3/8&quot;</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>9.5</td>
<td>½&quot;</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>12.5</td>
<td>3/4&quot;</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>19.0</td>
<td>1&quot;</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>25.0</td>
<td>1 ½&quot;</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>37.5</td>
<td></td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

Note 2: When the mass of sample is greater than the maximum capacity of the extraction equipment, divide the sample into approximately equal portions for testing. The masses for calculations will then be the sum of like masses of the test portions.
3. Weigh extraction test apparatus and/or samples on a balance meeting the requirements of 1038.03 part 3 when the capacity is sufficient; otherwise, use a balance meeting the requirements of 1038.03 part 4.

1038.06 Apparatus

1. In addition to the apparatus listed in section 1038.03, apparatus similar to that shown in Figure 1, AASHTO T 164(76), Method A, is required.

1.1 Extraction Apparatus, consisting of a bowl approximately that shown in Figure 1 and an apparatus in which the bowl may be revolved at controlled variable speeds up to 3600 rpm. Provided a container for catching the solvent thrown from the bowl and a drain for removing the solvent.

Note 3: Similar apparatus of large size may be used.

1.2 Filter Ring: A smooth, white, medium fast filter paper of a diameter at least equal to the bowl sealing surfaces outside diameter and to internally exceed the bowl sealing surface width by at least 25.4 mm (1 inch).

1038.07 Procedure

1. Weigh a 1000 to 3000g sample into the bowl.

2. Cover the sample in the bowl with solvent and allow sufficient time for solvent to disintegrate the sample (not over 1 hour). Place the bowl containing the sample and the solvent in the extraction apparatus. Fit the filter ring around the edge of the bowl. Clamp the cover on the bowl tightly and place a graduated container under the drain to collect the extract.

3. Start the centrifuge revolving slowly and gradually increase the speed to a maximum of 3600 rpm or until solvent ceases to flow from the drain. Allow the machine to stop, add 500 ml solvent and repeat the procedure. Use sufficient 500 ml solvent additions (not less than three) so that the extract is clear and near a light straw color. Collect the extract and the washings in a suitable graduate.

4. Remove as much of the mineral matter adhering to the ring as possible and add to the aggregate in the bowl. Dry the contents of the bowl to a constant mass in an oven at 110 ± 5 °C (230 ± 9 °F) or on a hot plate.

Note 4: Dry the sample until further drying at 110 ± 5 °C (230 ± 9 °F) does not alter the mass 0.1 percent.

5. Record the volume of the total extract in the graduate. Agitate the extract thoroughly and immediately measure approximately 100 ml into a previously weighed ignition dish. Dry on a hot plate. Burn the residue at a dull red heat (500 to 600 °C), cool, and weigh.
1038.08 Calculations

1. The mass of the mineral matter in the total volume of extract as follows:

   Total mineral value \( G = \frac{V_1}{V_1 - V_2} \)

   where: \( G \) = mineral matter in grams
   \( V_1 \) = total volume in milliliters, and
   \( V_2 \) = volume after removing aliquot in milliliters.

2. Calculate the percentage of asphalt binder in the sample as follows:

   Binder content of dry sample, percent = \( \frac{W_2 - (W_2 + W_3)}{W_1} \) x 100

   where: \( W_1 \) = mass of sample
   \( W_2 \) = mass of extracted mineral matter, and
   \( W_3 \) = mass of mineral matter in extract.

1038.09 Report

1. Report the asphalt binder content to the nearest 0.1 percent.
STATE OF OHIO
DEPARTMENT OF TRANSPORTATION

SUPPLEMENT 1039
METHOD OF TEST FOR
MECHANICAL ANALYSIS OF EXTRACTED AGGREGATE

April 18, 2008

1039.01 SCOPE This method of test covers a procedure for the determination of the particle size distribution of fine and coarse aggregates extracted from asphalt concrete mixtures, using sieves with square openings.

1039.02 APPARATUS The apparatus consists of the following:

1. Balance: A balance conforming to AASHTO M 231, Class D for samples less than 5000 g, Class E for samples 5000 g or more.

2. Sieves: Sieves with square openings mounted on substantial frames constructed in a manner that will prevent loss of material during sieving. Suitable sieve sizes selected to furnish the information required by the specifications covering the material to be tested. The woven wire cloth sieve conforming to the requirements of AASHTO M 92 for Sieves for Testing Purposes.

1039.03 PROCEDURE

1. Dry the sample until further drying at 230 + 9 °F (110 + 5 °C) does not alter the weight 0.1 percent. The total weight of aggregate in the asphalt concrete mixture being tested is the sum of the weights of the dried aggregates and the mineral matter contained in the extracted asphalt binder. The latter is to be taken as the weight of ash in the extract.

2. Sieve the aggregate over sieves of the various sizes required by the specification covering the mixture, including the 75 μm sieve. Sieve in accordance with AASHTO T 27 Standard Method of Test for Sieve Analysis of Fine and Course Aggregates. Commencing with the largest sieve, record an accumulated weight (consisting of the weight of material retained on a particular sieve plus the weight of material on all previous sieves) of material retained on each successive sieve and the pan. The total accumulated weight must check the total weight of the sample within 0.2 percent. Add the weight of dry material passing the 75 μm sieve by dry sieving to the weight of mineral matter in the extracted asphalt binder in order to obtain the total passing the 75 μm sieve. Determine the percent of material passing each sieve using the following formula:

\[
\frac{\% \text{ Passing}}{\text{P}_t} = 100 \left(1 - \frac{\text{P}_w}{\text{P}_t}\right)
\]

where:

\[\text{P}_w\] = the accumulated weight for a particular sieve

\[\text{P}_t\] = the total weight of aggregate in the asphalt concrete mixture from 3.1.

1039.04 REPORT Report percentages to the nearest whole number except for the percentage passing the 75 μm sieve which is reported to the nearest 0.1 percent.
1043.01 Scope. This supplement specifies the procedures for using an Asphalt Content Nuclear Gauge (AC Gauge) to correctly determine:

1. a background count.
2. a calibration.
3. a proper AC content offset amount.
4. the asphalt binder content of a sample of asphalt concrete.

Ensure the gauge meets the requirements of Supplement 1041.04. Ensure the manufacturer provided ‘reference voltage’ is properly entered into the gauge.

1043.02 General. Turn on the AC Gauge for a minimum of 10 minutes prior to performing any tests.

For QC and QA test reporting take AC Gauge readings at 16 minutes. For quick checks, readings may be taken at lesser times.

Ensure the AC Gauge operator or any other hydrogen sources are no closer than 5 feet (1.6m) to the AC Gauge when it is performing a test. If a hydrogen source moves closer than 5 feet (1.6M) to an AC Gauge during a test, retest the sample.

Calculate and record asphalt binder contents as percent of total mix.

1043.03 Background Count. Take two background counts before the start of each production day to make sure they are within 1.0 % of each other (also determines gauge stability/gauge warm up). If the two counts are within 1.0 % save the second background count as the current count. Before each test run a background to check that it is within 1.0 % of the previous. If so save and use that current value for the test. If not investigate reasons for background variation. This may include changes in background (hydrogen) or gauge issues.

1043.04 Laboratory Produced Mixtures. This section describes the procedures for making laboratory mixes of asphalt concrete to calibrate an AC Gauge. Prepare mixes in an approved Level 3 laboratory.

Mix aggregate meeting the JMF with the specified percent asphalt binder and grade. Prior to mixing the samples for calibration, mix a sample of the asphalt concrete, at the minimum asphalt binder content to be mixed, to prime the mixing bowl. Discard this sample. Scrape the mixing bowl and mixer beater clean and weigh the mixing bowl.
Scrape the mixing bowl and mixer beater clean after mixing each batch of asphalt concrete so that the mixing bowl weighs the same before each batch is mixed. After all the batches are mixed clean all of the mixing equipment.

**1043.05 Blank Sample.** Prior to performing each calibration, prepare and weigh a blank sample to determine the weight of asphalt concrete to add to an AC Gauge pan for an AC Gauge test. Prepare a blank sample as follows:

1. Weigh an empty, clean AC Gauge pan.
2. Mix a sample of asphalt concrete, having an asphalt binder content at the JMF design asphalt binder content, in accordance with 1043.04. Use a mix temperature 25.0° F less than the JMF lab compaction temperature or 270° F (132° C), whichever is higher. Ensure this sample is of a sufficient size to completely fill an AC Gauge pan.
3. Fill an AC Gauge pan with the asphalt concrete in accordance with the first 3 steps of 1043.06.
4. Add additional asphalt concrete to just slightly over the top edge of the AC Gauge pan. Lightly press the top of the sample with a hot spoon or other instrument to settle the asphalt concrete into the edges and corners of the AC Gauge pan. Fill in any low spots and the corners with additional asphalt concrete as needed. Ensure the blank sample is level with the top edge of the AC Gauge pan. If not, redo the blank sample.

After the blank sample and pan is prepared weigh the sample and pan to the nearest gram. The weight of the blank sample is the difference between the sample and pan weight and the weight of the AC Gauge pan. Prepare a new blank sample for each JMF. The blank sample may be used as a calibration sample in accordance with 1043.07.

**1043.06 Filling AC Gauge Pans.** Fill the AC Gauge pans with laboratory or plant mixed asphalt concrete as follows:

1. Weigh an empty, clean AC Gauge pan.
2. Fill the AC Gauge pan about 1/3 full with the asphalt concrete and settle the contents by dropping it 3 to 4 inches (75 to 100 mm) onto a level surface 3 times.
3. Add additional asphalt concrete until the AC Gauge pan is about 2/3 full and settle the contents by again dropping it 3 to 4 inches (75 to 100 mm) onto a level surface 3 times.
4. Place the AC Gauge pan on a scale, tare the scale, and add additional asphalt concrete until the weight of the asphalt concrete in the AC Gauge pan equals the weight of the blank sample.
5. Remove the pan from the scale and lightly press the top of the sample with a hot spoon or other instrument to settle the asphalt concrete into the edges and corners of the AC Gauge pan. Note: For an accurate test it is essential that the corners are filled and that the mix surface is flush with the pan top.
6. Weigh the AC Gauge pan with the asphalt concrete to confirm the weight of the blank sample.

**1043.07 Calibration.** Calibrate the AC Gauge using a minimum of 3 separate calibration samples mixed in accordance with 1043.04. Ensure these samples have asphalt binder contents as follows:

1. Design asphalt binder content.
2. 1.0 percent above the design asphalt binder content.
3. 1.0 percent below the design asphalt binder content.

Perform the calibration of the AC Gauge in accordance with the AC Gauge manufacturer's instructions. Calibrate the AC Gauge such that the Fit Coefficient is 0.995 or above. If the Fit Coefficient is less than 0.995 calibrate the AC Gauge with new calibration samples.
To verify the calibration is properly working in the AC gauge mix a separate Verification sample at the JMF asphalt binder content. Contact the District for availability for witnessing the mixing and testing of the Verification sample. In place of witnessing the sample the District may opt to extract a Verification sample for Quality Assurance purposes and request a replacement Verification sample at any time. Determine the asphalt binder content of the Verification sample by the calibrated AC Gauge in accordance with 1043.09. The AC Gauge will be considered calibrated if the asphalt binder content determined by the AC Gauge is within 0.14 percent of the actual asphalt binder content of the sample. Retain and label the Verification sample above for District use.

If not full, store the calibration in the AC Gauge. Record the calibration so that it may be retrieved whenever a sample of asphalt concrete with the same design is to be tested for asphalt binder content.

Print out the following information for each calibration:

1. Date
2. Contractor's name
3. AC Gauge serial number
4. Calibration number (assigned by the Laboratory)
5. Type of asphalt concrete
6. Background count
7. Blank sample weight
8. Fit coefficient
9. Calibration constants
10. Programmed asphalt binder contents, corresponding measure counts and percent differences

Submit the printouts from the calibration and verification sample, along with the "Calibration Inspection Form", to the DET.

1043.08 Determining Plant and District AC Gauge Offset Amounts. Calculate an AC Gauge offset amount in accordance with procedures outlined in Appendix A. Do not use another procedure.

Every combination of aggregates and asphalt binder will have a unique offset amount. Before an offset amount is determined and applied to an AC Gauge the asphalt plant printout results for total asphalt binder content must be verified for accuracy. (Be sure to include SBR, if used, in this total asphalt binder content.) To accomplish this asphalt concrete samples are extracted with solvent to determine their asphalt content. Although extractions are not perfectly accurate they are critical in confirming the plant printout total asphalt content. Should extraction results appear out of line compared to the plant printout total asphalt content there may be an issue with the plant. Do not use the plant printout total asphalt content in determining an offset amount. Investigate the reason for the problem, correct the problem and record the investigation and findings on the TE-199 before proceeding with further extraction testing to verify the new plant printout total asphalt content used in determining the offset amount.

After determining an AC Gauge offset amount proceed with determining AC contents of production samples by the AC gauge according to 1043.09.

Correct sample test results that are tested by the AC Gauge prior to determining an offset amount by applying the offset amount to the previous AC Gauge determined AC contents by hand on the TE 199.

Only determine one AC Gauge offset amount per Job Mix Formula per project. For re-use of an offset on a new project if more than 30 days has lapsed since the JMF was last tested, re-do the offset procedure in Appendix A. If an AC Gauge offset amount is later determined, by an investigation of both the Contractor and the District, to be incorrect re-do the offset procedure in Appendix A.

1043.09 Determining Asphalt Binder Content. During initial production of asphalt concrete determine a proper AC Gauge offset amount in accordance with 1043.08. Enter the offset into the AC gauge in accordance with the manufacturer's instruction. Determine the asphalt binder content of a sample of asphalt concrete in a properly
offset AC gauge as follows:

1. Set the AC Gauge for the calibration that corresponds with the JMF of the asphalt concrete to be tested.

2. Place the AC Gauge pan containing the sample of asphalt concrete in the AC Gauge and test in accordance with the manufacturer’s instructions.

3. Determine the moisture content of a 3.3 pound (1500-gram) sample in accordance with 1043.10 and record with each AC Gauge and test.

4. Print out the following information for each AC Gauge test:
   a. Date
   b. Time
   c. Contractor’s name
   d. AC Gauge serial number
   e. Calibration Number
   f. Measure count
   g. Background count
   h. Percent asphalt binder to the nearest 0.01 percent

**1043.10 Determining Moisture Content.** Determine the moisture content of a sample of asphalt concrete as follows:

1. Determine and record the combined weight of the empty sample pan and stirrer to the nearest 0.004 ounce (0.1 gram).

2. Place a 3.3 pound (1500-gram) sample of asphalt concrete and stirrer in the sample pan. Determine and record the weight of the filled sample pan to the nearest 0.1 gram (initial weight).

3. Place the filled sample pan in an oven for a minimum of 2 hours. Ensure the oven temperature is 355 +/- 20 °F (180 +/- 11 °C).

4. Remove the filled sample pan from the oven. Determine and record the weight of the filled pan to the nearest 0.1 gram. Stir the sample and place the filled sample pan back in the oven.

5. Repeat Step #4 every 15 minutes until the total mix weight loss between 2 consecutive 15 minute readings is less than 0.1 percent. The last 15 minute reading is the final weight. Subtract the empty sample pan and stirrer weight to determine the final sample weight.

6. Calculate the moisture content (expressed as a percent) as follows:
   \[
   \text{Moisture content} = \frac{(\text{initial sample weight} - \text{final sample weight})}{\text{final sample weight}} \times 100
   \]

7. Subtract the percent moisture content from the asphalt binder content as determined by the AC Gauge to determine the corrected asphalt binder content.
Appendix A, page 1

AC Gauge Verification and Offset Record

District ________ Date __________

Project No. __________________ Contractor ______________

JMF No. ________ Calibration No. ______ Type __________

JMF AC _________ P-4 ___________ %RAP __________

Original Calibration Constants:

A1_____________ A2_____________ A3__________

Blank Sample Weight _________g Background Count ___________ Fit Coef.____________

Verification Sample Gauge Correlation and Initial Offset:

Plant Gauge (1)________(2)________ Avg. _________ Gauge Serial No. ______

District Gauge (1)________(2)________ Avg _________ Gauge Serial No. ______

Initial Offset Plant = JMF AC-Plant Avg = +/- __________

Initial Offset District=JMF AC-District Avg = +/- __________

Initial Offset Calibration No. Plant ____________ District ______________

Total Offset Determination for Plant Gauge:
Minimum four extractions at the plant required. Test results on page two.

Plant Offset Avg = +/- ______________

Total Offset Plant = Initial Offset Plant + Plant Offset =

Initial Offset Plant + Plant Offset Avg. = (+/- )_____ + (+/-)______ = (+/-)________

Total Offset Determination for District Gauge: Total Offset District=

Initial Offset District + Plant Offset Avg = (+/-) _____+ (+/-)______ = (+/-)_______

Note: Enter offsets using same plant sample before and after to verify correct entry.
Appendix A, page 2

AC Gauge Verification and Offset Record

Offsets Verification from Extraction and Plant Data
(Attach plant tickets and gauge printouts)

Extraction (plant, four minimum)

1) Date _____ Time _____ P-4 ___ AC ___
   Plant Ticket Avg AC ______ Plant Gauge ______ - Moisture ____ = Corrected Plant Gauge_____
   Difference (Plant Ticket AC-Corr. Plant Gauge) = +/-_________

2) Date _____ Time _____ P-4 ___ AC ___
   Plant Ticket Avg AC ______ Plant Gauge ______ - Moisture ____ = Corrected Plant Gauge_____
   Difference (Plant Ticket AC-Corr. Plant Gauge) = +/-_________

3) Date _____ Time _____ P-4 ___ AC ___
   Plant Ticket Avg AC ______ Plant Gauge ______ - Moisture ____ = Corrected Plant Gauge_____
   Difference (Plant Ticket AC-Corr. Plant Gauge) = +/-_________

4) Date _____ Time _____ P-4 ___ AC ___
   Plant Ticket Avg AC ______ Plant Gauge ______ - Moisture ____ = Corrected Plant Gauge_____
   Difference (Plant Ticket AC-Corr. Plant Gauge) = +/-_________

5) Date _____ Time _____ P-4 ___ AC ___
   Plant Ticket Avg AC ______ Plant Gauge ______ - Moisture ____ = Corrected Plant Gauge_____
   Difference (Plant Ticket AC-Corr. Plant Gauge) = +/-_________

Plant Offset Avg = Avg Difference (Plant Ticket AC - Corrected Plant Gauge) = +/- _______

Note: Is extraction sample P-4 +/- (6%) of JMF? Do not proceed until corrected. Does extraction data reasonably confirm plant data? If not, do not proceed with offset procedure and check plant operation / calibration. If so, calculate offset using plant ticket data. Calculating the plant offset average may require judgment on the part of the monitor if any one value appears to be out of place. If a single value is out of line but the rest are close then use the remaining data to calculate the average.

Level 2 Tech Sign. _____________________________ Date ________________

District Monitor Initials._____________________________ Date ________________
FORMULA for Calculating the Grams of PG Binder needed for an Asphalt Content Point:

**Formula:**

\[(C \times A) \div (100 - A)\]

- A = Desired Asphalt Point
- C = Weight of Dry Aggregates

**Example:**

Desired AC% = 6.0%
Weight of Dry Aggregates = 7000 Grams

\[(7000 \times 6.0) \div (100 - 6.0) = 42000 \div 94.0 = 446.80\]

Rounded = 447

According to this calculation, you need 447 grams of liquid asphalt (PG Binder) combined to the 7000 grams of Aggregate to give you a sample with a 6.0% Asphalt Cement content.
AC GAUGE VERIFICATION AND OFFSET RECORD

District – 4

Date – 1/1/2008

Project No. - 199-03

Contractor – Adam’s Paving

JMF No.- B413060

Calibration No.- 3060

Type - 441-1

JMF AC - 5.6%

P-4 - 55%

%RAP - 20%

Original Calibration Constants:

A1) -0.133262 A2) +3.910774 A3) +0.00

Bland Sample Weight - 7000 grams

Verification Sample – Gauge Correlation and Initial Offset:

Plant Gauge - 5.67% & 5.63%  Avg.  5.65%  Gauge Serial No. - 1500

District Gauge - XXXX  Avg - XXXX  Gauge Serial No. - XXXX

Initial Offset Plant = JMF AC - Plant Avg = +/- 5.60% - 5.65% = -0.05%

Initial Offset District = JMF AC - District Avg = +/- - XXXX

Initial Offset Calibration No. Plant - 3060 / 1  District - 4

Total Offset Determination for Plant Gauge:
Minimum three extractions at the plant required. Test results on page two. Plant Offset Avg = +/-

Plant Offset + Initial Offset = Total Plant Offset

(+/-) -0.39 + (+/-) -0.05 = (+/-) -0.44

Plant Offset Calibration No. - 3060 / 2

Total Offset Determination for District Gauge:

Plant Offset + Initial Offset District = Total Offset District

(+/-) -0.00 + (+/-) -0.00 = (+/-) -0.00
## Extraction (Plant)

### District split if used

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<tr>
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<th>/ P-4</th>
<th>AC</th>
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<td><strong>Moisture</strong></td>
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<td><strong>Difference</strong></td>
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<td><strong>Plant Gauge</strong></td>
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### Notes
- Is extraction sample P-4 +/− 6% of JMF? If not, resample and check plant. Does extraction data reasonably confirm plant data? If not, do not proceed with offset procedure and check plant operation/calibration. If so, calculate offset using plant ticket data.

### Calculating the plant offset average
- May require judgment on the part of the monitor if any one value appears to be out of place. If a value is out but the rest are close then use the remaining data to calculate the average.

## Contractor

<table>
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### Contractor

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<tr>
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<td><strong>0.02 %</strong></td>
<td><strong>5.79 %</strong></td>
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<tr>
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<td><strong>AC</strong></td>
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<td><strong>Plant Gauge</strong></td>
<td><strong>= 0.25 %</strong></td>
<td></td>
</tr>
</tbody>
</table>

### Plant Offset Avg = 5.54 % - 5.93 %

### Avg Difference (Plant Ticket AC - Corrected Plant Gauge) = − 0.39 %

## Conclusion
- Is extraction sample P-4 +/− 6% of JMF? If not, resample and check plant. Does extraction data reasonably confirm plant data? If not, do not proceed with offset procedure and check plant operation/calibration. If so, calculate offset using plant ticket data.
STATE OF OHIO
DEPARTMENT OF TRANSPORTATION

SUPPLEMENT 1054

TEST METHOD FOR DETERMINATION
OF ASPHALT BINDER CONTENT BY
THE IGNITION METHOD

April 18, 2008

1054.1 Scope
1054.2 Safety
1054.3 References
1054.4 Summary of Test Method
1054.5 Apparatus
1054.6 Sampling and Preparation
1054.7 Calibration
   A. Three Sample Calibration
   B. Blank Aggregate Sample Calibration (if required)
1054.8 Oven Test Procedure
1054.9 Determining Moisture Content
1054.10 Final Calculations

1054.1 Scope

This test method covers the determination of asphalt binder content of hot mixed paving mixtures by ignition of the asphalt binder in a furnace. The aggregate remaining can be used for sieve analysis.

1054.2 Safety

This standard may involve hazardous materials, operations, and equipment. This standard does not presume to address all of the safety problems associated with ignition oven's use. It is the responsibility of the user to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

Do not attempt to bypass the safety interlock on the oven door!!

1054.3 References

AASHTO Standards:
   T 248  - Practice for Sampling Asphalt Paving Mixtures
   T 30   - Mechanical Analysis of Extracted Aggregate
1054.4 Summary of Test Method

The asphalt binder in a sample of hot mixed paving material is burned by ignition at high temperature. The asphalt binder content is calculated from the mass of ignited aggregate, moisture content, and temperature compensation. The asphalt binder content is expressed as mass percentage of the moisture free mixture. This method may not be applicable to certain modified mixes. Contact the Laboratory if any question.

1054.5 Apparatus

A. A forced air ignition furnace capable of maintaining a temperature of 1100 °F (600 °C). The oven may or may not have an internal balance. If so it must be thermally isolated from the furnace chamber. The internal balance must be accurate to 0.1 g. Ensure the balance is capable of weighing a 3500 gram sample in addition to the sample baskets. Ensure the furnace calculates a temperature compensation factor for the change in weight of the sample baskets and provide for the input of a correction factor for aggregate loss. If the furnace has an internal balance provide a printed ticket with the initial specimen weight, specimen weight loss, temperature compensation, correction factor, corrected asphalt binder content (percent), test time and test temperature. As well ensure the furnace automatically determines weight loss and when weight is constant for two minutes signals the operator by an indicator light and audible alarm. Provide a method for reducing furnace emissions. Provide an automatic locking door.

B. Two or more tempered stainless steel 2.36mm (No. 8) mesh or similar perforated baskets nested into a catch pan. Provide screening on the legs to confine the aggregate. Ensure a minimum surface area of 265mm (10.5 inch) x 265mm (10.5 inch) for one basket.

C. One stainless steel catch pan.

D. Ovens, balance and miscellaneous equipment as outlined in Supplement 1041.

E. Safety equipment: safety glasses or face shield, high temperature gloves, and long sleeve jacket or heat resistant sleeves. A heat resistant surface capable of withstanding 1200 °F (650 °C) and a protective cage appropriately labeled and capable of surrounding the sample baskets.

F. Vent the furnace so no odors are noticeable in the laboratory. Ensure exhaust air moves by means of a fan on the furnace outlet. Ensure exhaust air movement is limited so as to not affect oven operation adversely.

1054.6 Sampling and Preparation

A. Obtain the test sample in accordance with the appropriate specification. Plant samples may need to be quartered (AASHTO T 248). Testing road samples after testing in an asphalt binder content nuclear gauge will require quartering as well.
B. Preparation of test specimens:

1. If the mix is too cold to separate, warm in an oven at less than 302 °F (150 °C) for sufficient time to soften.

2. The size of the test sample is governed by the type of asphalt concrete mix as shown in the table below. Conform to any existing requirements for sample size. Ensure no single oven test has a sample greater than 3000g. However, the test specimen may be divided into suitable increments, tested, and results recombined for calculation of the asphalt binder content (weighted average).

<table>
<thead>
<tr>
<th>Minimum Sample Size by Mix Type</th>
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<tr>
<td>448 Type 1&amp;2, 446 Type 1&amp;2</td>
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<tr>
<td>301</td>
</tr>
<tr>
<td>302</td>
</tr>
<tr>
<td>308</td>
</tr>
<tr>
<td>Open Graded Friction Course</td>
</tr>
<tr>
<td>All other mixes</td>
</tr>
</tbody>
</table>

3. A 1000g minimum sample is required for a moisture determination for each mix sample per 9.0. Do not use the specimen for moisture determination for asphalt binder content determination.

1054.7 Calibration (if required)
Test mixes containing any limestone coarse aggregate (including reclaimed asphalt concrete pavement) at 930 °F (500 °C) unless otherwise approved by the Laboratory. Test all other mixes at 1000 °F (540 °C) provided no indication of aggregate breakdown by erroneous data exists.

Obtain the asphalt binder content of reclaimed asphalt concrete pavement determinations by averaging results from ignition oven testing on three separate samples.

A. Three Sample Calibration

1. Prepare three calibration specimens conforming to 1054.6.B.2 at the design asphalt binder content and include the appropriate specification for cure time. Prepare a butter mix as above and discard prior to mixing calibration samples. Sample aggregate used for the calibration specimens from the most recently available aggregate source or pile. Batch and grade an additional blank sample to verify gradation meets the JMF.

2. Preheat the oven to the required test temperature. Record the oven temperature prior to the start of the test.
3 Enter a correction factor of 0.00 in the ignition oven if applicable.

4 Weigh the sample basket assembly.

5 With the sample in the baskets weigh and record the sample, baskets, catch pan, and basket guards. Calculate and record the initial weight of the sample specimen (total weight - the weight of the sample basket assembly).

6 Input the initial weight of the sample in whole grams into the oven if applicable. Verify that the correct weight has been entered.

7 Zero the balance if applicable. Place the sample in the oven. Verify that the sample weight (including baskets) equals the total weight in 1054.7.A.6 within 5 g. Differences greater than 5 grams or failure of the oven balance to stabilize may indicate that the sample basket assembly is touching the oven wall. Begin the test.

For internal balance ovens:

8 Allow the test to continue until the oven indicates the test is complete. Stop the test.

9 Remove the baskets to a safe location allowing to cool 20 minutes.

10 Record all data on the Mixture Calibration form.

For ovens with no internal balance:

8 Test the sample for 75 to 85 minutes for the 930 °F test and 60 minutes for the 1000 °F test. Stop the test and visually check the sample appearance. If any dark sooty ash remains on the aggregate or in the tray restart the test. Check the appearance every 5 minutes until no dark ash remains. Weigh the basket assembly recording the weight at 20 seconds. Restart the test and weigh again after 5 minutes recording the weight at 20 seconds. If the difference in hot weight is less than 1 gram the test is complete.

9 Calculate the difference in beginning weight and final hot weight.

10 Record all required data on the Mixture Calibration form.

B. Blank Aggregate Sample Calibration (if required)

1 Prepare two calibration samples conforming to 1054.6.B.2 in the lab or taken from the plant belt or hot bins. Any batching method may be used to prepare the samples. Grade one sample to verify the gradation conforms reasonably to the JMF. Extract reclaimed asphalt concrete pavement before incorporation into the blank sample.
2 Dry the blank sample before test. This can be done by drying in an oven (at least 230 °F (110 °C)) for 20 minutes (with some stirring).

3 Preheat the ignition oven to the required temperature. Record the oven temperature set point prior to the initiation of the test.

4 Enter a correction factor of 0.00 in the ignition oven if applicable.

5 Weigh the sample basket assembly.

6 With the sample in the basket assembly weigh and record the specimen and entire basket assembly. Calculate and record the initial weight of the sample (total weight - the weight of the sample basket assembly).

7 Input the initial weight of the sample in whole grams into the ignition oven, if applicable. Verify that the correct weight has been entered.

8 Zero the balance if applicable. Place the sample into the oven. Verify that the sample weight (including basket assembly) equals the total weight in 7B6 within 5 grams. Differences greater than this or failure of the scale to stabilize may indicate the basket assembly is touching the oven wall. Begin the test.

For internal balance ovens:

9 Allow the test to continue until the oven indicates the test is complete. Stop the test.

10 Remove the basket assembly to a safe location allowing to cool 20 minutes.

11 Record all required data on the Mixture Calibration form.

For ovens with no internal balance:

9 Test the sample for 75 minutes for the 930 °F test and 60 minutes for the 1000 °F test. Stop the test and visually check the sample appearance. If any dark sooty ash remains on the sample or in the tray restart the test. Check the sample every 5 minutes until no dark ash remains. Weigh the basket assembly recording the weight at 20 seconds. Restart the test and weigh again after 5 minutes recording the weight at 20 seconds. If the difference in hot weight is less than 1 gram the test is complete.

10 Calculate the difference in beginning weight and final hot weight.

11 Record all required data on the Mixture Calibration form.
1054.8 Oven Test Procedure

1 Preheat the ignition oven to the required temperature. Record the oven temperature prior to starting the test.

2 Perform a moisture correction test in accordance with 1054.6.B.3 and 1054.9

3 Weigh and record the weight of the sample basket assembly.

4 With the sample in the basket assembly weigh and record the weight of the sample and basket assembly. Calculate and record the initial weight of the sample (total weight - weight of the basket assembly).

5 Input the initial weight of the sample in whole grams into the oven, if applicable. Verify that the correct weight has been entered.

6 Place the sample and basket assembly into the oven. Verify that the sample and basket weight equals the sample and basket weight from 1054.8.4 within 5 grams. Differences greater than this or failure of the balance to stabilize may indicate that the sample is touching the oven wall. Begin the test.

For internal balance ovens:

7 Allow the test to continue until the oven indicates the test is complete. Stop the test.

8 Remove the sample and basket assembly to a safe location allowing to cool for 20 minutes.

For ovens with no internal balance:

7 Test the sample for 75 to 85 minutes for the 930 °F test and 60 minutes for the 1000 °F test. Stop the test and visually check the sample appearance. If any dark sooty ash remains on the sample or in the tray restart the test. Check the sample every 5 minutes until no dark ash remains. Weigh the basket assembly recording the weight at 20 seconds. Restart the test and weigh again after 5 minutes recording the weight at 20 seconds. If the difference in hot weight is less than 1 gram the test is complete.

8 Calculate the difference in beginning weight and final hot weight as percent total mix (percent).

1054.9 Determining Moisture Content

1 Determine and record the combined weight of the empty sample pan and stirrer to the nearest 0.1 gram (pan weight).
Place the sample of asphalt concrete and stirrer in the sample pan. Determine and record the weight of the filled sample pan to the nearest 0.1 gram (initial weight).

Place the filled sample pan in an oven for a minimum of 2 hours. Use an oven temperature of 355 °F (180 °C) ± 10 °F (6 °C).

Remove the filled sample pan from the oven. Determine and record the weight of the filled pan to the nearest 0.1 gram. Stir the sample and place the filled sample pan back in the oven.

Repeat step 1054.9.4 every 15 minutes until the total weight loss between 2 consecutive 15 minute readings is less than 0.1 percent. The last 15 minute reading is the final weight.

Calculate the moisture content (expressed as a percent) as follows:

\[
A = \text{Initial weight} \\
B = \text{Final weight} \\
C = \text{Pan weight} \\
\]

\[
F = \frac{\text{Moisture content (percent)}}{\left(\frac{A - B}{B - C}\right) \times 100}
\]

1054.10 Final Calculations

The final asphalt binder content is a result of combining the oven test loss, correction factor and moisture content for the sample.

\[
D = \text{Weight loss of ignition oven tested sample (percent)} \\
E = \text{Correction factor from the Mixture Calibration form (percent)} \\
F = \text{Moisture content from Section 9.6 (percent)} \\
\text{Final corrected asphalt binder content (percent)} = D - E - F
\]
448 Asphalt Concrete

1. Specifications and Policies:
Section 448.

Appendix J - Policies and Instructions

2. Sampling and/or Inspection Requirements:
Aggregate shall be handled per 703.02. (Field)
Asphalt Material shall be handled per 702.01. (Field)

Asphalt Concrete Monitoring:
1 in 10 sets of Marshall Pans produced by the contractor shall be tested by the district. (District)
Obtain a sample of mix which the contractor has used to determine the MTD and test. (District)
In the event of conflicting results, the district sample should be sent to OMM as a referee.

Asphalt Concrete Acceptance:
Follow 403 for 448 procedures.

3. Methods of Tests:
Supplement 1038, 1039, 1043
448 Asphalt Concrete

1. Specifications and Policies:

Section 448.

Appendix I - Policies and Instructions

2. Sampling and/or Inspection Requirements:

Aggregate shall be handled per 703.02. (Field)

Asphalt Material shall be handled per 702.01. (Field)

Asphalt Concrete Monitoring:

1 in 10 sets of Marshall Fills produced by the contractor shall be tested by the district. (District)

Obtain a sample of mix which the contractor has used to determine the MTD and test. (District)

In the event of conflicting results, the district sample should be sent to OMM as a referee.

Asphalt Concrete Acceptance:

Follow 403 for 448 procedures.

3. Methods of Tests:

Supplement 1038, 1039, 1043
10/22/08
Appendix J

Asphalt Materials District Testing and Monitoring Instructions and Guidelines

Index

1) General Plant and Testing Items
   a) Plant Random Scale Checks
   b) Screen-less Batch Plants
   c) Small Quantity Asphalt
   d) Testing with the Nuclear Asphalt Content Gauge, Calibrations, Offset Form, Worksheets
   e) Automatic Ticket Printer
   f) Plant Moisture Settings
   g) Dust Correction Procedure for Centrifuge Extraction
   h) Non-approved Personnel in Testing

2) 403 (301, 302, 448), 441, 442 Specific Items
   a) 301 Blend Calculations
   b) Testing Priorities
   c) Monitoring 403, 441, 442 projects
   d) Procedure for Establishing the MTD
   e) Use of Mineral Filler in JMF’s
   f) District JMF Review/ Approval
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3) Asphalt Binder Items
   a) Asphalt Binder Sample Containers
   b) Sampling PG binders
   c) Taking a Liquid Binder Sample
1) General Plant and Testing Items

a) Plant Random Scale Checks (6/27/05)

Random weighting of trucks for checking scales should be a minimum of once per day. Should questions come up, the District Engineer of Tests can check scales as often as necessary to solve the problem.

Should truck and plant scales be outside +/-1%, the first such load of mix is allowed to be placed. Adjustments should then be made by watching the plant operations. If the next load is also outside +/-1%, then that load is to be rejected.

b) Screen-less Batch Plants (6/27/05)

Asphalt batch plants with the screen deck removed are allowed for production of 301, 302, and Type (2) (441) asphalt provided the following conditions are met and maintained. If uncontrolled and/or inconsistent material properties (AC, voids, segregation etc...) exist, screens will be required and no future screen-less operation of that plant will be allowed. Additional testing may be required by ODOT at the discretion of the central laboratory.

Requirements:

1) The modified plant must be inspected and approved by the Laboratory.
2) The material flow must be diverted into the center of one hot bin.
3) The plant must have extended dividers on cold bins.
4) A device to sample total flow with the belt in motion.
5) Lockable cold feeders.
6) Calibration of RAP and virgin belts.
7) Scalping screens on RAP and virgin belts. (2in)
8) Weight Bridges on RAP belts
9) Sensors on all cold feeders
10) Maximum of 30% RAP.
11) Give written approval.
12) This approval is subject to field verification.
c) Small Quantity Asphalt Concrete Testing and Acceptance (6/27/05)

Following is the procedure for the quality control and acceptance of small quantities of asphalt concrete. The contractor must have an approved Quality Control Plan (QCP) for producing under this procedure.

This procedure is intended for the use of the contractor. However, small quantity acceptance is not permitted for JMF’s that have not been verified by acceptable production under normal testing during the current construction season. The use of new JMF’s for small quantities must be approved by the District. The total seasonal production per project for each material type shall not exceed 1500 tons.

The District can sample, test and/or reject any material received under this procedure. Material may be rejected by visual inspection by the project or rejected thru district comparison testing. Poor plant or mix control, poor mix performance, poor mix quality, failure to submit the required form as required or ongoing District sample failures can mean disallowing further use of this procedure on the project or future projects. This procedure may be disallowed by the District for any contractor when documented pre-mature small quantity mix failure in any application has occurred on the contractor’s previous project(s).

When material is being produced under this procedure and has a quantity of less than 200 tons a day for each type, the acceptance is by contractor certification as outlined below. No quality control testing is required. A quick check plant calibration must have been performed in accordance with the contractor’s QCP as outlined in 403. Computerized plant operation tickets, a copy of the dated and signed quick check calibration(s) and a TE 199 SMQ form (attached) must be submitted as outlined below.

If the daily production does not exceed 500 tons a day for each type, the acceptance shall be by contractor certification as outlined below. The contractor shall perform an asphalt binder content test for every two hours of production. The asphalt binder content shall be determined by a nuclear gauge that has been properly offset for the JMF being used. Computerized plant operation tickets and a TE-199 SMQ form must be submitted as outlined below. Contractor samples shall be held at the lab for three days.

The required certification (TE 199 SMQ form) and other required information must be submitted by the next working day to the District testing office unless otherwise notified by the District. The TE-199 SMQ form shall be signed by an employee of the contractor having authority to represent the contractor as outlined in the contractor's QCP. The TE 199 SMQ form shall be sent to the Project Engineer if desired by the district.
Ohio Department of Transportation

Small Quantities of Asphalt Concrete Form TE 199SMQ

Project No. ________________ JMF Number ________________

Producer ________________ Location/Plant ________________

Send to: Project Engineer or District Engineer of Tests as required by the district.

This is to notify you that small quantities of asphalt concrete have been produced.

<table>
<thead>
<tr>
<th>Production Date</th>
<th>Quantity (tons)</th>
<th>AC% 1</th>
<th>AC% 2</th>
<th>Ref No</th>
<th>ODOT Sample ID</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

Note 1 - To be provided by contractor

Attached are copies of worksheets (gauge printouts, gradation, etc.), plant printouts and our most recent quick check calibration. I certify that the material was produced in accordance with our approved QCP. The asphalt plant was operated at the approved JMF and the mix met specifications.

Signed: ___________________________  Date: ___________________________

Title: ___________________________
d) **Testing with the Nuclear Asphalt Content Gauge, Offset Form, Calibration Worksheet and Calibration (6/28/05)**

**Testing**

The following procedure will be followed when testing using the nuclear asphalt content gauge. The intent is to make use of the plant and (1) district nuclear gauges, (2) plant quality control testing and (3) computerized plant data for an accurate and consistent acceptance and monitoring test procedure.

**Verification Sample**

A minimum of (2) work days prior to the start of production, a JMF Calibration Verification Sample (Verification Sample) shall be made by the Contractor with a Department representative observing. The Contractor shall mix a sample of asphalt concrete meeting the JMF and fill an AC gauge pan with the sample in accordance with Supplemental Specification 1043.06. A verification sample shall be made for each JMF and held by the contractor as long as the JMF is active.

**Initial Offset**

Prior to the start of production, the asphalt binder content of the verification sample shall be determined by the Contractor's plant AC gauge in accordance with Supplement 1043. An initial offset, if needed, will be entered into the plant AC gauge so it will read the proper asphalt binder content of the verification sample. The AC gauge printout for this test shall be retained by the Department. For determining the asphalt binder content for 448 acceptance or 446 monitoring samples the District will also enter an initial offset, if needed, into their AC gauge to read the proper asphalt binder content of the verification sample. The Contractor's plant AC gauge is now correlated with the District's AC gauge. All of the data used to calculate the initial offsets shall be recorded on a form approved by the laboratory.

**Total Offset**

A total offset, if needed, for the plant gauge shall be determined by the Contractor and / or Department within the production of (2) lots or (3) production days, whichever comes sooner. For 441 mixes the total offset will also be applied to the District AC gauge. This offset shall be based on asphalt binder content data from the Computerized Plant System, verified by the extraction of samples of asphalt concrete obtained from the material represented by the plant data. This plant data shall consist of one of the following.

The average of (5) consecutive readings from a drum mix plant.

The average of (5) consecutive readings when a batch plant's asphalt concrete is loaded from a storage silo.

The asphalt binder content from a single batch weight ticket when a batch plant's asphalt concrete is loaded directly in a truck.
A minimum of (3) sets of Computerized Plant System data verified by (3) corresponding extractions checked for gradation shall be used to establish the total offset. All of the data used to calculate the total offset shall be recorded on a form approved by OMM.

Prior to entering the total offset into an AC gauge, determine a plant sample's asphalt binder content with the AC gauge. Enter the total offset in the AC gauge and record the amount of the offset and the time it was performed on the Contractor's Quality Control Report (TE199). At this time, the asphalt binder content of the same plant sample as above will be determined by the plant AC gauge to verify the total offset was entered correctly. For 441 mixes, if the total offset is verified, this sample, still in the AC gauge pan, shall be held by a representative of the Department so it can be used to enter a total offset into the District's AC gauge using the same procedure described above.

Should discrepancies occur over the asphalt binder content between the district and plant after all of the above procedures are followed and no indication of any other correctable reasons are evident to the OMM, then 403 acceptance shall revert to full extraction testing, corrected for aggregate absorption. For 448 mixes the following testing procedure shall be followed:

For district testing at a minimum all nuclear gauge acceptance samples for lot one are to be extracted for gradation.

For lot two all four sub-lots are to be extracted for gradation but the sub-lot acceptance samples can be quartered and only one bowl run for asphalt binder determination.

For lots three and higher one randomly chosen sample will be extracted for gradation. This random sample can be quartered so that only one bowl is run for asphalt binder determination. Acceptance will be using a (4) test tolerance from 448 Table D or less if a partial lot. If not in tolerance samples for the entire lot will be run.

When quartering a sample the remaining portion of the sample must be retained until the extraction is complete. If the extracted sample meets the gradation tolerances as in the specification then that extraction result stands. If it is outside of the specification then the remaining portion of the original sample will be extracted and the results combined for a composite gradation. If the composite gradation is still out then the entire lot is to be run for lots three and higher.
Office of Materials Management

AC GAUGE VERIFICATION AND OFFSET RECORD

District _______ Date ________
Project No. _______________ Contractor _______________
JMF No. ___________ Calibration No. ______ Type _________
JMF AC ___________ P-4 ___________ %RAP ___________

Original Calibration Constants:
A1 ___________ A2 ___________ A3 ___________
Blank Sample Weight ______________________ g
Verification Sample Gauge correlation and Initial Offset:

Plant Gauge __________________________ Avg. ___________ Gauge Serial No. ________
District Gauge __________________________ Avg ___________ Gauge Serial No. ________

Initial Offset Plant = JMF AC-Plant Avg=+/- ___________
Initial Offset District=JMF AC-District Avg=+/- ___________
Initial Offset Calibration No. Plant ________________ District ________________

Total Offset Determination for Plant Gauge:
Minimum three extractions at the plant required. Test results on page two.

Plant Offset Avg=+/- ___________
Total Offset Plant = Initial Offset Plant + Plant Offset =
Initial Offset Plant + Plant Offset= (+/-) ______ + (+/-) ______ = (+/-) ________

Plant Offset Calibration No. ________________

Total Offset Determination for District Gauge: Total Offset District=
Initial Offset District + Plant Offset= (+/-) ______ + (+/-) ______ = (+/-) ________

District Offset Calibration No. ________________ Note: AC data to be two decimal places.
Enter offsets using same plant sample before and after.
Offsets Verification from Extraction and Plant Data (Attach plant tickets and gauge printouts)

Extraction (plant)

1. Date ___ Time ___ P-4 ___ AC ___
   Plant Ticket Avg AC ___ Plant Gauge ___ - Moisture ___ = Corrected Plant Gauge ___
   Difference (Plant Ticket AC-Corr. Plant Gauge) = +/- ___

2. Date ___ Time ___ P-4 ___ AC ___
   Plant Ticket Avg AC ___ Plant Gauge ___ - Moisture ___ = Corrected Plant Gauge ___
   Difference (Plant Ticket AC-Corr. Plant Gauge) = +/- ___

3. Date ___ Time ___ P-4 ___ AC ___
   Plant Ticket Avg AC ___ Plant Gauge ___ - Moisture ___ = Corrected Plant Gauge ___
   Difference (Plant Ticket AC-Corr. Plant Gauge) = +/- ___

4. Date ___ Time ___ P-4 ___ AC ___
   Plant Ticket Avg AC ___ Plant Gauge ___ - Moisture ___ = Corrected Plant Gauge ___
   Difference (Plant Ticket AC-Corr. Plant Gauge) = +/- ___

5. Date ___ Time ___ P-4 ___ AC ___
   Plant Ticket Avg AC ___ Plant Gauge ___ - Moisture ___ = Corrected Plant Gauge ___
   Difference (Plant Ticket AC-Corr. Plant Gauge) = +/- ___

Plant Offset Avg = Avg Difference (Plant Ticket AC-Corr. Plant Gauge) = +/- ___

Note: Is extraction sample P-4 +/- (6%) of IMF? If not, resample and check plant. Does extraction data reasonably confirm plant data? If not, do not proceed with offset procedure and check plant operation/calibration. If so, calculate offset using plant ticket data. Calculating the plant offset average may require judgment on the part of the monitor if any one value appears to be out of place. If a value is out but the rest are close then use the remaining data to calculate the average.

Level 2 Tech Sign. ___________________________ Date ____________
Office of Materials Management

Calibration Inspection Worksheet for A.C. Nuclear Gauge

Producer ______________ at ______________ Date ____________

Coarse Aggregate #1 ______________ Coarse Aggregate #2 ______________

Fine Aggregate #1 ______________ Fine Aggregate #2 ______________

RAP Source ______________

Design (s) to be covered by this calibration:

<table>
<thead>
<tr>
<th>Mix ID</th>
<th>Calib #</th>
<th>P4%</th>
<th>AC%</th>
<th>C.A. #1 %</th>
<th>C.A. #2 %</th>
<th>F.A. #1 %</th>
<th>F.A. #2 %</th>
<th>RAP%</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
</tbody>
</table>

Background count ______________ Background verification count ______________
Is Background verification within 1% of original? Yes/No

New Background count (if needed) ______________

Blank sample weight ______________ g.

Calibration Pan Counts:

<table>
<thead>
<tr>
<th>Pan #</th>
<th>AC %</th>
<th>Counts</th>
<th>Counts</th>
<th>Counts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Fit Coefficient ______________
Verification Sample

Desired A.C. % (A) __________

Wt. of mixing bowl ________g

Aggregate wt. (C) ___________g

Wt. of A.C. (AxC)/(100-A) _________g

Gauge Counts _______________

Allowable A.C. Range ________ to __________

State Monitor ________________ District _____

Note: Nuclear Asphalt Content Gauge Calibrations
All nuclear
gauge calibrations can be verified by the district at any time. This can be done either
with an existing verification sample, a new verification sample or a new calibration if
discrepancies cannot be resolved. The tolerance of ±-.14% still applies.
e) Asphalt Concrete Plant Auto Ticket Printer (6/28/05)

Only those auto printer tickets generating the following minimum information will be permitted to be used in lieu of the TE-27

DATE, PROJECT NUMBER

PRODUCER NAME, PRODUCER LOCATION OR PLANT NUMBER

MATERIAL IDENTIFICATION, TIME LEFT PLANT

GROSS WEIGHT, NET WEIGHT, TARE WEIGHT

f) Moisture Settings on Asphalt Concrete Plants (6/28/05)

The district can request that moisture tests of virgin aggregate, RAP and/or asphalt mix be performed any time suspected discrepancies exist. The Contractor is expected to operate the plant with the most recent moisture test data in the computer according to his QCP. If not the contractor should be informed he is not compliance with his QCP and the monitor should document the event for possible future reference.

g) Dust Correction Procedure for Centrifuge Extraction (6/28/05)

Questions have been raised recently concerning the proper procedure for obtaining a 100 ml sample of effluent for determining a dust correction for a centrifuge extraction test. The questions have pertained to the use of a 100 ml ladle vs. pouring the sample out of a jug.

Accepted practice has been to use the 100 ml ladle and dip the sample from a bucket or wide mouthed container. This is how all the Level 2 Schools have taught the procedure.

The consensus of a state/industry group was to use the bucket and ladle method over the pouring method with the following caution. When stirring the effluent in the bucket clockwise and counter clockwise care should be taken not to spin the effluent so fast that a deep vortex is formed because in doing this some of the dust can be forced to the outside edge. The proper method is to stir the effluent clockwise and counter clockwise enough to lift settled dust off the bottom into suspension and then agitate the effluent several times across the diameter of the
bucket. Dip the ladle 1/3 of the way across the diameter of the bucket for the 100 ml sample.

If a wide mouthed container which can be sealed is used then the container can be shaken and then the ladle dipped for the 100 ml sample.

h) Non-approved Personnel in Testing (6/28/05)

Concerns have been raised in the industry about the use of non-approved (Level 2) personnel working on jobs. Past practice has been to allow limited involvement of non approved personnel at the plant provided they are under direct hands-on supervision of a Level 2 or level 3 person. This practice allowed for flexibility in the use of personnel by the contractor and also provided a training period for personnel intended to receive Level 2 status.

The following policy has been decided to maintain a level of flexibility in the use of personnel and provide a suitable training period. This policy will at the same time maintain ODOT's need for clarity in quality control responsibilities at the plant for both the District's and the technician's benefit.

A three month period is allowed in which a non approved person can work under the direct hands-on supervision of a Level 2 or Level 3 person at the plant. The intent is that this person will be receiving training and experience leading to Level 2 approval. A Level 2 test can be scheduled to accommodate those needing certification.

Any person not approved and who is involved in any manner in testing should have their name noted on the TE-199 each day of involvement. This way monitoring teams can have assurance as to the involvement of both Level 2 and non Level 2 personnel.
2) 403 (301, 302, 448), 441, 442 Specific Items

a) 301 Blend Calculations (6/28/05)

The 301 Blend shall be calculated from the gradations of the individual components and the blend percentages supplied by the Contractor. The following example demonstrates the procedure to be followed:

The blend is to be (85%) Sand and Gravel, (10%) No. 57 Gravel and (5%) Natural Sand.

The amount passing the No. 4 shall be (45%). Laboratory Gradations:

<table>
<thead>
<tr>
<th>Sieve</th>
<th>Sand &amp; Gravel</th>
<th>No. #57</th>
<th>Natural Sand</th>
</tr>
</thead>
<tbody>
<tr>
<td>2&quot;</td>
<td>100</td>
<td>100</td>
<td>n/a</td>
</tr>
<tr>
<td>1&quot;</td>
<td>99</td>
<td>100</td>
<td>n/a</td>
</tr>
<tr>
<td>¾&quot;</td>
<td>92</td>
<td>86</td>
<td>n/a</td>
</tr>
<tr>
<td>½&quot;</td>
<td>78</td>
<td>37</td>
<td>n/a</td>
</tr>
<tr>
<td>3/8&quot;</td>
<td>68</td>
<td>18</td>
<td>n/a</td>
</tr>
<tr>
<td>No.4</td>
<td>49</td>
<td>2</td>
<td>100</td>
</tr>
<tr>
<td>No.8</td>
<td>37</td>
<td>0</td>
<td>92</td>
</tr>
<tr>
<td>No.16</td>
<td>26</td>
<td>n/a</td>
<td>73</td>
</tr>
<tr>
<td>No.30</td>
<td>17</td>
<td>n/a</td>
<td>50</td>
</tr>
<tr>
<td>No.50</td>
<td>8</td>
<td>n/a</td>
<td>22</td>
</tr>
<tr>
<td>No.100</td>
<td>4</td>
<td>n/a</td>
<td>7</td>
</tr>
<tr>
<td>No.200</td>
<td>2.6</td>
<td>n/a</td>
<td>3.8</td>
</tr>
</tbody>
</table>

The final blend is arrived at by multiplying the percentage of that component in the Blend. The sum of the products on each sieve is the blend percentage.
<table>
<thead>
<tr>
<th></th>
<th>n/a</th>
<th>7x.05= 0.4</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.6x.85= 2.2</td>
<td>n/a</td>
<td>3.8x.05=.19</td>
<td>2.4</td>
</tr>
</tbody>
</table>

* Note that these are included in the calculation since all sieves larger than the one passing 100% of the material also pass 100%.

** Note that the amount passing the No. 4 sieve is within the +/- 6% allowable.
b) Testing Priorities for 441 Mixes (10 8 08)

Following are listed various asphalt samples in order of testing priority. In some case is difficult to say one sample type has priority over another, but you are already aware of this and judgments must be made. However, IN GENERAL and MOST OF THE TIME the following applies.

1. 403 Verification Samples: (Top priority for 3 samples from earliest production per project minimum and tested and reviewed within one day of receipt)

2. At least one set of Rice and Bulk samples from earliest production and tested and reviewed within one day of receipt. Investigate and document any comparison problems.

3. 446 lots 1,2: (tested and reviewed within 1 day of receipt)

4. Remaining 403 Verification samples (within 3 days) (Note: ALL 403 samples and contractor tests must be compared and recorded with responses.)

5. Remaining monitoring samples (within 3 days, reduce to 5 days after 3 consecutive good tests)

6. Remaining 446 lots (within 5 days)

7. Maintenance (purchase order) samples (within 20 days)

Important! As in the past, should you find yourself in a position of not keeping up testing at peak season please contact the Central Lab. In many cases in the past we have been able to help but if not we can find a district which may be a bit slow at that time to help out.

c) Monitoring 403, 441, 442 projects (10 14 08)

Following is a discussion of the QC specification and also district monitoring procedures.

The QC specification places greater emphasis on the contractor to do what is necessary to maintain his mix rather than the district taking on the unnecessary burden of ensuring the technician follows some cookbook testing program. The district has the full authority and responsibility of assuring and satisfying itself that the mix is being made properly. This is accomplished thru monitoring procedures of split samples, plant lab visits, IAS testing and sometimes most importantly direct communication between the plant and the District Engineer of Tests or Asphalt Supervisor as to production progress or concerns. Lack of district
satisfaction with mix quality or control should lead to reasonable problem resolution on the contractors part provided district monitoring provides evidence a problem exists. Lack of a reasonable response by the contractor or proper mix control is justification for production being stopped or going to a load and hold process. In the case of 403 projects removal from Verification Acceptance is always an option.

Official monitoring of a job is accomplished thru the testing of split samples and plant monitoring reviews. Any monitoring activity should only validate or invalidate particular contractor tests, technician procedures or plant operations. A response to invalid tests or procedures should be quick, decisive and documented. Reviews of test and procedures must also be documented. Reasonable response by the contractor to invalid tests or procedures is expected because of the terms of the contractor QC program and job contract. Responses to invalid tests can include additional testing, retests, load and hold tests, plant re-calibration, a different technician, scale checks or whatever legitimate action is necessary to achieve proper mix control.

The minimum monitoring requirements are as follows unless altered by 403. In event of conflicting results, the District should contact OMM to referee.

1. **446 Daily FHWA Sample**
   These samples have been required by the FHWA for some time for the purpose of monitoring the asphalt plant testing. The daily nuclear asphalt binder content on a properly offset gauge and only one extraction for gradation per week are necessary to meet FHWA requirements. In order to accomplish this, three plate samples will need to be taken per Supplement 1035 from the project or sufficient sample from the plant or hopper. Initial and final offsets may be determined as specified above. The intent of the sample is to compare the test result to the corresponding contractor test on the daily TE-199. Doing so will help check for possible poor contractor testing. In the past we looked for differences in AC of +/- 0.3% two days in a row before investigating. This will still be a good starting point but with using the nuclear gauge the tolerance could become tighter.

2. **Run a minimum of (1) MSG split sample and (1) contractor AC Gauge sample each week.** (Rice comparisons to be within 0.012, 0.012 to 0.020 as an alarm and investigate and above 0.020 – confirm, stop production and/or investigate. If most comparisons are between 0.012 and 0.020 do not allow production to continue until resolved.)

3. **Run a minimum of (1) set of pills produced by the contractor to check for air void compliance each week.** (air voids within 0.2% are OK, between 0.2% and 0.3% OK if not consistently different over multiple tests and above 0.3% confirm, stop production and investigate.)

4. **Observe a minimum of (1) set of QC tests in the first 2 days of production.**
5. Verify test procedures at least once a week.

6. Verify plant AC and moisture settings at least once a week. (monitor form)

The specification discusses split sample retention. The AC Gauge sample does not have to be an actual split sample. Instead the contractor will hold all AC Gauge samples in the pan for two days. If an AC Gauge sample is not picked up after two days it can be dumped and the pan reused.

Besides more accurate air voids results because of the MSG testing other useful information can be derived from the MSG testing. However, a discussion of the MSG testing and control in detail is necessary so as to not confuse MSG test results and their indication of production quality versus AC tests, gradations and air voids and what they show about mix quality.

The Rice (MSG) test is an accurate test of the mix maximum specific gravity. A change in Rice values indicates primarily either an asphalt binder content change, abnormal gradation change, a blend change or an aggregate gravity change. Of course more than one of these things can change at the same time. Initially, for our purposes, the most important thing we can learn from all the extra Rice testing is the possibility of an asphalt binder content change. To accomplish using the test in a meaningful way it was decided to look at a band of +/- .012. This value, in general, could indicate a potential asphalt binder content change of +/- 0.3%.

However, the specification is misleading at this point as to the intent of using the +/- .012. The confusion is because blend, aggregate gravity, or even sample quality can make individual Rice results go outside of the +/- .012 and the asphalt binder content may still be OK. The +/- .012 is not a magical number. It is only useful in so far as indicating a potential asphalt binder content change.

A proper use of the Rice test in the revised QC specification should be as follows. If an individual Rice value goes outside the +/- 0.12 the contractor must contact the District Engineer of Tests. At that point the District Engineer of Tests will ask what corresponding AC gauge, gradation and air voids results are. If there is indication of an asphalt binder content change or other change thru the AC test or air voids test then corrective action must be taken. Regardless, the contractor should immediately test a new Rice sample and again report the results to the District Engineer of Tests. In many cases no asphalt binder content or air voids change will be indicated by the AC and voids testing.
This simply indicates that something else may have happened such as a poor sample, bad test or a trend change in the aggregate specific gravities.

Should the District Engineer of Tests be satisfied that asphalt binder content, air voids and gradation are OK, but a trend toward the high or low side of the band is confirmed by several Rice test results the District Engineer of Tests can allow the contractor to re-establish an MTD. The MTD should be based upon test results representative of the new trend and proceed with the +/- 0.12 from that point.

Finally, if no other reasons can be found for a trend in Rice tests changing it can be reasonably assumed aggregate gravities are changing. Should this progress to an extreme the contractor will have difficulty controlling air voids. At some point the contractor will have to be told to correct the situation thru a stockpile change and / or redesign. Re-establishing the MTD is useless at this point until the mix properties are back in control.

d) Procedure for Establishing the MTD (6/28/05)

By specification, the contractor shall determine the MSG by the rice method (corrected for moisture content) once per test series. When the range of three consecutive MSG determined is equal to or less than 0.020, these three determinations shall be averaged to determine the maximum theoretical Density (MTD). The following must also be met on the Rice test, to be accepted for establishing the MTD.

The pay sieves must be within the tolerances of (½ +/-6%, #4 +/-5% and #8 +/-4%)

The Fines / Asphalt ratio shall be maintained so no F/A Ratio is less than 0.5 or greater than 1.1

The asphalt binder content must be +/-0.5% (corrected for moisture) from the design.

No Air void determination shall be less than 2.0% or greater than 6.0%

If any of the above requirements are not met, the Rice can be used for determining the air void content but not for establishing the MTD.

e) Use of Mineral Filler in JMF’s (6/28/05)
It has been requested of ODOT to look into a policy for the use of mineral filler as an addition to asphalt concrete mixes for the purpose of controlling air voids or F/A ratio.

Mineral filler will be used in mixes in the following manner. A design in which it is desired to use mineral filler will be submitted to the OMM with the mineral filler incorporated into the mix up to 2% of blended aggregates. Calculation of the VMA will be done as if no mineral filler has been added to the mix. The percent mineral filler should be added to the percent of fine aggregate for calculation of VMA. In extreme cases this will cause a 0.1% change in VMA but will eliminate the question of specific gravity of the mineral filler.

Adjustment of the JMF to meet air voids or F/A ratio specified limits for production shall follow the 441.04 field adjustment procedures except for the following procedure:

After an attempt to adjust gradation to meet air voids or F/A ratio according to 441.04 it is found the mix is still out of the specified limits a mix that has an approved incorporation of mineral filler may be adjusted by changing the amount of mineral filler up to +/- 1%. If this change does not solve the air voids or F/A ratio problem then JMF a re-design is required.

Following the mineral filler adjustment a rice test must be performed to show conformance to the MTD within .020 provided an MTD has been established. Mineral filler must be added to the mix separately from its own dry storage. Provision for accurate proportioning is required.

f) District Asphalt JMF Re-approval Process

1) Note received date.
2) Check plans and or proposal/supplemental spec 800 for any particular notes that may apply
3) Check CMS for JMF validity and is within the 2 (3) year time frame.
4) Materials Codes checked to see if correct.
5) Aggregate Producers checked for 1069 program and any group list changes.
6) If 442, sample course gravel aggregate for crush count if not known, sample fine aggregate for FAA if not on the FAA web site. Only sample what you know will be used on the project.
7) Check for approved binder
8) If JMF is using RAP is the source listed in remarks and does RAP pile need checked?
9) Precursory review JMF agg percentages, liquid content percentages, voids etc
10) Looked at for problems that may have occurred on previous project
11) Update PBOM and enter conversion factor when enough detail of what is actually being used is known.
12) Send approval letter to contractor, copy project inspector and construction and others as district desires or use the contractor request letter, attach the BCJMF printout, send out and notify the contractor.

Additions to this list may be made as experience dictates is necessary.

g) Procedure for Isolating Causes of Test Comparison Problems

This method will apply to any test where technician procedure or technique is key to an accurate test result. This method should be used when District comparison tests are outside acceptable tolerances when compared to the contractor QC test. Typically monitoring or QA samples split or obtained from QC samples are what are tested for comparison. The specification and this section of the S&T Manual will spell out requirements for sampling frequency and type. For sake of simplicity the MSG or Rice test will be used as an example. All testing must be documented!

1) When a comparison problem is noted first contact the QC Manager and plant technician. Most of the time this solves the problem. Immediately take a new comparison sample upon notification and test.

2) If a repeated history of poor comparison with a given project, technician or plant equipment exists take ALL monitor Rice samples from the QC lab to the District. Stopping or continuing mix production will depend on the circumstances. Run more than one sample to develop a record of the issue. It is also useful to have a different District technician run the same sample to verify results. Notify the QC Manager.

3) At this point a specific investigation should be conducted as follows:
   a. Do a cursory check of the District and Plant lab equipment: temperatures, pressures, hoses, anything obvious. If problems are found correct and re-run samples on both equipment to verify. End the investigation and deal with future comparison issues (on this project or other projects with the same QC technician or plant) as below. If no problems are found use the below procedure to isolate the problem cause.
   b. Choose one of the Rice samples already run with known results from the District and QC lab. Have the District and QC technicians (both technicians must be the same ones who ran the previous tests in question) run the same sample at the QC and District labs. This should be done together (all personnel present) at both labs and the District should have a third person present to help observe procedures. The contractor can have any additional person present they want. Record
all results. Email the results to the Central Laboratory.

c. Several conclusions can be reached from this special testing: 1) Good comparison, 2) Differences between lab equipment but good technician comparison, or 3) Differences between technicians. Discuss with the Central Lab what constitutes good comparisons for technicians vs labs.

   i. Good comparison between technicians and labs with the original District test result. This means the equipment is sound and the technicians are capable of good test technique. However, this also means the contractor QC technician incorrectly performed the original test. Please inform the QC manager and the technician in writing of the results and state in the letter that a copy of the letter will be placed in the technician file in Central Office. Send a letter copy to the Central Lab for filing in the technician certification file.

   ii. Good comparison between technicians and labs but not with the original District test result. This means the equipment is sound and the technicians are capable of good test technique. However, this also means the District technician incorrectly performed the original test (unless an equipment problem was found previously). Review the technician procedure. Have the technician come to Columbus for retraining in the Central Lab if necessary.

   iii. Differences between lab equipment. Contact the Central Lab to send someone to investigate the equipment.

   iv. Differences between technicians. Send the same sample to the Central Lab to run. The Central Lab conclusion, after a review of available information, will be final. Send the QC technician or District technician to the Central Lab for a review of procedures and retraining.

   v. There may be a rare possibility of both items iii. and iv. happening. If so carry out instruction for both items.
3) **Asphalt Binder Items (6/28/05)**

   a) **Asphalt Binder Sample Containers**

   Compliance with AASHTO T40-78 (1986) "SAMPLING BITUMINOUS MATERIALS" requires that the following materials be sampled into appropriate containers for shipment to the Laboratory.

   **Metal Pint (Friction Top) - PG Binder, Asphalt Concrete Underseal (M-238), Waterproofing Asphalt, Bituminous Pipe Joint Filler**

<table>
<thead>
<tr>
<th>PLASTIC QUART (SCREW TOP)</th>
<th>METAL QUART (SCREW TOP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SS-1</td>
<td>MC-30</td>
</tr>
<tr>
<td>SS-1H CRS-2</td>
<td>MC-70</td>
</tr>
<tr>
<td>RS-1</td>
<td>MC-250</td>
</tr>
<tr>
<td>RS-2 CMS-2</td>
<td>MC-800</td>
</tr>
<tr>
<td>MS-1</td>
<td>MC3000</td>
</tr>
<tr>
<td>MS-2</td>
<td>Asphalt Primer</td>
</tr>
<tr>
<td>MS-3</td>
<td>Primer-20</td>
</tr>
<tr>
<td>MS-2H HFMS-1</td>
<td>RC-70</td>
</tr>
<tr>
<td>MWS-60 HFMS-2</td>
<td>RC-250</td>
</tr>
<tr>
<td>MWS-90 HFMS-2H</td>
<td>RC-800</td>
</tr>
<tr>
<td>MWS-150 HFMS-2S</td>
<td>RC-3000</td>
</tr>
<tr>
<td>MWS-300 HFRS-2</td>
<td></td>
</tr>
</tbody>
</table>

   Distribution of this requirement should include all personnel required to sample or observe sampling of the above items. It should also be noted that each container should be full and the lid be applied securely.
b) Sampling PG Binders

Increased check sampling has brought out some issues with proper sampling procedures. Sample integrity is critical when deductions are to be incurred.

It is common for monitors to hand a plant person cans for taking samples because of plant operational issues etc. That is not a problem BUT here are the only ways this is acceptable.

1) From this point forward TWO sample cans of each grade must be taken for each check sample desired and sent to Columbus. These will be under ONE sample ID. If we see a failure we will contact you to take new samples to determine the extent of the problem. We will also test the 2nd sample to verify a failure to meet the deduction policy.

2) The cans must be labeled as to grade BEFORE the sample is taken. (Do your monitors have permanent markers for labeling?)

3) The monitor must witness the samples being taken from a tank or truck. (If you have new personnel who have no clue about how to take a tank sample then send them to us for training or train them yourself.)

4) The monitor must witness the handling and control of the samples until he takes possession. The monitor must take immediate possession of the samples.

5) If the monitor has any question about the proper labeling of a sample, handling of a sample or integrity of a sample throw it away and take another one.

6) The monitor must hand deliver the sample to the district lab ASAP for processing and sending to Columbus.

c) Taking a Liquid Binder Sample

There are four critical steps to having a legit sample.

1) Use only a clean container. Use only containers as described in Appendix J, Section 3a of the Sampling and Testing Manual at http://www.dot.state.oh.us/testlab

2) When sampling from a valve drain 1 gallon of material into a separate container and have the contractor discard. The ASTM language below describes this for valve sampling. Dip sampling described below does not require the 1 gallon disposal. Take sample (s).

From ASTM D140-01

10. Sampling from Tank Cars, Vehicle Tanks, Distributor Trucks or Recirculating Storage Tanks
10.1 The sample may be taken from the sample valve or tap if the tanks are provided with them. When such sampling devices are required, they are to be built into the tank itself. A sampling device of this type is shown in Fig. 1. Before the sample is taken, 4 L (1 gal) shall be drawn from the sample valve and discarded.

10.2 Samples of liquid materials and materials made liquid by heating may be taken by the dip method using a clean wide-mouth or friction-top can in a suitable holder as shown in Fig. 4. A clean container must be used to take each sample, and the material sampled shall then be transferred to another new and clean container for retention or testing sample.

3) Properly label the container with material type and amount represented as well as all other required data on forms and required per this manual.

4) Maintain custody of the sample(s) from beginning to end and immediately send to OMM for test.
Standard Method of Test for

Mechanical Analysis of Extracted Aggregate

AASHTO Designation: T 30-10

1. SCOPE

1.1 This method covers a procedure for the determination of the particle-size distribution of fine and coarse aggregates extracted from hot mix asphalt (HMA), using sieves with square openings.

1.2 The values stated in SI units are to be regarded as the standard.

2. REFERENCED DOCUMENTS

2.1 AASHTO Standards:
- M 92, Wire-Cloth Sieves for Testing Purposes
- M 231, Weighing Devices Used in the Testing of Materials
- T 164, Quantitative Extraction of Asphalt Binder from Hot Mix Asphalt (HMA)
- T 255, Total Evaporable Moisture Content of Aggregate by Drying
- T 308, Determining the Asphalt Binder Content of Hot Mix Asphalt (HMA) by the Ignition Method

2.2 ASTM Standard:
- C 670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

3. SIGNIFICANCE AND USE

3.1 This method is used to determine the grading of aggregates extracted from HMA. The results are used to determine compliance of the particle-size distribution with applicable specification requirements and to provide necessary data for control of the production of various aggregates to be used in HMA.

4. APPARATUS

4.1 The balance shall have sufficient capacity, be readable to 0.1 percent of the sample mass or better, and conform to M 231.

4.2 Sieves—The sieve cloth shall be mounted on substantial frames constructed in a manner that will prevent loss of material during sieving. The sieve cloth and standard sieve frames shall conform to the requirements of M 92. Nonstandard sieve frames shall conform to the requirements of M 92 as applicable.
4.3 Mechanical Sieve Shaker—A mechanical sieving device, if used, shall create motion of the sieves to cause the particles to bounce, tumble, or otherwise turn so as to present different orientations to the sieving surface. The sieving action shall be such that the criterion for adequacy of sieving described in Section 6.7 is met in a reasonable time period.

Note 1—Use of a mechanical sieve shaker is recommended when the size of the sample is 20 kg (44 lb) or greater, and may be used for smaller samples, including fine aggregate. Excessive time (more than approximately 10 min) to achieve adequate sieving may result in degradation of the sample. The same mechanical sieve shaker may not be practical for all sizes of samples, since the large sieving area needed for practical sieving of a large nominal size coarse aggregate very likely could result in loss of a portion of the sample if used for a smaller size of coarse aggregate or fine aggregate.

4.4 Oven—An oven of sufficient size, capable of maintaining a uniform temperature of 110 ± 5°C (230 ± 9°F).

4.5 Wetting Agent—Any dispersing agent, such as Calgon, Joy, or other detergent that will promote separation of the fine materials.

4.6 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.

5. SAMPLE

5.1 The sample shall consist of the entire lot or sample of aggregate obtained according to T 164 or T 308 from which the binder material has been extracted.

6. PROCEDURE

6.1 Sample:

6.1.1 The sample shall be dried, if necessary, until further drying at 110 ± 5°C (230 ± 9°F) does not alter the mass by more than 0.1 percent, the precision of weighing. The total mass of aggregate in the HMA being tested is the sum of the mass of the dried aggregate and the mineral matter contained in the extracted asphalt binder. The latter is to be taken as the sum of the mass of ash in the extract and the increase in mass of the filter element as determined in T 164.

6.1.2 Determine and record the mass of the sample to the nearest 0.1 g. This mass shall agree with the mass of aggregate remaining after ignition (Mf from T 208) within 0.1 percent of Mf for an aggregate sample obtained from T 308. If the variation exceeds 0.1 percent, the results of this test should not be used for acceptance purposes.

6.2 The test sample shall be placed in a container and covered with water. Add a sufficient amount of wetting agent to assure a thorough separation of the material finer than the 75-μm (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. The quantity will depend on the hardness of the water, the quality of the detergent, and the agitation process. Excessive suds may overflow the sieves and carry some material with them. The contents of the container shall be agitated vigorously and the wash water immediately poured over a nest of two sieves consisting of a 2.00- or 1.18-mm (No. 10 or No. 16) sieve superimposed on a 75-μm (No. 200) sieve. The use of a large spoon to stir and agitate the aggregate in the wash water has been found to be satisfactory.

TS-25
T 30-2
4ASHTO
123
The use of a mechanical apparatus to perform the washing operation is allowable, providing mechanical wash does not degrade the sample. 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 75-µm (No. 200) sieve.

6.3

The agitation shall be sufficiently vigorous to result in the complete separation of all particles finer than the 75-µm (No. 200) sieve from the coarse particles and bring them into suspension in order that they may be removed by decantation of the wash water. Care should be taken to avoid, as much as possible, the decantation of the coarse particles of the sample. The operation shall be repeated until the wash water is clear.

6.4

All material retained on the nested sieves shall be returned to the container. The washed aggregate in the container shall be dried to constant mass per T 255, and weighed to the nearest 0.1 percent.

6.5

The aggregate shall then be sieved over sieves of various sizes required by the specification covering the HMA, including the 75-µm (No. 200) sieve. Nest the sieves in order of decreasing size of opening from top to bottom and place the sample on the top sieve. Agitate the sieves by a mechanical apparatus for a sufficient period, established by trial or checked by measurement on the actual test sample, to meet the criterion for adequacy of sieving described in Section 6.7.

6.6

Limit the quantity of material on a given sieve so that all particles have opportunity to reach sieve openings a number of times during the sieving operation. For sieves with openings smaller than 4.75 mm (No. 4), the mass retained on any sieve at the completion of the sieving operation shall not exceed 6 kg/m² (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 × (sieve opening in mm) × (the sieving surface area in m²). In no case shall the mass be so great as to cause permanent deformation of the sieve cloth.

Note 2—The 6 kg/m² (4 g/in.²) amounts to 200 g for the usual 203-mm (8-in.) diameter sieve. The amount of material retained on a sieve may be regulated by (1) the introduction of a sieve with larger openings immediately above the given sieve or (2) testing the sample in a number of increments.

6.7

Continue sieving for a sufficient period and in such manner that, after completion, not more than 0.5 percent by mass of the total sample passes any sieve during 60 s of continuous hand-sieving performed as follows: Hold the individual sieve, provided with a snug-fitting pan and cover, in a slightly inclined position in one hand. Strike 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. In determining the adequacy of sieving for sizes larger than the 4.75-mm (No. 4) sieve, limit the material on the sieve to a single layer of particles. If the size of the mounted testing sieves makes the described sieving motion impractical, use 203-mm (8-in.) diameter sieves to verify the adequacy of sieving.

7. CALCULATIONS

7.1

The mass of material passing each sieve and retained on the next and the amount passing the 75-µm (No. 200) sieve shall be recorded. The summation of these various masses must check the dried mass after washing within 0.2 percent of the total mass. The mass of dry material passing the 75-µm (No. 200) sieve by dry sieving shall be added to the mass removed by washing, and if applicable, the mass of mineral matter in the asphalt binder, in order to obtain the total passing the 75-µm (No. 200) sieve. The masses of fractions retained on the various sieves and the total passing the 75-µm (No. 200) sieve shall be converted to percentages by dividing each by the total mass of aggregate in the HMA from Section 6.1.
7.2 For aggregate samples obtained from T 308, apply the aggregate correction factor, as required in T 308, to obtain the final total passing percentages.

8. REPORT

8.1 The results of the sieve analysis shall be reported as follows: (a) total percentages passing each sieve; or (b) total percentages retained on each sieve; or (c) percentages retained between consecutive sieves, depending upon the form of the specifications for the use of the material being tested. Percentages shall be reported to the nearest whole number, except for the percentage passing the 75-μm (No. 200) sieve, which shall be reported to the nearest 0.1 percent.

9. PRECISION AND BIAS

9.1 Precision—The estimates of precision for this test method are listed in Table 1. The estimates are based on the results from the AASHTO Materials Reference Laboratory Proficiency Sample Program, with testing conducted by T 30. The data are based on the analyses of the test results from 47 to 190 laboratories that tested 17 pairs of proficiency test samples (Samples No. 1 through 34). The values in the table are given for different ranges of total percentage of aggregate passing a sieve.

Table 1—Precision

<table>
<thead>
<tr>
<th>Total Percentage of Material Passing a Sieve</th>
<th>Standard Deviation (1s) Percent</th>
<th>Acceptable Range of Two Results—(d2s) Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excluded aggregate 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single Operator Precision</td>
<td></td>
<td></td>
</tr>
<tr>
<td>95 to 100</td>
<td>0.49</td>
<td>1.4</td>
</tr>
<tr>
<td>40 to 94</td>
<td>1.06</td>
<td>3.9</td>
</tr>
<tr>
<td>25 to 39</td>
<td>0.65</td>
<td>1.8</td>
</tr>
<tr>
<td>10 to 24</td>
<td>0.46</td>
<td>1.3</td>
</tr>
<tr>
<td>5 to 9</td>
<td>0.29</td>
<td>0.8</td>
</tr>
<tr>
<td>2 to 4</td>
<td>0.21</td>
<td>0.6</td>
</tr>
<tr>
<td>0 to 1</td>
<td>0.17</td>
<td>0.5</td>
</tr>
<tr>
<td>Multilaboratory Precision</td>
<td></td>
<td></td>
</tr>
<tr>
<td>95 to 100</td>
<td>0.57</td>
<td>1.6</td>
</tr>
<tr>
<td>40 to 94</td>
<td>1.24</td>
<td>3.5</td>
</tr>
<tr>
<td>25 to 39</td>
<td>0.84</td>
<td>2.4</td>
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<tr>
<td>10 to 24</td>
<td>0.81</td>
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<tr>
<td>5 to 9</td>
<td>0.56</td>
<td>1.6</td>
</tr>
<tr>
<td>2 to 4</td>
<td>0.43</td>
<td>1.2</td>
</tr>
<tr>
<td>0 to 1</td>
<td>0.32</td>
<td>0.9</td>
</tr>
</tbody>
</table>

* These numbers represent, respectively, the (1s) and (d2s) limits described in ASTM C 670.

** The precision estimates are based on aggregates with nominal maximum sizes of 19 mm (3/4 in.) to 9.5 mm (5/32 in.).

9.2 Bias—This test method has no bias since the values determined can only be defined in terms of this test method.
Standard Test Method for Mechanical Size Analysis of Extracted Aggregate

This standard is issued under the fixed designation D 5444; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers a procedure for determination of the particle size distribution of fine and coarse aggregates extracted from bituminous mixtures using sieves with square openings.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

D2172 Test Methods for Quantitative Extraction of Bitumen From Bituminous Paving Mixtures

D303 Test Method for Asphalt Content of Hot-Mix Asphalt by Ignition Method

E11 Specification for Wire Cloth and Sieves for Testing Purposes

2.2 AASHTO Standard:

AASHTO Test Method T30 Mechanical Analysis of Extracted Aggregate

3. Significance and Use

3.1 This test method is used to determine the grading of aggregates extracted from bituminous mixtures. The results are used to determine compliance of the particle size distribution with applicable specifications requirements, and to provide necessary data for control of the production of various aggregates to be used in bituminous mixtures.

4. Apparatus

4.1 Balances, or scales, readable to 0.1 g and accurate to 0.1 g or 0.1% of the test load, whichever is greater, at any point within the range of use.

4.2 Sieves, with square openings, mounted on substantial frames constructed in a manner that will prevent the loss of materials during sieving. Suitable sieve sizes shall be selected to furnish the information required by the specifications covering the material to be tested. The woven wire cloth sieves shall conform to the requirements of Specification E11.

4.3 Mechanical Sieve Shaker—If used, it shall impart a vertical, or lateral and vertical, motion to the sieve, causing the particles thereon to bounce and turn so as to present different orientations to the sieving surface. The sieving action shall be such that the criterion for adequacy of sieving described in 6.8 is met in a reasonable time period.

4.4 Oven, of appropriate size, capable of maintaining a uniform temperature of 110 ± 5°C (230 ± 9°F).

4.5 Container—A pan or vessel of a size sufficient to contain the sample covered with water and to permit vigorous agitation without loss of any of the sample or water.

5. Sample

5.1 The sample shall consist of the entire sample of aggregate from Test Method D2172 or Test Method D3037.

5.1.1 Aggregate extracted by the ignition method in Test Method D3037 shall not be used for gradation analysis if the correction factor obtained in Test Method D3037 is greater than 1.0 (see Note 1).

5.2 The size of the test sample shall be governed by the nominal maximum aggregate size and shall conform to the mass requirements shown in Table 1.

<table>
<thead>
<tr>
<th>Size of Sample</th>
<th>Minimum Mass of Sample, kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.79 (No. 4)</td>
<td>0.5</td>
</tr>
<tr>
<td>8.5 (No. 6)</td>
<td>1</td>
</tr>
<tr>
<td>12.5 (No. 8)</td>
<td>1.5</td>
</tr>
<tr>
<td>18.0 (No. 10)</td>
<td>2</td>
</tr>
<tr>
<td>25.0 (No. 12)</td>
<td>3</td>
</tr>
<tr>
<td>37.5 (No. 16)</td>
<td>4</td>
</tr>
</tbody>
</table>

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1. This test method is under the jurisdiction of ASTM Committee D04 on Road and Paving Materials and is the direct responsibility of Subcommittee D04.05 on Aggregate Tests.
3. For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page at the ASTM website.
6. Procedure

6.1 Dry the sample at 110 ± 5°C (250 ± 9°F) to constant weight. Determine the weight to the nearest 0.1% of the sample weight. The total weight of aggregate in the bituminous mixture being tested is the sum of the weights of the dried aggregates and the mineral material contained in the extracted bitumen. When using Test Method D 2172, the latter is to be taken as the sum of the weight of ash in the extract and the increase in weight of the filter element as determined in the test method.

6.2 After drying and weighing the test sample, place it in a container and cover it with water. Add a sufficient amount of wetting agent to ensure a thorough separation of the material finer than the 75-µm sieve from the coarser particles (see Note 2). The contents of the container shall be agitated vigorously and the washwater poured immediately over a nest of two sieves consisting of a 2.00 or 1.18-mm sieve superimposed on a 75-µm sieve. The use of a large spoon to stir and agitate the aggregate in the washwater has been found satisfactory.

Note 2—Wetting agents may include any dispersing agent such as a liquid detergent, or a soap, that will promote the separation of fine material. There should be enough wetting agent to produce a small amount of suds when the sample is agitated. The quantity of wetting agent will depend on the hardness of the water and quality of the agent. Excessive suds may overflow the sieves and carry some material with them.

6.3 The agitation shall be sufficiently vigorous to result in complete separation from the coarse particles of all particles finer than the 75-µm sieve and to bring them into suspension so that they may be removed by decantation of the washwater. Take care to avoid decantation of the coarse particles of the sample as much as possible. Repeat the operation until any wetting agent used is removed and the washwater is clear.

6.4 Return all material retained on the nested sieves to the container. Dry the washed aggregate in the container to constant weight at a temperature not to exceed the mixture laboratory compaction temperature +4°F (+5°C) and not less than 221°F (105°C), and weigh to the nearest 0.1% of the original dry weight of the sample.

6.5 Then sieve the aggregate over sieves of the various sizes required by the specification covering the mixture, including the 75-µm sieve. Record the weight of material passing each sieve and retained on the next and the amount passing the 75-µm sieve. The summation of these various weights must check the dried weight after washing within 0.2% of the total weight. Add the weight of dry material passing the 75-µm sieve by dry sieving to the weight of mineral matter in the bitumen and the weight removed by washing in order to obtain the total passing the 75-µm sieve. If it is desired to check the weight of material washed through the 75-µm sieve, the washwater may be evaporated to dryness or filtered through a tared filter paper that is dried and weighed subsequently. Convert the weights of fractions retained on the various sieves and the total passing the 75-µm sieve to percentages by dividing each by the total weight of aggregate in the bituminous mixture from 6.1.

6.6 Nest the sieves in order of decreasing size of opening from top to bottom, and place the sample on the top sieve. Agitate the sieves by hand or by mechanical apparatus for a sufficient period, established by trial or checked by measurement on the actual test sample, to meet the criterion for adequacy of sieving described in 6.7.

6.7 Limit the quantity of material on a given sieve so that all particles have the opportunity to reach sieve openings a number of times during the sieving operation. For sieves with openings smaller than 4.75 mm (No. 4), the weight retained on any sieve at the completion of the sieving operation shall not exceed 6 kg/m² (4 g/in.²) of sieving surface. For sieves with openings 4.75 mm (No. 4) and larger, the weight in kg/m² of sieving surface shall not exceed the product of 2.5 × (sieve opening in mm). In no case shall the weight be so great as to cause permanent deformation of the sieve cloth.

6.8 Continue sieving for a sufficient period and in such manner that, after completion, not more than 0.5% by weight of the total sample passes any sieve during 1 min of continuous hand sieving performed as follows: hold the individual sieve, provided with a snug-fitting pan and cover, in a slightly inclined position in one hand. Strike the side of the sieve sharply and with an upward motion against the inclined position in one hand. Strike the side of the sieve sharply and with an upward motion against the heel of the other hand at a rate of approximately 150 times per minute, turning the sieve approximately one-sixth of a revolution at intervals of approximately 25 strokes. In determining the efficiency of sieving for sizes larger than the 4.75-mm (No. 4) sieve, limit the materials on the sieve to a single layer of particles. If the size of the mounted testing sieves makes the described sieving motion impractical, use 203-mm (8-in.) diameter sieves to verify the efficiency of sieving.

7. Calculation

7.1 Calculate the results of the sieve analysis as follows: (1) total percentages passing each sieve, (2) total percentages retained on each sieve, or (3) percentages retained between consecutive sieves, depending on the form of the specifications for use of the material under test. Calculate percentages to the nearest 0.1%.

8. Report

8.1 Depending on the form of the specification for use of the material under test, report the following information:

8.1.1 Total percentage of material passing each sieve, or
8.1.2 Total percentage of material retained on each sieve, or
8.1.3 Percentage of material retained between consecutive sieves.

8.2 Report percentages to the nearest whole number except for the percentage passing the 75-µm (No. 200) sieve, which shall be reported to the nearest 0.1%.

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*Information presented at the Annual Symposium of the "International Center for Aggregate Research," April 2004, Denver, CO.*
Standard Method of Test for

Theoretical Maximum Specific Gravity and Density of Hot Mix Asphalt (HMA)

AASHTO Designation: T 209-10

1. SCOPE

1.1. This test method covers the determination of the theoretical maximum specific gravity and density of uncompacted hot mix asphalt (HMA) at 25°C (77°F).

Note 1—The precision of the method is best when the procedure is performed on samples that contain aggregates that are completely coated. In order to assure complete coating, it is desirable to perform the method on samples that are close to the optimum asphalt binder content.

1.2. The values stated in SI units are to be regarded as the standard.

1.3. This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. REFERENCED DOCUMENTS

2.1. AASHTO Standards:

- M 231, Weighing Devices Used in the Testing of Materials
- PP 57, Establishing Requirements for and Performing Equipment Calibrations, Standardizations, and Checks
- R 47, Reducing Samples of Hot Mix Asphalt (HMA) to Testing Size
- T 168, Sampling Bituminous Paving Mixtures

2.2. ASTM Standards:

- C 670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
- D 4311, Standard Practice for Determining Asphalt Volume Correction to a Base Temperature

3. TERMINOLOGY

3.1. Definitions:

3.1.1. density, as determined by this test method—the mass of a cubic meter of the material at 25°C (77°F) in SI units, or the mass of a cubic foot of the material at 25°C (77°F) in inch-pound units.

3.1.2. residual pressure, as employed by this test method—the pressure in a vacuum vessel when vacuum is applied.
3.1.3. **specific gravity, as determined by this test method**—the ratio of a given mass of material at 25°C (77°F) to the mass of an equal volume of water at the same temperature.

4. **SUMMARY OF TEST METHOD**

4.1. A weighed sample of oven-dry HMA in the loose condition is placed in a tared vacuum container. Sufficient water at a temperature of 25 ± 0.5°C (77 ± 0.9°F) is added to completely submerge the sample. Vacuum is applied for 15 ± 2 min to gradually reduce the residual pressure in the vacuum container to 3.7 ± 0.3 kPa (27.5 ± 2.5 mm Hg). At the end of the vacuum period, the vacuum is gradually released. The volume of the HMA sample is obtained either by immersing the vacuum container with the sample into a water bath and determining the mass (Section 13.1) or by filling the vacuum container level full of water and determining the mass in air (Section 13.2). At the time of weighing, the temperature is measured as well as the mass. From the mass and volume measurements, the specific gravity or density at 25°C (77°F) is calculated. If the temperature employed is different than 25°C (77°F), an appropriate correction is applied.

5. **SIGNIFICANCE AND USE**

5.1. The theoretical maximum specific gravities and densities of HMA are intrinsic properties whose values are influenced by the composition of the mixtures in terms of types and amounts of aggregates and asphalt materials.

5.1.1. These properties are used to calculate percent air voids in compacted HMA.

5.1.2. These properties provide target values for the compaction of HMA.

5.1.3. These properties are essential when calculating the amount of asphalt binder absorbed by the internal porosity of the individual aggregate particles in HMA.

6. **APPARATUS**

6.1. Follow the procedures for performing equipment calibrations, standardizations, and checks found in PP 57.

6.2. **Vacuum Container**

6.2.1. The vacuum containers described must be capable of withstanding the full vacuum applied, and each must be equipped with the fittings and other accessories required by the test procedure being employed. The opening in the container leading to the vacuum pump shall be covered by a piece of 0.075-mm (No. 200) wire mesh to minimize the loss of fine material.

6.2.2. The capacity of the vacuum container should be between 2000 and 10,000 mL and depends on the minimum sample size requirements given in Section 7.2. Avoid using a small sample in a large container.

6.2.3. **Vacuum Bowl**—Either a metal or plastic bowl with a diameter of approximately 180 to 260 mm (7 to 10 in.) and a bowl height of at least 160 mm (6.3 in.) equipped with a transparent cover fitted with a rubber gasket and a connection for the vacuum line.

6.2.4. **Vacuum Flask for Mass Determination in Air Only (Section 13.2)**—A thick-walled volumetric glass flask and a rubber stopper with a connection for the vacuum line.

6.2.5. **Pycnometer for Mass Determination in Air Only**—A glass, metal, or plastic pycnometer.
6.3. **Balance**—A balance conforming to the requirements of AASHTO M 231, Class G 2. The balance shall be standardized at least every 12 months.

6.3.1. For the mass determination-in-water method (Section 13.1), the balance shall be equipped with a suitable apparatus and holder to permit determining the mass of the sample while suspended below the balance. The wire suspending the holder shall be the smallest practical size to minimize any possible effects of a variable immersed length.

6.4. **Vacuum Pump or Water Aspirator**—Capable of evacuating air from the vacuum container to a residual pressure of 4.0 kPa (30 mm Hg).

6.4.1. When a vacuum pump is used, a suitable trap of one or more filter flasks, or equivalent, shall be installed between the vacuum vessel and vacuum source to reduce the amount of water vapor entering the vacuum pump.

6.5. **Vacuum Measurement Device**—Residual pressure manometer or vacuum gauge to be connected directly to the vacuum vessel and capable of measuring residual pressure down to 4.0 kPa (30 mm Hg) or less (preferably to zero). The gauge shall be standardized at least annually and be accurate to 0.1 kPa (1 mm Hg). It shall be connected at the end of the vacuum line using an appropriate tube and either a "T" connector on the top of the vessel or a separate opening (from the vacuum line) in the top of the vessel to attach the hose. To avoid damage, the manometer shall not be situated on top of the vessel.

**Note 2**—A residual pressure of 4.0 kPa (30 mm Hg) absolute pressure is approximately equivalent to a 97 kPa (730 mm Hg) reading on a vacuum gauge at sea level.

**Note 3**—Residual pressure in the vacuum container, measured in millimeters of mercury, is the difference in the height of mercury in the Torricellian vacuum leg of the manometer and the height of mercury in the other leg of the manometer that is attached to the vacuum container.

**Note 4**—An example of a correct arrangement of the testing equipment is shown in Figure 1. In the figure, the purpose of the train of small filter flasks is to trap water vapor from the vacuum container that otherwise would enter the oil in the vacuum pump and decrease the pump's ability to provide adequate vacuum. Insertion of a valve to isolate the line to each vacuum chamber can reduce wear on the bleeder valve atop each chamber and assist in tracing sealing leaks.

![Diagram of testing apparatus](image)

**Figure 1**—Example of Correct Arrangement of Testing Apparatus

6.6. **Bleeder Valve**—attached to the vacuum train to facilitate adjustment of the vacuum being applied to the vacuum container.

6.7. **Thermometric Device (Mass Determination in Air)**—A liquid-in-glass thermometer or other thermometric device, accurate to 0.5 °C (1 °F), of suitable range with subdivisions of 0.5 °C (1 °F). The thermometric device shall be standardized at the test temperature at least every 12 months.
6.8. Water Bath:

6.8.1. For vacuum bowls, a water bath capable of maintaining a constant temperature between 20 and 30°C (68 and 86°F) is required. (See Appendix X for a method for correcting the theoretical maximum specific gravity to 25°C (77°F) when measurements are made at temperatures other than 25°C (77°F).

6.8.2. Thermometric Device (Mass Determination in Water)—A liquid-in-glass thermometer or other thermometric device, accurate to 0.5°C (1°F) shall be used to measure the temperature of the water bath. The thermometric device shall be standardized at least every 12 months.

6.8.3. When using the mass determination-in-water technique (Section 13.1), the water bath must be suitable for immersion of the suspended container with its deaerated sample.

6.9. Drying Oven—A thermostatically controlled drying oven capable of maintaining a temperature of 135 ± 5°C (275 ± 9°F) or 105 ± 5°C (221 ± 9°F).

6.9.1. Thermometric Device—A liquid-in-glass thermometer or other thermometric device accurate to 3°C (5°F) shall be used to measure the temperature of the oven. The thermometric device shall be standardized at least every 12 months.

6.10. Protective Gloves—used when handling glass equipment under vacuum.

7. SAMPLING

7.1. Obtain the sample in accordance with T 168.

7.2. The size of the sample shall conform to the following requirements. Samples larger than the capacity of the container may be tested a portion at a time.

<table>
<thead>
<tr>
<th>Nominal Maximum Aggregate Size, mm</th>
<th>Minimum Sample Size, g</th>
</tr>
</thead>
<tbody>
<tr>
<td>37.5 or greater</td>
<td>4000</td>
</tr>
<tr>
<td>19 to 25</td>
<td>2500</td>
</tr>
<tr>
<td>12.5 or smaller</td>
<td>1500</td>
</tr>
</tbody>
</table>

8. STANDARDIZATION OF FLASKS, BOWLS, AND PYCNOMETERS

8.1. For the mass determination-in-water method (Section 13.1), standardize the vacuum bowls for temperature correction by determining the mass of each container when immersed in water over the range of water bath temperatures likely to be encountered in service (Figure 2).
Figure 2—Example Standardization Curve for Volumetric Flask

8.2. For the mass determination-in-air method (Section 13.2), standardize the volumetric flasks or pycnometers for temperature correction by determining the mass of the container when filled with water over the range of water bath temperatures likely to be encountered in service (Figure 3). When standardized at 25 ± 0.5°C (77 ± 0.9°F) designate this mass as D. Accurate filling may be ensured by the use of a glass cover plate.
Figure 3—Example Standardization Curve for Pycnometer

8.3. Standardize the large-size plastic pycnometer by accurately determining the mass of water required to fill it over a range of temperature from about 20 to 65°C (70 to 150°F), and construct a standardization curve of mass versus temperature as shown in Figure 3. Care should be taken to follow exactly the same procedure in standardization as in conducting a test.

8.3.1. The following filling procedure may be used for the model with a latched lid and vented stopper. The domed lid is latched in place and the pycnometer nearly filled with water. Leave about 50 mm (2 in.) empty. The release of air bubbles may be facilitated by applying vacuum and by dropping first one side then the other of the pycnometer about 10 mm (1/2 in.) above a hard, flat surface. This vacuum application and bubble release procedure should take about 10 min so that the temperature equilibrium between the shell and the water approximates that attained when performing a test. The final amount of water is then gently poured in until the level is about halfway up the neck. Any air bubbles caught against the dome that cannot be released by jarring or by swirling the water may be “pricked” or pushed to the surface with a bent wire or other suitable device. Insert the vented stopper using only enough force to just seat the stopper and immediately wipe the excess water off the top.

8.3.2. For the models with a quick-disconnect vacuum line and unlatched lid, the filling procedure is as follows. With the inlet valve closed, apply a vacuum of about 30 kPa (225 mm Hg). Open the inlet valve slowly letting water in until the level reaches 25 mm (1 in.) below the top of the dome and close the valve. Continue applying vacuum and release the bubbles by jarring and rapping the vessel with a rubber mallet. Slowly open the inlet valve and allow more water in until the water overflows into the aspirator (vacuum) line and then close the valve. This vacuum application and bubble release procedure should take about 10 min so that the temperature equilibrium between the shell and the water approximates that attained when performing a test. Disconnect the vacuum line by pulling it out at the quick-disconnect joint below the gauge.

8.3.3. Wipe the outside of the pycnometer dry, determine the mass of the full pycnometer and measure the water temperature.
Note 5—The shape of the standardization curve is a function of two opposing factors that can be rationally defined. As the temperature is increased, the container itself expands (adding mass—"Pycnometer" line in Figure 4) and the density of the contained water decreases (resulting in loss of mass—"Water" line in Figure 4). These relationships are shown in Figure 4 for a typical large-size pycnometer. The "Water" curve may be constructed by multiplying the volume at 25°C (77°F) by the difference between the density of water at 25°C (77°F), which is 0.9970, and the density of water at the standardization temperature (see Equation 1).

![Graph showing the relationship between temperature and mass](image)

**Figure 4—Effect of Change in Density of Water and Volume of Pycnometer with Change in Temperature**

Difference Due to Water Expansion = \( V_{25} (0.9970 - \Delta w) \)

Since \( V_{25} = W_{25} / 0.9970 \)

\[ V_{25} (0.9970 - \Delta w) \text{ reduces to } W_{25} \left(1 - \frac{\Delta w}{0.9970}\right) \]  

(1)

where:

- \( V_{25} \) = volume of water to fill a container at 25°C (77°F), cm³;
- \( W_{25} \) = mass of water to fill a container at 25°C (77°F), g; and
- \( \Delta w \) = density of water at the standardization temperature, Mg/m³.

The rate of change in capacity of the container due to thermal expansion of the pycnometer itself is essentially constant over the temperature range from 20 to 65°C (70 to 150°F). Thus, the "Pycnometer" line in Figure 4 can be drawn through the 0 at 25°C (77°F) point knowing only the slope of the straight line relationship. The slope can be established by averaging at least five standardization mass determinations at some elevated temperature, adding the loss due to water expansion and subtracting the mass at 25°C (77°F), \( W_{25} \), to give the gain in capacity due to expansion of the container. The difference in mass divided by the difference in temperature is the
slope of the “Pycnometer” line. For a polycarbonate pycnometer of about 13,500-mL capacity, the slope thus established was 2.75 g/°C (1.53 g/°F). This value is believed to be typical and reasonably constant.

The bending of the standardization curve (Figure 3) due to these offsetting thermal factors thus minimizes experimental error due to temperature effects in the normal working range, 25°C (77°F), for both the volumetric flask and the pycnometer containers. Defining the standardization curve makes it possible to correct for temperature, rather than “bringing the container and sample to temperature” thereby eliminating the cost of a water bath and making it feasible to improve accuracy by testing larger samples and to materially reduce the testing time.

8.4. While standardization of the flask or either pycnometer need to be performed only once, the standardization should be checked occasionally, particularly at 25°C (77°F). The equipment must be kept clean and free from any accumulation that would change the mass if the volume standardization is to remain constant. Care should be taken to use only neutral solvents, especially with plastic containers; glass vessels should not be subjected to high vacuum if they are scratched or damaged.

9. SAMPLE PREPARATION

9.1. Separate the particles of the HMA sample by hand, taking care to avoid fracturing the aggregate, so that the particles of the fine aggregate portion are not larger than 6.3 mm (1/4 in.). If an HMA sample is not sufficiently soft to be separated manually, place it in a pan, and warm it in an oven until it can be separated as described.

9.2. Samples prepared in a laboratory shall be conditioned and dried in an oven at 135 ± 5°C (275 ± 9°F) for a minimum of 2 h or as appropriate to match the mix design procedure being used. Longer drying time may be necessary for the sample to achieve a constant mass (mass repeats within 0.1 percent). HMA which has not been prepared in a laboratory with oven-dried aggregates shall be dried to a constant mass at a temperature of 105 ± 5°C (221 ± 9°F). This drying and conditioning operation shall be combined with any warming described in Section 9.1.

**Note 6**—The minimum 2 h time in the oven is specified as the short-term conditioning time for laboratory-prepared specimens. The short-term conditioning at the specified temperature is especially important when absorptive aggregates are used. This short-term conditioning will ensure the computation of realistic values for the amount of asphalt absorbed by the aggregate and void properties of the mix. Plant-produced HMA should not be short-term conditioned since absorption takes place during production.

9.3. Cool the sample to room temperature, and place it in a tared and standardized flask, bowl or pycnometer. The sample is to be placed directly into a vacuum container. A container within a container is not to be used. Determine the mass and designate the net mass of the sample as A. Add sufficient water at a temperature of approximately 25°C (77°F) to cover the sample completely.

**Note 7**—The release of entrapped air may be facilitated by the addition of a suitable wetting agent such as Aerosol OT in concentration of 0.001 percent or 0.2 g in 20 L of water. This solution is then diluted by about 20:1 to make a wetting agent of which 5 to 10 mL may be added to the apparatus.
TEST METHOD A—MECHANICAL AGITATION

10. APPARATUS

10.1. In addition to the apparatus listed in Section 6, the following apparatus is required for Method A:

10.1.1. *Mechanical Shaker*—Shaker for removing air from asphalt mix.

11. PROCEDURE

11.1. Remove air trapped in the sample by applying gradually increased vacuum until the residual pressure manometer reads 3.7 ± 0.3 kPa (27.5 ± 2.5 mm Hg). Maintain this residual pressure for 15 ± 2 min. Agitate the container and contents using the mechanical device during the vacuum period. Glass vessels should be shaken on a resilient surface such as a rubber or plastic mat, and not on a hard surface, so as to avoid excessive impact while under vacuum.

11.2. At the end of the vacuum period, release the vacuum by increasing the pressure at a rate not to exceed 8 kPa (60 mm Hg) per second and proceed with one of the mass determination methods in Section 13.

TEST METHOD B—MANUAL AGITATION

12. PROCEDURE

12.1. Remove air trapped in the sample by applying gradually increased vacuum until the residual pressure manometer reads 3.7 ± 0.3 kPa (27.5 ± 2.5 mm Hg). Maintain this residual pressure for 15 ± 2 min. Agitate the container and contents during the vacuum period by vigorously shaking at intervals of about 2 min. Glass vessels should be shaken on a resilient surface such as a rubber or plastic mat, and not on a hard surface, so as to avoid excessive impact while under vacuum.

12.2. At the end of the vacuum period, release the vacuum by increasing the pressure at a rate not to exceed 8 kPa (60 mm Hg) per second and proceed with one of the mass determination methods in Section 13.

13. MASS DETERMINATION

13.1. *Mass Determination in Water*—Suspend the container and contents in the water bath and determine the mass after a 10 ± 1 min immersion. Measure the water bath temperature, and if different from 25 ± 1°C (77 ± 2°F), correct the mass to 25°C (77°F) using the standardization temperature adjustment developed in Section 8.1. Designate the mass of the sample in water at 25°C (77°F) as C.

*Note 8*—Instead of using a chart like Figure 2 to establish the mass correction for the temperature of the vacuum vessel submerged by itself in the water bath, this correction can be easily established by rapidly and completely emptying the vacuum container immediately following the final mass determination, and then without delay, determining the mass of the vessel by itself when totally submerged in the water bath.

13.2. *Mass Determination in Air*—Fill the flask or any one of the pycnometers with water and adjust the contents to a temperature of 25 ± 1°C (77 ± 2°F). Determine the mass of the container and contents, completely filled, in accordance with Section 8.2 within 10 ± 1 min after completing Section 11.1 or 12.1. Designate this mass as E.
**Note 9**—See Appendix X1 for correcting the theoretical maximum specific gravity when measurements are made at temperatures other than 25°C (77°F).

### 14. **CALCULATION**

#### 14.1.
Calculate the theoretical maximum specific gravity of the sample at 25°C (77°F) as follows:

#### 14.1.1. **Mass Determination in Water:**

Theoretical Maximum Specific Gravity = \[ \frac{A}{A - C} \]  

where:
- \( A \) = mass of the oven-dry sample in air, g; and
- \( C \) = mass of the water displaced by the sample at 25°C (77°F), g.

#### 14.1.2. **Mass Determination in Air:**

Theoretical Maximum Specific Gravity = \[ \frac{A}{A + D - E} \]  

where:
- \( A \) = mass of the oven-dry sample in air, g;
- \( D \) = mass of the container filled with water at 25°C (77°F), g; and
- \( E \) = mass of the container filled with the sample and water at 25°C (77°F), g.

#### 14.1.3. **Large-Size Plastic Pycnometer Determinations:**

#### 14.1.3.1.
If the test temperature is between 22.2 and 26.7°C (72 and 80°F), Equation 3 may be used to calculate specific gravity within a minor amount of error due to thermal effects (0.001 points of less).

#### 14.1.3.2.
If the test temperature differs significantly from 25°C (77°F), correct for thermal effects as follows:

\[
\text{Specific Gravity} = \frac{A}{(A + F) - (G + H)} \times \frac{d_w}{0.9970}
\]

where:
- \( A \) = mass of the oven-dry sample in air, g;
- \( F \) = mass of the pycnometer filled with water at the test temperature (Figure 3), g;
- \( G \) = mass of the pycnometer filled with water and the sample at the test temperature, g;
- \( H \) = correction for thermal expansion of asphalt (Figure 5), g;
- \( d_w \) = density of water at the test temperature, Curve D in Figure 6, Mg/m³; and
- 0.9970 = density of water at 25°C (77°F), Mg/m³.

The ratio \( d_w/0.9970 \) is Curve R in Figure 6.
**Figure 5**—Correction Curves for Expansion of Asphalt, \( H \), in Equation 4

**Figure 6**—Curves D and R for Equation 4
Note 10—This general procedure for correcting for thermal effects should also be applicable to corresponding measurements made with other suitable containers.

Note 11—When samples are tested a portion at a time, differences between the maximum specific gravities for each portion should be within the precision statements listed in Section 17. If the values are within the precision statements, the specific gravities for each portion shall be averaged. If the values are outside the precision statements, the test shall be performed again.

14.2. Theoretical maximum density at 25°C (77°F):

14.2.1. Calculate the corresponding theoretical maximum density at 25°C (77°F) as follows:

Theoretical maximum density at 25°C (77°F) = theoretical maximum specific gravity × 997.1 kg/m³ in SI units, or

Theoretical maximum density at 25°C (77°F) = theoretical maximum specific gravity × 62.245 lb/ft³ in inch-pound units.

where:

The density of water at 25°C (77°F) = 997.1 kg/m³ in SI units or 62.245 lb/ft³ in inch-pound units.

15. SUPPLEMENTAL PROCEDURE FOR MIXTURES CONTAINING POROUS AGGREGATE

Note 12—Experiments indicate that this supplemental procedure has an insignificant effect on the test results if the HMA contains individual aggregate with a water absorption below 1.5 percent.

15.1. If the pores of the aggregates are not thoroughly sealed by an asphalt film, they may become saturated with water during the application of vacuum. To determine if this condition has occurred, proceed as follows after completing Section 13.1 or 13.2. Drain the water from the sample. To prevent the loss of fine particles, decant the water through a towel held over the top of the container. Break several large pieces of aggregate and examine the broken surfaces for wetness.

15.2. If the aggregate has absorbed water, spread the sample before an electric fan to remove the surface moisture. Determine the mass at 15 min intervals, and when the loss in mass is less than 0.05 percent for this interval, the sample may be considered to be surface dry. This procedure requires about 2 h and shall be accompanied by intermittent stirring of the sample. Break conglomerations of HMA by hand. Take care to prevent loss of the HMA particles.

15.3. To calculate the specific gravity of the sample, substitute the final surface-dry mass determined in Section 15.2 for \( A \) in the denominator of Equation 2 or 3 as appropriate.

16. REPORT

16.1. Report the following information:

16.1.1. Specific gravity and density of the HMA to the nearest 0.001 for specific gravity or nearest 1 kg/m³ (0.1 lb/ft³) for density as follows: sp gr 25/25°C (77/77°F) or density at 25°C (77°F),

16.1.2. Type of HMA,

16.1.3. Size of the sample,

16.1.4. Number of samples,

16.1.5. Type of container, and
16.1.6. Type of procedure.

17. PRECISION

17.1. Criteria for judging the acceptability of specific gravity test results obtained by this test method are given in the following table:

Table 2—Precision Estimates

<table>
<thead>
<tr>
<th>Test and Type Index</th>
<th>Standard Deviation (1s)</th>
<th>Acceptable Range of Two Results (2s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test results obtained without use of Section 15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Method A</td>
<td>0.0051</td>
<td>0.014</td>
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<tr>
<td>Single-operator precision</td>
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<td>Multilaboratory precision</td>
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<tr>
<td>Method B</td>
<td>0.0064</td>
<td>0.018</td>
</tr>
<tr>
<td>Single-operator precision</td>
<td>0.0100</td>
<td>0.029</td>
</tr>
<tr>
<td>Multilaboratory precision</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Basis of estimate: 1 replicate, 1 material, 344 laboratories.

17.2. The figures given in Column 2 are the standard deviations that have been found to be appropriate for the conditions of the test described in Column 1. The figures given in Column 3 are the limits that should not be exceeded by the difference between the results of two properly conducted tests. Multi-laboratory precision has not been verified for 4500-mL or larger pycnometers.

17.3. The values in Column 3 are the acceptable range for two tests. When more than two results are being evaluated, the range given in Column 3 must be increased. Multiply the standard deviation(s) in Column 2 by the multiplier given in Table 1 of ASTM C 670 for the number of actual tests.

Example for three tests: 0.004 \times 3.3 = 0.013.

Additional guidance and background is given in ASTM C 670.

APPENDIX

(Nonmandatory Information)

X1. THEORETICAL MAXIMUM SPECIFIC GRAVITY FOR LOOSE HMA

X1.1. Scope:

X1.1.1. This appendix has two objectives:

X1.1.1.1. To indicate a method for correcting the theoretical maximum specific gravity to 25°C (77°F) when measurements are made at temperatures other than 25°C (77°F).

X1.1.1.2. To indicate the range of temperature in °C above or below 25°C (77°F) within which no temperature correction is required, because the measured theoretical maximum specific gravity values are shown to be 0.0004 or less away from the value determined at 25°C (77°F).
X1.2.  

**Indicated Values:**

X1.2.1.  
The following example values are indicated for the theoretical maximum specific gravity of a loose HMA sample:

X1.2.1.1.  
Mass of the loose HMA sample = 1251.3 g.

X1.2.1.2.  
Volume of the loose HMA sample at 25°C (77°F) = 492.77 mL.

X1.2.1.3.  
Asphalt binder content = 5.0 percent of total mix.

X1.2.1.4.  
Specific gravity of the asphalt at 25°C (77°F) = 1.029.

X1.2.1.5.  
Combined bulk specific gravity of the aggregate = 2.714.

X1.2.1.6.  
Cubical coefficient of expansion of the asphalt binder at 20°C (68°F) = 6.2 × 10⁻⁴ mL/mL°C

(ASTM D 4311).

X1.2.1.7.  
Cubical coefficient of expansion of the aggregate at 20°C (68°F) = 2.2 × 10⁻⁵ mL/mL°C.

X1.3.  

**Basis of Calculation for One Gram of Loose HMA at 20°C (68°F):**

X1.3.1.  
Mass of the asphalt binder = 0.05 g.

X1.3.2.  
Volume of the asphalt binder = 0.05/1.029 = 0.0486 mL.

X1.3.3.  
Mass of the aggregate = 0.95 g.

X1.3.4.  
Volume of the aggregate = 0.95/2.714 = 0.3500 mL.

X1.3.5.  
Volume of the asphalt binder plus aggregate in one gram of loose HMA at 20°C (68°F) = 0.0486 + 0.3500 = 0.3986 mL.

X1.4.  

**Basis of Calculation for Volume Change of One Gram of Loose HMA for 1°C (2°F) from 20°C (68°F):**

X1.4.1.  
Volume change for the asphalt binder = 6.2 × 10⁻⁴ × 0.0486 = 0.3013 × 10⁻⁴ mL = 3.0130 × 10⁻⁵ mL.

X1.4.2.  
Volume change for the aggregate = 2.2 × 10⁻⁵ × 0.3500 = 0.77 × 10⁻⁵ mL.

X1.4.3.  
Volume change for one gram of loose HMA for 1°C (2°F) change in temperature from 20°C (68°F) = 3.0130 × 10⁻⁵ + 0.7700 × 10⁻⁵ = 3.7830 × 10⁻⁵ mL.

X1.5.  

**Volume Correction:**

X1.5.1.  
For a difference in water temperature of 1°C (2°F) above or below 20°C (68°F), a correction to the volume of water displaced by one gram of loose HMA can be made by the following equation:

\[ \text{Correction} = \Delta T \times K_v \times V_f \text{ mL} \]

where:

\[ \Delta T = 1°C (2°F), \]
\( K_T \) = volume change of 1 g of loose HMA for a 1°C (2°F) change in temperature above or below 20°C (68°F) = 3.7830 \times 10^{-3} \text{ mL}, and

\( V_T \) = volume of water for a corresponding 1251.3-g mass of loose HMA at a test temperature of 20°C (68°F) = 492.77 mL.

Substituting these values into the equation gives the following:

\[
\text{Correction} = 1 \times 3.7830 \times 10^{-3} \times 492.77 = 0.01864 \text{ mL/g at 20°C (68°F).}
\]

**X1.6.**

Table X1.1 illustrates an example of the influence of temperature corrections. For a measured volume and a given mass of HMA tested at specific temperatures, this table relates these influences to the specific gravity of the HMA.

**Table X1.1—Influence of Temperature Corrections to a Measured Volume at 20°C of a Given Mass of Loose Paving Mixture, to Provide the Required Theoretical Maximum Specific Gravity at 25°C**

<table>
<thead>
<tr>
<th>Temperature, °C</th>
<th>Volume of HMA at 20°C (68°F), mL</th>
<th>Volume Correction for Temp Change</th>
<th>Corrected Volume of HMA at 20°C (68°F), mL</th>
<th>Mass of HMA, g</th>
<th>Specific Gravity of HMA</th>
</tr>
</thead>
<tbody>
<tr>
<td>31</td>
<td>492.77</td>
<td>0.2046</td>
<td>492.975</td>
<td>1251.3</td>
<td>2.5383</td>
</tr>
<tr>
<td>30*</td>
<td>492.77</td>
<td>0.1850</td>
<td>492.956</td>
<td>1251.3</td>
<td>2.5384</td>
</tr>
<tr>
<td>25</td>
<td>492.77</td>
<td>0.1674</td>
<td>492.937</td>
<td>1251.3</td>
<td>2.5385</td>
</tr>
<tr>
<td>28*</td>
<td>492.77</td>
<td>0.1488</td>
<td>492.919</td>
<td>1251.3</td>
<td>2.5386</td>
</tr>
<tr>
<td>27*</td>
<td>492.77</td>
<td>0.1302</td>
<td>492.900</td>
<td>1251.3</td>
<td>2.5386</td>
</tr>
<tr>
<td>26</td>
<td>492.77</td>
<td>0.1116</td>
<td>492.882</td>
<td>1251.3</td>
<td>2.5387</td>
</tr>
<tr>
<td>25*</td>
<td>492.77</td>
<td>0.0930</td>
<td>492.863</td>
<td>1251.3</td>
<td>2.5388</td>
</tr>
<tr>
<td>24*</td>
<td>492.77</td>
<td>0.0744</td>
<td>492.844</td>
<td>1251.3</td>
<td>2.5389</td>
</tr>
<tr>
<td>23*</td>
<td>492.77</td>
<td>0.0558</td>
<td>492.826</td>
<td>1251.3</td>
<td>2.5390</td>
</tr>
<tr>
<td>22*</td>
<td>492.77</td>
<td>0.0372</td>
<td>492.807</td>
<td>1251.3</td>
<td>2.5391</td>
</tr>
<tr>
<td>21*</td>
<td>492.77</td>
<td>0.0186</td>
<td>492.789</td>
<td>1251.3</td>
<td>2.5392</td>
</tr>
<tr>
<td>20</td>
<td>492.77</td>
<td>0.0000</td>
<td>492.772</td>
<td>1251.3</td>
<td>2.5393</td>
</tr>
<tr>
<td>19</td>
<td>492.77</td>
<td>-0.0186</td>
<td>492.751</td>
<td>1251.3</td>
<td>2.5394</td>
</tr>
</tbody>
</table>

* Range less than 0.0005.

**Notes:** Strictly speaking, the above table shows that the specific gravity for this particular mix, as measured at 20°C (68°F), just fails to meet the corrected theoretical maximum specific gravity at 25°C (77°F), 2.5388 versus 2.5391, that is, by 0.0005, and that a temperature correction would be required. If the measurement for volume had been made at 21°C (70°F), the table indicates that no temperature correction would have been necessary, because the measurement at 21°C (70°F) would have satisfied the theoretical maximum specific gravity at 25°C (77°F), 2.5388 versus 2.5390, a difference of less than 0.0005.

---

1. Sargent Welch, 39745 Gauge-Vacuum, Mercury Prefilled (or equivalent).
Standard Method of Test for


1. SCOPE

1.1. This method covers the measurement of the resistance to plastic flow of cylindrical specimens of bituminous paving mixture loaded on the lateral surface by means of the Marshall apparatus. This method is for use with mixtures containing asphalt cement, asphalt cutback or tar, and aggregate up to 25.4-mm (1-in.) maximum size.

2. APPARATUS

2.1. *Specimen Mold Assembly*—Mold cylinders 101.6 mm (4 in.) in diameter by 76.2 mm (3 in.) in height, base plates, and extension collars shall conform to the details shown in Figure 1. Three mold cylinders are recommended.

![Compaction Mold Diagram]

*Figure 1—Compaction Mold*
Table 1—Table of Equivalents for Figures 1 and 3

<table>
<thead>
<tr>
<th>Metric Equivalents, mm</th>
<th>U.S. Customary Units, in.</th>
<th>Metric Equivalents, mm</th>
<th>U.S. Customary Units, in.</th>
<th>Metric Equivalents, mm</th>
<th>U.S. Customary Units, in.</th>
<th>Metric Equivalents, mm</th>
<th>U.S. Customary Units, in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.11</td>
<td>0.005</td>
<td>17.5</td>
<td>1 11/16</td>
<td>58.7</td>
<td>2 1/16</td>
<td>104.8</td>
<td>4 1/4</td>
</tr>
<tr>
<td>0.8</td>
<td>1/32</td>
<td>19.0</td>
<td>1/4</td>
<td>63.5</td>
<td>2 1/2</td>
<td>108.7</td>
<td>4 9/16</td>
</tr>
<tr>
<td>1.6</td>
<td>1/16</td>
<td>22.2</td>
<td>1/8</td>
<td>69.8</td>
<td>2 1/4</td>
<td>109.1</td>
<td>4 9/64</td>
</tr>
<tr>
<td>3.2</td>
<td>1/4</td>
<td>23.8</td>
<td>1 3/16</td>
<td>73.0</td>
<td>2 7/8</td>
<td>114.2</td>
<td>4 1/2</td>
</tr>
<tr>
<td>4.8</td>
<td>3/16</td>
<td>25.4</td>
<td>1</td>
<td>76.2</td>
<td>3</td>
<td>117.5</td>
<td>4 1/8</td>
</tr>
<tr>
<td>6.4</td>
<td>1/4</td>
<td>28.6</td>
<td>1 1/8</td>
<td>82.6</td>
<td>3 1/4</td>
<td>120.6</td>
<td>4 7/16</td>
</tr>
<tr>
<td>7.1</td>
<td>9/32</td>
<td>31.8</td>
<td>1 5/16</td>
<td>87.3</td>
<td>3 7/16</td>
<td>128.6</td>
<td>5 1/16</td>
</tr>
<tr>
<td>9.5</td>
<td>3/8</td>
<td>34.9</td>
<td>1 11/16</td>
<td>98.4</td>
<td>3 3/8</td>
<td>132.2</td>
<td>5 3/16</td>
</tr>
<tr>
<td>12.6</td>
<td>0.496</td>
<td>38.1</td>
<td>1 7/16</td>
<td>101.2</td>
<td>3 5/16</td>
<td>146.0</td>
<td>6</td>
</tr>
<tr>
<td>12.67</td>
<td>0.499</td>
<td>41.3</td>
<td>1 9/16</td>
<td>101.35</td>
<td>3.990</td>
<td>152.4</td>
<td>6</td>
</tr>
<tr>
<td>12.7</td>
<td>1/2</td>
<td>44.4</td>
<td>1 13/16</td>
<td>101.47</td>
<td>3.995</td>
<td>158.8</td>
<td>6 1/16</td>
</tr>
<tr>
<td>14.3</td>
<td>5/16</td>
<td>50.8</td>
<td>2</td>
<td>101.6</td>
<td>4</td>
<td>193.7</td>
<td>7 3/16</td>
</tr>
<tr>
<td>15.9</td>
<td>5/8</td>
<td>57.2</td>
<td>2 1/16</td>
<td>101.73</td>
<td>4.005</td>
<td>685.8</td>
<td>27</td>
</tr>
</tbody>
</table>

2.2. Specimen Extractor, steel, in the form of a disk with a diameter not less than 100 mm (3.95 in.) and 12.7 mm (1/2 in.) thick for extracting the compacted specimen from the specimen mold with the use of the mold collar. A suitable bar is required to transfer the load from the ring dynamometer adapter to the extension collar while extracting the specimen.

2.3. Compaction Hammer—The compaction hammer (Figure 2) shall have a flat, circular tamping face and a 4536 ± 9 g (10 ± 0.02 lb) sliding weight (including safety finger guard if so equipped) with a free fall of 457.2 ± 1.524 mm (18 ± 0.06 in.).

---

Figure 2—Compaction Hammer
**Note 1**—The compaction hammer may be equipped with a finger safety guard as shown in Figure 2.

**Note 2**—Instead of a hand-operated hammer, and associated equipment described in Sections 2.3, 2.4, and 2.5, a mechanically operated hammer may be used provided it has been calibrated to give results comparable with the hand-operated hammer.

2.4. 

*Compaction Pedestal*—The compaction pedestal shall consist of a 203.2 by 203.2- by 457.2-mm (8- by 8- by 18-in.) wooden post capped with a 304.8- by 304.8- by 25.4-mm (12- by 12- by 1-in.) steel plate. The wooden post shall be oak, pine, or other wood having an average dry weight of 0.67 to 0.77 g/cm$^3$ (42 to 48 lb/ft$^3$). The wooden post shall be secured by four angle brackets to a solid concrete slab. The steel cap shall be firmly fastened to the post. The pedestal assembly shall be installed so that the post is plumb and the cap is level.

2.5. 

*Specimen Mold Holder*—mounted on the compaction pedestal so as to center the compaction mold over the center of the post. It shall hold the compaction mold, collar, and base plate securely in position during compaction of the specimen.

2.6. 

*Breaking Head*—(Figure 3) shall consist of upper and lower cylindrical segments or test heads having an inside radius of curvature of 50.8 mm (2 in.) accurately machined. The lower segment shall be mounted on a base having two perpendicular guide rods or posts extending upward. Guide sleeves in the upper segment shall be in such a position as to direct the two segments together without appreciable binding or loose motion on the guide rods.
2.7. **Loading Jack**—The loading jack (Figure 4) shall consist of a screw jack mounted in a testing frame and shall produce a uniform vertical movement of 50.8 mm (2 in.)/min. An electric motor may be attached to the jacking mechanism.

![Diagram of Compression Testing Machine](image)

**Figure 4**—Compression Testing Machine

**Note 3**—Instead of the loading jack, a mechanical or hydraulic testing machine may be used provided the rate of movement can be maintained at 50.8 mm (2 in.)/min while the load is applied.

2.8. **Ring Dynamometer Assembly**—One-ring dynamometer (Figure 4) of 22.2 kN (5000 lbf) capacity and sensitivity of 44.5 N (10 lb) up to 4.45 kN (1000 lbf) and 111.2N (25 lb) between 4.45 and 22.2 kN (1000 and 5000 lbf) shall be equipped with a micrometer dial. The micrometer dial shall be graduated in 0.0025 mm (0.0001 in.). Upper and lower ring dynamometer attachments are required for fastening the ring dynamometer to the testing frame and transmitting the load to the breaking head.

**Note 4**—Instead of the ring dynamometer assembly, any suitable load-measuring device may be used provided the capacity and sensitivity meet the above requirements.

2.9. **Flowmeter**—The flowmeter shall consist of a guide sleeve and a gauge. The activating pin of the gauge shall slide inside the guide sleeve with a slight amount of frictional resistance. The guide sleeve shall slide freely over the guide rod of the breaking head. The flowmeter gauge shall be adjusted to zero when placed in position on the breaking head when each individual test specimen is inserted between the breaking head segments. Graduations of the flowmeter gauge shall be in 0.25 mm (0.01 in.) divisions.

**Note 5**—Instead of the flowmeter, a micrometer dial or stress-strain recorder graduated in 0.25 mm (0.01 in.) may be used to measure flow.
2.10. **Ovens or Hot Plates**—Ovens or hot plates shall be provided for heating aggregates, bituminous material, specimen molds, compaction hammers, and other equipment to the required mixing and molding temperatures. It is recommended that the heating units be thermostatically controlled so as to maintain the required temperature within 2.8°C (5°F). Suitable shields, baffle plates, or sand baths shall be used on the surfaces of the hot plates to minimize localized overheating.

2.11. **Heating Device**—A small hot plate with continuously variable heating rate, a sand bath, infrared lamp, or other suitable device shall be available for supplying sufficient heat under the mixing bowl to maintain the aggregate and bituminous material at the desired temperature during mixing. If a hot plate is used, a wire mesh or similar material shall be placed on the hot plate to prevent direct contact between the hot plate and mixing bowl.

2.12. **Mixing Apparatus**—Mechanical mixing is recommended. Any type of mechanical mixer may be used provided it can be maintained at the required mixing temperature and will produce a well-coated, homogeneous mixture of the required amount in the allowable time, and further provided that essentially all of the batch can be recovered. A metal pan or bowl of sufficient capacity and hand mixing may also be used.

2.13. **Water Bath**—The water bath shall be at least 152.4 mm (6 in.) deep and shall be thermostatically controlled so as to maintain the bath at 60 ± 1°C (140 ± 2°F) or 37.8 ± 1°C (100 ± 2°F). The tank shall have a perforated false bottom or be equipped with a shelf for supporting specimens 50.8 mm (2 in.) above the bottom of the bath.

2.14. **Air Bath**—The air bath for asphalt cutback mixtures shall be thermostatically controlled and shall maintain the air temperature at 25 ± 1°C (77°F ± 2°F).

2.15. **Miscellaneous Equipment:**

2.15.1. **Containers for Heating Aggregates**—flat-bottom metal pans or other suitable containers.

2.15.2. **Containers for Heating Bituminous Material**—either gill-type tins, beakers, pouring pots, or saucepans may be used.

2.15.3. **Mixing Tool**—either a steel trowel (garden type) or spatula, for spading, and hand mixing.

2.15.4. **Thermometers**—for determining temperatures of aggregates, bitumen, and bituminous mixtures. Armored-glass, dial type, or digital thermometers with metal stems are recommended. A range from 9.9 to 204°C (50 to 400°F), with sensitivity of 2.8°C (5°F) is required.

2.15.5. Thermometers for water and air baths sensitive to 0.2°C (0.4°F) with a range sufficient to determine the specified bath temperature.

2.15.6. **Balance**—2-kg capacity, sensitive to 0.1 g, for weighing molded specimens.

2.15.7. **Balance**—5-kg capacity, sensitive to 1.0 g, for batching mixtures.

2.15.8. **Gloves**—for handling hot equipment.

2.15.9. **Rubber Gloves**—for removing specimens from water bath.

2.15.10. **Marking Crayons**—for identifying specimens.
2.15.11. *Scoop*—flat bottom, for batching aggregates.

2.15.12. *Spoon*—large, for placing the mixture in the specimen molds.

### 3. TEST SPECIMENS

3.1. *Number of Specimens*—Prepare at least three specimens for each combination of aggregates and bitumen content.

3.2. *Preparation of Aggregates*—Dry aggregates to constant mass at 105 to 110°C (221 to 230°F) and separate the aggregates by dry-sieving into the desired size fractions.¹ The following size fractions are recommended:

- 25.0 to 19.0 mm (1 to 3/4 in.)
- 19.0 to 9.5 mm (3/4 to 3/8 in.)
- 9.5 mm to 4.75 mm (3/8 in. to No. 4)
- 4.75 mm to 2.36 mm (No. 4 to No. 8)
- Passing 2.36 mm (No. 8)

3.3. *Determination of Mixing and Compacting Temperatures*:

3.3.1. The temperatures to which the asphalt cement and asphalt cutback must be heated to produce a viscosity of 170 ± 20 cSt shall be the mixing temperature.

3.3.2. The temperature to which asphalt cement must be heated to produce a viscosity of 280 ± 30 cSt shall be the compacting temperature.

3.3.3. From a composition chart for the asphalt cutback used, determine from its viscosity at 60°C (140°F) the percentage of solvent by mass. Also determine from the chart the viscosity at 60°C (140°F) of the asphalt cutback after it has lost 50 percent of its solvent. The temperature determined from the viscosity temperature chart to which the asphalt cutback must be heated to produce a viscosity of 280 ± 30 cSt after a loss of 50 percent of the original solvent content shall be the compacting temperature.

3.3.4. The temperature to which tar must be heated to produce Engler specific viscosities of 25 ± 3 and 40 ± 5 shall be, respectively, the mixing and compacting temperature.

3.4. *Preparation of Mixtures*:

3.4.1. An initial batch shall be mixed for the purpose of “buttering” the mixture bowl and stirrers. This batch shall be emptied after mixing and the sides of the bowl and stirrers shall be cleared of mixture residue by scraping with a small limber spatula but shall not be wiped with cloth or washed clean with solvent, except when a change is to be made in the binder or at the end of a run.

3.4.2. Weigh into separate pans for each test specimen the amount of each size fraction required to produce a batch that will result in a compacted specimen 63.5 ± 1.27 mm (2.5 ± 0.05 in.) in height (about 1200 g). Mix the aggregate in each pan and place the pans on a hot plate or in the oven and heat to a temperature not exceeding the mixing temperature established in Section 3.3 by more than approximately 28°C (50°F) for asphalt cement and tar mixes at 14°C (25°F) for cutback asphalt mixes. Heat, to the established mixing temperature, just sufficient bituminous material for the batch in a separate container. Charge the mixing bowl with the heated aggregate. Form a crater in the dry-blended aggregate and weigh the preheated required amount of bituminous material into
the mixture. For mixes prepared with cutback asphalt, introduce the mixing blade in the mixing bowl and determine the total mass of the mix components plus bowl and blade before proceeding with mixing. Care must be exercised to prevent loss of the mix during mixing and subsequent handling. At this point, the temperature of the aggregate and bituminous material shall be within the limits of the mixing temperature established in Section 3.3. Mix the aggregate and bituminous material rapidly until thoroughly coated. To maintain proper mixing temperature, one of the methods described in Section 2.11 may be used.

3.4.3. Following mixing, cure asphalt cutback mixtures in a ventilated oven maintained at approximately 11.1°C (20°F) above the compaction temperature. Curing is to be continued in the mixing bowl until the precalculated weight of 50 percent solvent loss or more has been obtained. The mix may be stirred in a mixing bowl during curing to accelerate the solvent loss. However, care should be exercised to prevent loss of the mix. Weigh the mix during curing in successive intervals of 15 minutes initially and less than 10-minute intervals as the weight of the mix at 50 percent solvent loss is approached.

3.5. Compaction of Specimens:

3.5.1. Thoroughly clean the specimen mold assembly and the face of the compaction hammer and heat them either in boiling water, on the hot plate, or in an oven, to a temperature between 93.3 and 148.9°C (200 and 300°F). Place a piece of filter paper or paper toweling cut to size in the bottom of the mold before the mixture is introduced. Place the entire batch in the mold, space the mixture vigorously with a heated spatula or trowel 15 times around the perimeter and 10 times over the interior. Remove the collar and smooth the surface of the mix with a trowel to a slightly rounded shape. Temperatures of the mixtures immediately prior to compaction shall be within the limits of the compacting temperature established in Section 3.3.

3.5.2. Replace the collar, then place a piece of filter paper or paper toweling cut to size on top of the mixture and place the mold assembly on the compaction pedestal in the mold holder, and unless otherwise specified, apply 50 or 75 blows with the compaction hammer with a free fall in 457.2 mm (18 in.). Hold the axis of the compaction hammer perpendicular to the base of the mold assembly during compaction. Remove the base plate and collar, and reverse and reassemble the mold. Apply the same number of compaction blows to the face of the reversed specimen. After compaction, remove the base plate and place the sample extractor on the end of the specimen. Place the assembly with the extension collar up in the testing machine, apply pressure to the collar by means of the load transfer bar, and force the specimen into the extension collar. Lift the collar from the specimen. Carefully transfer the specimen to a smooth, flat surface and allow it to stand overnight at room temperature. Weigh, measure, and test the specimen.

Note 6—In general, specimens shall be cooled as specified in Section 3.5.2. When more rapid cooling is desired, table fans may be used. Mixtures that lack sufficient cohesion to result in the required cylindrical shape on removal from the mold immediately after compaction may be cooled in the mold in air until sufficient cohesion has developed to result in the proper cylindrical shape.

4. PROCEDURE

4.1. Bring the specimens prepared with asphalt cement or tar to the specified temperature by immersing in the water bath 30 to 40 minutes or placing in the oven for two hours. Maintain the bath or oven temperature at 60 ± 1°C (140 ± 1.8°F) for the asphalt cement specimens and 37.8 ± 1°C (100 ± 1.8°F) for tar specimens. Bring the specimens prepared with asphalt cutback to the specified temperature by placing them in the air bath for a minimum of two hours. Maintain the air bath temperature at 25 ± 1°C (77 ± 1.8°F). Thoroughly clean the guide rods and the inside surfaces of the test heads prior to making the test, and lubricate the guide rods so that the upper test head slides freely over them. The testing-head temperature shall be maintained between 21.1 to 37.8°C
(70 to 100°F) using a water bath when required. Remove the specimen from the water bath, oven, or air bath, and place in the lower segment of the breaking head. Place the upper segment of the breaking head on the specimen, and place the complete assembly in position on the testing machine. Place the flowmeter, where used, in position over one of the guide rods and adjust the flowmeter to zero while holding the sleeve firmly against the upper segment of the breaking head. Hold the flowmeter sleeve firmly against the upper segment of the breaking head while the test load is being applied.

4.2. Apply the load to the specimen by means of the constant rate of movement of the loadjack or testing-machine head of 50.8 mm (2 in.) per minute until the maximum load is reached and the load decreases as indicated by the dial. Record the maximum load noted on the testing machine or converted from the maximum micrometer dial reading. Release the flowmeter sleeve or note the micrometer dial reading, where used, the instant the maximum load begins to decrease. Note and record the indicated flow value or equivalent units in twenty-five hundredths of a millimeter (hundredths of an inch) if a micrometer dial is used to measure the flow. The elapsed time for the test from removal of the test specimen from the water bath to the maximum load determination shall not exceed 30 seconds.

Note 7—For core specimens, correct the load when thickness is other than 63.5 mm (2 1/2 in.) by using the proper multiplying factor from Table 2.

5. REPORT

5.1. The report shall include the following information:

5.1.1. Type of sample tested (laboratory sample or pavement core specimen);

Note 8—For core specimens, the height of each test specimen in millimeters (or inches) shall be reported.

5.1.2. Average maximum load in pounds-force (or newtons) of at least three specimens, corrected when required;

5.1.3. Average flow value, in hundredths of an inch, twenty-five hundredths of a millimeter, of three specimens; and

5.1.4. Test temperature.

TS-2d T 245-9 AASHTO
Table 2—Stability Correlation Ratios\(^a,b\)

<table>
<thead>
<tr>
<th>Volume of Specimen, (\text{cm}^3)</th>
<th>Approximate Thickness</th>
<th>Correlation Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 to 213</td>
<td>(\frac{1}{16}) in.</td>
<td>23.4</td>
</tr>
<tr>
<td>214 to 225</td>
<td>(\frac{1}{16}) in.</td>
<td>27.0</td>
</tr>
<tr>
<td>226 to 237</td>
<td>(\frac{1}{8}) in.</td>
<td>28.6</td>
</tr>
<tr>
<td>238 to 250</td>
<td>(\frac{1}{8}) in.</td>
<td>30.2</td>
</tr>
<tr>
<td>251 to 264</td>
<td>(\frac{1}{4}) in.</td>
<td>31.8</td>
</tr>
<tr>
<td>265 to 276</td>
<td>(\frac{1}{4}) in.</td>
<td>33.3</td>
</tr>
<tr>
<td>277 to 289</td>
<td>(\frac{1}{4}) in.</td>
<td>34.9</td>
</tr>
<tr>
<td>290 to 301</td>
<td>(\frac{1}{4}) in.</td>
<td>36.5</td>
</tr>
<tr>
<td>302 to 316</td>
<td>(\frac{1}{4}) in.</td>
<td>38.1</td>
</tr>
<tr>
<td>317 to 328</td>
<td>(\frac{1}{4}) in.</td>
<td>39.7</td>
</tr>
<tr>
<td>329 to 340</td>
<td>(\frac{1}{4}) in.</td>
<td>41.3</td>
</tr>
<tr>
<td>341 to 353</td>
<td>(\frac{1}{8}) in.</td>
<td>42.9</td>
</tr>
<tr>
<td>354 to 367</td>
<td>(\frac{1}{8}) in.</td>
<td>44.4</td>
</tr>
<tr>
<td>368 to 379</td>
<td>(\frac{1}{8}) in.</td>
<td>46.0</td>
</tr>
<tr>
<td>380 to 392</td>
<td>(\frac{1}{8}) in.</td>
<td>47.6</td>
</tr>
<tr>
<td>393 to 405</td>
<td>(\frac{1}{8}) in.</td>
<td>49.2</td>
</tr>
<tr>
<td>406 to 420</td>
<td>2</td>
<td>50.8</td>
</tr>
<tr>
<td>421 to 432</td>
<td>2(\frac{1}{16}) in.</td>
<td>52.4</td>
</tr>
<tr>
<td>432 to 443</td>
<td>2(\frac{1}{8}) in.</td>
<td>54.0</td>
</tr>
<tr>
<td>444 to 456</td>
<td>2(\frac{1}{8}) in.</td>
<td>55.6</td>
</tr>
<tr>
<td>457 to 470</td>
<td>2(\frac{1}{4}) in.</td>
<td>57.2</td>
</tr>
<tr>
<td>471 to 482</td>
<td>2(\frac{1}{4}) in.</td>
<td>58.7</td>
</tr>
<tr>
<td>483 to 495</td>
<td>2(\frac{1}{4}) in.</td>
<td>60.3</td>
</tr>
<tr>
<td>496 to 508</td>
<td>2(\frac{1}{4}) in.</td>
<td>61.9</td>
</tr>
<tr>
<td>509 to 522</td>
<td>2(\frac{1}{2}) in.</td>
<td>63.5</td>
</tr>
<tr>
<td>523 to 533</td>
<td>2(\frac{1}{2}) in.</td>
<td>65.1</td>
</tr>
<tr>
<td>536 to 546</td>
<td>2(\frac{1}{2}) in.</td>
<td>66.7</td>
</tr>
<tr>
<td>547 to 559</td>
<td>2(\frac{1}{2}) in.</td>
<td>68.3</td>
</tr>
<tr>
<td>560 to 573</td>
<td>2(\frac{1}{2}) in.</td>
<td>69.9</td>
</tr>
<tr>
<td>574 to 585</td>
<td>2(\frac{1}{2}) in.</td>
<td>71.4</td>
</tr>
<tr>
<td>586 to 598</td>
<td>2(\frac{1}{4}) in.</td>
<td>73.0</td>
</tr>
<tr>
<td>599 to 610</td>
<td>2(\frac{1}{4}) in.</td>
<td>74.6</td>
</tr>
<tr>
<td>611 to 625</td>
<td>3</td>
<td>76.2</td>
</tr>
</tbody>
</table>

\(a\) The measured stability of a specimen multiplied by the ratio for the thickness of the specimen equals the corrected stability for a 63.5 mm (\(2\frac{1}{8}\) in.) specimen.

\(b\) Volume-thickness relationship is based on a specimen diameter of 101.6 mm (4 in.).

\(^1\) Detailed requirements for these sieves are given in M 92, Wire-Cloth Sieves for Testing Purposes.
ITEM 442 SUPERPAVE ASPHALT CONCRETE

442.01 Description
442.02 Type A Mix Design
442.03 Type B Mix Design
442.04 Asphalt Binder
442.05 Quality Control
442.06 Compaction
442.07 Acceptance
442.08 Basis of Payment

442.01 Description. This work consists of gyratory mix design, material, and quality control requirements for constructing a Superpave asphalt concrete pavement surface or intermediate course. The asphalt concrete pavement course consists of aggregate, and asphalt binder mixed in a central plant and spread and compacted on a prepared surface.

The requirements of Item 441 apply, except as modified by this specification. Do not use the warm mix asphalt method for 12.5 mm mixtures.

442.02 Type A Mix Design. Design the mixture composition for a Type A mix according to 441.02 and the most recent Asphalt Institute Superpave Mix Design Manual (SP-2) for design procedures and material properties except as modified by this subsection. Include in the JMF submittal the standard Department cover and summary page; all printouts from the gyratory compactor (all gyratory points not necessary); and analysis covering the required mix properties. Submit one compacted gyratory sample and loose mix for compaction of another sample, in addition to a 5-pound (2000 g) loose sample, for each JMF.

The Contractor may use the Marshall flow test in design as an indicator of potential for excess tenderness.

Supply aggregate according to the lane current average daily truck traffic (Lane ADTT) as follows unless otherwise shown on the plans:

\[ \text{Lane ADTT} = \text{Current ADT} \times T_{24} \times 0.45 \]

Where:
- \( \text{Current ADT} \) = current average daily traffic count from the plans
- \( T_{24} \) = percent trucks per day from the plans

<table>
<thead>
<tr>
<th>Lane ADTT</th>
<th>Nini</th>
<th>Ndes</th>
<th>Nmax</th>
<th>Coarse Aggregate Angularity</th>
<th>Fine Aggregate Angularity</th>
<th>Flat and Elongated Particles</th>
<th>Sand Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;4000</td>
<td>7</td>
<td>65</td>
<td>105</td>
<td>95 * /90 **</td>
<td>44</td>
<td>10</td>
<td>45</td>
</tr>
<tr>
<td>&gt;4000</td>
<td>7</td>
<td>65</td>
<td>105</td>
<td>100 * /100 **</td>
<td>44</td>
<td>10</td>
<td>50</td>
</tr>
</tbody>
</table>

* Percent fractured (one or more faces) according to ASTM D5821
** Percent fractured (two or more faces) according to ASTM D5821

Submit aggregate to be used to the Laboratory for approval a minimum of 3 weeks before submitting a JMF for approval.

If fine aggregate is from crushed carbonate stone or air-cooled blast furnace slag, the Department will not require the fine aggregate angularity (FAA) test. The Department will allow a blend of a material not meeting the FAA with a material that meets the FAA, but calculate the FAA result based on the individual Department FAA results and actual blend percentages. Obtain Department approval of any blends.
The restricted zone does not apply. Use control points according to SP-2, except as specified in Table 442.02-2.

**TABLE 442.02-2 AGGREGATE GRADATION REQUIREMENTS**

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>9.5 mm mix (% passing)</th>
<th>12.5 mm mix (% passing)</th>
<th>19 mm mix (% passing)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 1/2 inch (37.5 mm)</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3/4 inch (19 mm)</td>
<td></td>
<td>100</td>
<td>85 to 100</td>
</tr>
<tr>
<td>1/2 inch (12.5 mm)</td>
<td>100</td>
<td>95 to 100</td>
<td>90 max</td>
</tr>
<tr>
<td>3/8 inch (9.5 mm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 4 (4.75 mm)</td>
<td>70 max</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 8 (2.36 mm)</td>
<td>32 to 52</td>
<td>32 to 45</td>
<td>28 to 45</td>
</tr>
<tr>
<td>No. 200 (75 µm)</td>
<td>2 to 8</td>
<td>2 to 8</td>
<td>2 to 6</td>
</tr>
</tbody>
</table>

Ensure that the F/A ratio is a maximum of 1.2. Use a 2-hour cure in design process.

If more than 15 percent fine aggregate not meeting FAA is used, perform a loaded wheel test (LWT) according to Supplement 1057. To estimate a LWT sample mix volume, use the bulk density from gyratory specimens at Ndes. Results less than 0.20 inch (5.0 mm) at 120 °F (49 °C) are considered passing.

The Contractor may use reclaimed asphalt concrete pavement according to 401.04. Test design volumetric properties at Ndes. Test Nmax for the required criteria. Ensure that the VMA is not less than the minimum values of Table 442.02-3.

**TABLE 442.02-3 VMA CRITERIA**

<table>
<thead>
<tr>
<th>Mix</th>
<th>VMA (percent minimum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.5 mm</td>
<td>15</td>
</tr>
<tr>
<td>12.5 mm</td>
<td>14</td>
</tr>
<tr>
<td>19.0 mm</td>
<td>13</td>
</tr>
</tbody>
</table>

**442.03 Type B Mix Design.** Apply the mix design specified in 442.02 for a Type A mix except as modified by this subsection:

Modify the Coarse Aggregate Angularity of Table 442.02-1 according to Table 442.03-1.

**TABLE 442.03-1**

<table>
<thead>
<tr>
<th>Lane ADTT</th>
<th>Coarse Aggregate Angularity</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;4000</td>
<td>65 * /65 **</td>
</tr>
<tr>
<td>&gt;4000</td>
<td>75 * /70 **</td>
</tr>
</tbody>
</table>

* Percent fractured (one or more faces) according to ASTM D5821
** Percent fractured (two or more faces) according to ASTM D5821

Ensure that at least 50 percent by weight of virgin fine aggregate is aggregate meeting FAA or is crushed carbonate stone or air-cooled blast furnace slag. Modify the No. 8 (2.36 mm) sieve requirement for a 12.5 mm mix in Table 442.02-2 to 34 to 40 percent. Apply an F-T value of +2 according to 441.02 and 441.09.

**442.04 Asphalt Binder.** Use a PG 70-22M asphalt binder for surface courses and a PG 64-28 asphalt binder for intermediate courses.

The minimum total asphalt binder content for a surface course is 5.7 percent.

**442.05 Quality Control.** Conform to 441.09, except as specified in this subsection. Ensure that plant operation and quality control testing conform to the Contractor’s Quality Control Program (QCP).
Use a gyratory compactor conforming to the requirements of Superpave. If the gyratory compactor was moved to the plant before production, calibrate it and present the results to the DET. Condition samples for air voids for 2 hours.

Determine bulk gravity for air voids determination on specimens compacted to $N_{des}$. Once each day for the first 3 production days compact one set of specimens to $N_{max}$. Ensure that density at $N_{max}$ is less than 98.0 percent of MSG. The Department will not allow production to continue if $N_{max}$ is greater than or equal to 98.0 percent of MSG unless acceptable corrections and retest are made.

If the design gradation requires an LWT test, take a sample sufficient to run a LWT test once each day for the first 3 days and test it according to Supplement 1057. The Contractor may perform the LWT test in the Contractor’s Level 2 laboratory, but must compact the sample the same day the sample was taken, cure it overnight, and test it the following day. Give the test result and sample density to the DET the day of the LWT test. Report the LWT data on the Quality Control Report.

442.06 Compaction. Cease production if compaction causes bumps in the mix or the mix is excessively tender.

442.07 Acceptance. The Department will base acceptance of the asphalt concrete mix on the item specified in the Contract (i.e., Item 446, Item 448).

442.08 Basis of Payment. The Department will pay for accepted quantities at the contract prices as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>442</td>
<td>Cubic Yard (Cubic Meter)</td>
<td>Asphalt Concrete Surface Course, 12.5 mm, Type A (446)</td>
</tr>
<tr>
<td>442</td>
<td>Cubic Yard (Cubic Meter)</td>
<td>Asphalt Concrete Surface Course, 12.5 mm, Type B (446)</td>
</tr>
<tr>
<td>442</td>
<td>Cubic Yard (Cubic Meter)</td>
<td>Asphalt Concrete Surface Course, 9.5 mm, Type A (446)</td>
</tr>
<tr>
<td>442</td>
<td>Cubic Yard (Cubic Meter)</td>
<td>Asphalt Concrete Surface Course, 9.5 mm, Type B (446)</td>
</tr>
<tr>
<td>442</td>
<td>Cubic Yard (Cubic Meter)</td>
<td>Asphalt Concrete Intermediate Course, 19 mm, Type A (446)</td>
</tr>
<tr>
<td>442</td>
<td>Cubic Yard (Cubic Meter)</td>
<td>Asphalt Concrete Intermediate Course, 19 mm, Type B (446)</td>
</tr>
<tr>
<td>442</td>
<td>Cubic Yard (Cubic Meter)</td>
<td>Asphalt Concrete Intermediate Course, 9.5 mm, Type A (448)</td>
</tr>
<tr>
<td>442</td>
<td>Cubic Yard (Cubic Meter)</td>
<td>Asphalt Concrete Intermediate Course, 9.5 mm, Type B (448)</td>
</tr>
<tr>
<td>442</td>
<td>Cubic Yard (Cubic Meter)</td>
<td>Asphalt Concrete Surface Course, 12.5 mm, Type A (448)</td>
</tr>
<tr>
<td>442</td>
<td>Cubic Yard (Cubic Meter)</td>
<td>Asphalt Concrete Surface Course, 12.5 mm, Type B (448)</td>
</tr>
<tr>
<td>442</td>
<td>Cubic Yard (Cubic Meter)</td>
<td>Asphalt Concrete Surface Course, 9.5 mm, Type A (448)</td>
</tr>
<tr>
<td>442</td>
<td>Cubic Yard (Cubic Meter)</td>
<td>Asphalt Concrete Surface Course, 9.5 mm, Type B (448)</td>
</tr>
<tr>
<td>442</td>
<td>Cubic Yard (Cubic Meter)</td>
<td>Asphalt Concrete Intermediate Course 19 mm, Type A (448)</td>
</tr>
<tr>
<td>442</td>
<td>Cubic Yard (Cubic Meter)</td>
<td>Asphalt Concrete Intermediate Course 19 mm, Type B (448)</td>
</tr>
</tbody>
</table>
Standard Test Method for
Bulk Specific Gravity and Density of Non-Absorptive
Compacted Bituminous Mixtures

This standard is issued under the fixed designation D2726; the number immediately following the designation indicates the year of
original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reaffirmation. A
superscript epsilon (ε) indicates an editorial change since the last revision or reaffirmation.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method covers the determination of bulk
specific gravity and density of specimens of compacted bitu-
minous mixtures.

1.2 This test method should not be used with samples that
contain open or interconnected voids or absorb more than 2 %
of water by volume, or both, as determined in 10.3.

1.3 The values stated in SI units are to be regarded as the
standard. The values given in parentheses are for informa-
tion only.

1.4 This standard does not purport to address all of the
safety concerns, if any, associated with its use. It is the
responsibility of the user of this standard to establish appro-
 priate safety and health practices and determine the applica-
bility of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:

D979 Practice for Sampling Bituminous Paving Mixtures
D1188 Test Method for Bulk Specific Gravity and Density
of Compacted Bituminous Mixtures Using Coated
Samples
D3203 Test Method for Percent Air Voids in Compacted
 Dense and Open Bituminous Paving Mixtures
D3666 Specification for Minimum Requirements for Agen-
cies Testing and Inspecting Road and Paving Materials
D4753 Guide for Evaluating, Selecting, and Specifying
Balances and Standard Masses for Use in Soil, Rock, and
Construction Materials Testing
D5361 Practice for Sampling Compacted Bituminous Mix-
tures for Laboratory Testing

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 bulk density—as determined by this test method, the
mass of a metre cubed (or foot cubed) of the material at 25°C
(77°F).

3.1.2 bulk specific gravity—as determined by this test
method, the ratio of the mass of a given volume of material
at 25°C to the mass of an equal volume of water at the same
temperature.

4. Summary of Test Method

4.1 The specimen is immersed in a water bath at 25°C
(77°F). The mass under water is recorded, and the specimen is
taken out of the water, blotted quickly with a damp cloth towel,
and weighed in air. The difference between the two masses is
used to measure the mass of an equal volume of water at 25°C.

4.2 This test method provides guidance for determination of
the oven dry or thoroughly dry mass of the specimen. The bulk
specific gravity is calculated from these masses. Then the
density is obtained by multiplying the specific gravity of the
specimen by the density of the water.

5. Significance and Use

5.1 The results obtained from this test method can be used
to determine the unit weight of compacted dense bituminous
mixtures and in conjunction with Test Method D3203, to obtain
percent air voids. These values in turn may be used in
determining the relative degree of compaction.

5.2 Since specific gravity has no units, it must be converted
to density in order to do calculations that require units. This
conversion is made by multiplying the specific gravity at a
given temperature by the density of water at the same tempera-
ture.
6. Apparatus
6.1 Balance, with ample capacity, and with sufficient sensitivity to enable bulk specific gravities of the specimens to be calculated to at least four significant figures, that is, to at least three decimal places. It shall be equipped with a suitable apparatus to permit weighing the specimen while suspended in water. To avoid erroneous readings by undue displacement of water, use wire or fish line of the smallest practical size to suspend the specimen and holder. Do not use chains, strings, or sash cords. The balance shall conform to Guide D4753 as a Class GP2 balance.

Note 2—Since there are no more significant figures in the quotient (bulk specific gravity) than appear in either the dividend (the mass of the specimen in air) or the divisor (the mass of the volume of water equal to the volume of the specimen, obtained from the difference in weight of the saturated surface-dry specimen in air and in water), this means that the balance must have a sensitivity capable of providing both mass values to at least four figures. For example, a sensitivity of 0.1 g would provide four significant figures for mass in the range from 100.1 to 999.9 g.

6.2 Water Bath, capable of maintaining a temperature of 25 ± 1°C (77 ± 1.8°F) for immersing the specimen in water while suspended, equipped with an overflow outlet for maintaining a constant water level. The use of an overflow outlet is mandatory.

Note 3—The water bath does not need to be a sophisticated device. Any method that maintains 25°C ± 1°C can be used including tempering, aquarium heaters, stirrers, or other devices.

6.3 Calibration or standardization requirements of the apparatus used in this test, including balance, temperature indicating devices and drying apparatus shall be in accordance with the requirements in Practice D3666.

7. Sampling
7.1 Specimens may be either laboratory-molded bituminous mixtures or from bituminous pavements.
7.2 Obtain field samples in accordance with Practice D970.
7.3 Pavement specimens shall be taken from pavements with a core drill, diamond or a carborundum saw, or by other suitable means, in accordance with Practice D5361.

8. Test Specimens
8.1 Size of Specimens—It is recommended (1) that the diameter of cylindrically molded or cored specimens, or the length of the sides of sawed specimens, be at least equal to four times the maximum size of the aggregate; and (2) that the thickness of specimens be at least one and one half times the maximum size of the aggregate.

8.2 Care shall be taken to avoid distortion, bending, or cracking of specimens during and after removal from pavements or mold. Specimens shall be stored in a safe, cool place.

8.3 Specimens shall be free of foreign materials such as seal coat, tack coat, foundation material, soil, paper, or foil. When any of these materials are visually evident, they shall be removed by sawing. Wire brushing to remove paper, soil, and foil is acceptable if all traces of the materials are eliminated.

8.4 If desired, specimens may be separated from other pavement layers by sawing or other satisfactory means.

9. Procedure
9.1 For Cores and for Other Specimens that May Contain Moisture or Solvent—Only specimens that are known to be thoroughly dry (that is, laboratory-prepared dried specimens) are to be tested in accordance with 9.2. All others are assumed to contain moisture or solvent and are to be tested in accordance with 9.1. The sequence of testing for 9.1 is: in water, saturated-surface dry, dry.

9.1.1 Mass of Specimen in Water—Completely submerge the specimen in the water bath at 25 ± 1°C (77 ± 1.8°F) for 3 to 5 min then determine the mass by weighing in water. Designate this mass as C. If the temperature of the specimen differs from the temperature of the water bath by more than 2°C (3.6°F), the specimen shall be immersed in the water bath for 10 to 15 min, instead of 3 to 5 min.

9.1.2 Mass of Saturated Surface-Dry Specimen in Air—Surface dry the specimen by blotting quickly with a damp cloth towel and then determine the mass by weighing in air. Designate this mass as B.

9.1.3 After determining the mass in water and in a saturated-surface-dry condition, thoroughly dry the specimen to a constant mass at 110 ± 5°C (230 ± 9°F). Allow the specimen to cool and weigh in air. Designate this mass as A. Other methods may be used to dry the specimen as long as a constant mass is achieved (mass repeats within 0.1%).

Note 4—Drying the specimen at the required temperature of 110°C (230°F) will change the characteristics and shape of the specimen. This will make the specimen unsuitable for further testing. Drying the specimen at a reduced temperature such as 52°C (125°F), in order to keep it intact, will not meet the requirements of this test method.

9.1.3.1 Practice D7227, microwave drying or other approved methods may be used to dry the specimen if the specimen is not over-heated and documentation exists showing that the results are equivalent to oven drying. The interval of time between readings to determine constant mass must be sufficient to ensure that all moisture and solvent has been removed. This interval is dependent on the size of the specimen and can be determined by experimentation and confirmed with the oven-dried comparisons. Documentation must exist to validate the intervals.

9.2 For Laboratory-Prepared Thoroughly Dry Specimens:
9.2.1 Mass of Dry Specimen in Air—Determine the mass by weighing the specimen after it has been standing in air at room temperature for at least 1 h. Designate this mass as A.

9.2.2 Mass of Specimen in Water—Use the same procedure as described in 9.1.1.

9.2.3 Mass of Saturated Surface-Dry Specimen in Air—Surface dry the specimen by blotting quickly with a damp cloth towel and then determine the mass by weighing in air. Designate this mass as B.

10. Calculation
10.1 Calculate the bulk specific gravity of the specimen as follows:

\[
\text{Bulk Sp gr} = \frac{A}{(B - C)}
\]
where:

\[ A = \text{mass of the dry specimen in air, g;} \]
\[ (B - C) = \text{mass of the volume of water for the volume of the specimen at } 25^\circ C; \]
\[ B = \text{mass of the saturated surface-dry specimen in air, g; and} \]
\[ C = \text{mass of the specimen in water, g.} \]

10.2 Calculate the density of the specimen as follows:

\[ \text{Density} = \frac{\text{Bulk sp.gr} \times 997.0 \text{ (or 62.24)}}{\frac{B - A}{B - C} 	imes 100} \] (2)

where:

\[ 997.0 = \text{density of water in kg/m}^3 \text{ at } 25^\circ C \text{ (0.9970 g/cm}^3 \text{)} \]

10.3 Calculate the percent water absorbed by the specimen (on volume basis) as follows:

\[ \text{Percent water absorbed by volume} = \frac{B - A}{B - C} \times 100 \] (3)

10.4 If the percent water absorbed by the specimen in 10.3 exceeds 2 %, use Test Method D1188 or Test Method D6752.

10.5 This test method has been written expressing density in kilograms per cubic metre. Conversion to express the density in pounds per cubic foot is acceptable.

11. Report

11.1 Report the following:

11.1.1 Bulk specific gravity of the mixture to the third decimal place as bulk specific gravity at 25°C,

11.1.2 Density of the mixture with four significant figures in kg/m^3 or lb/ft^3 as density at 25°C,

11.1.3 Type of mixture,

11.1.4 Size of sample, and

11.1.5 Water absorption, %.

12. Precision and Bias

12.1 Precision:

12.1.1 Single Operator Precision—The single operator standard deviations (1σ limits) for specimens prepared in accordance with 9.2, for mixtures containing aggregate with absorption of less than 1.5 %, are shown in Table 1. The results of two properly conducted tests on the same material, by the same operator, using the same equipment, should be considered suspect if they differ by more than the d2s single operator limits shown in Table 1.

12.1.2 Multilaboratory Precision—The multilaboratory standard deviations (1σ limits) for specimens prepared in accordance with 9.2, for mixtures containing aggregate with absorption of less than 1.5 %, are shown in Table 1. The results of two properly conducted tests on the same material, by different operators, using different equipment, should be considered suspect if they differ by more than d2s multilaboratory limits shown in Table 1.

12.2 Bias—No information can be presented on the bias of the procedure because no material having an accepted reference value is available.

13. Keywords

13.1 air voids; compaction; density; specific gravity; unit weight

### Table 1: Precision Estimator

<table>
<thead>
<tr>
<th>Test Type</th>
<th>1σ limit</th>
<th>2σ limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Operator Precision</td>
<td>0.006</td>
<td>0.029</td>
</tr>
<tr>
<td>12.5-mm nominal max agg</td>
<td>0.013</td>
<td>0.037</td>
</tr>
<tr>
<td>19.0-mm nominal max agg</td>
<td>0.015</td>
<td>0.042</td>
</tr>
<tr>
<td>Multilaboratory Precision</td>
<td>0.015</td>
<td>0.042</td>
</tr>
<tr>
<td>12.5-mm nominal max agg</td>
<td>0.015</td>
<td>0.042</td>
</tr>
<tr>
<td>19.0-mm nominal max agg</td>
<td>0.015</td>
<td>0.042</td>
</tr>
</tbody>
</table>

*: Based on an interlaboratory study conducted under the ACHRP Project 9-29 involving 150-mm diameter specimens with 4.5 % air voids, 20 laboratories, two materials (a 12.5-mm mixture and a 19.0-mm mixture), and three replicates.

The precision statement in 12.1 was derived from data resulting from laboratories that compacted samples sent out by the AMRL.

SUMMARY OF CHANGES

Committee D04 has identified the location of selected changes to this standard since the last issue (D2726 - 08) that may impact the use of this standard. (Approved June 1, 2009.)

(1) Added new Section 6.3.

(2) Revised Section 8.3.

Committee D04 has identified the location of selected changes to this standard since the last issue (D2726 - 05a) that may impact the use of this standard. (Approved July 1, 2008.)

(1) Added Practice D7227 to Section 2 and 9.1.3.1.

(2) Modified 8.3.
Standard Test Method for Percent Air Voids in Compacted Dense and Open Bituminous Paving Mixtures

This standard is issued under the fixed designation D3203; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers determination of the percent air voids in compacted dense and open bituminous paving mixtures.

1.2 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:

D 1188 Test Method for Bulk Specific Gravity and Density of Compacted Bituminous Mixtures, Using Paraffin-Coated Specimens
D 2041 Test Method for Theoretical Maximum Specific Gravity of Bituminous Paving Mixtures
D 2726 Test Method for Bulk Specific Gravity and Density of Non-Absorbent Compacted Bituminous Mixtures
D 3549 Test Method for Thickness or Height of Compacted Bituminous Paving Mixture Specimens
D 4460 Practice for Calculating Precision Limits Where Values are Calculated from Other Test Methods
D 6752 Test Method for Bulk Specific Gravity and Density of Compacted Bituminous Mixtures Using Automatic Vacuum Sealing Method
D 6857 Test Method for Maximum Specific Gravity and Density of Bituminous Paving Mixtures Using the Automatic Vacuum Sealing Method
E 12 Terminology Relating to Density and Specific Gravity of Solids, Liquids, and Gases

3. Terminology

3.1 The terms specific gravity and density used in this test method are in accordance with Terminology E 12.

3.2 Definitions:

3.2.1 air voids—the pockets of air between the bitumen-coated aggregate particles in a compacted bituminous paving mixture.

3.2.2 dense bituminous paving mixtures—bituminous paving mixtures in which the air voids are less than 10 % when compacted.

3.2.3 open bituminous paving mixtures—bituminous paving mixtures in which the air voids are 10 % or more when compacted.

3.2.3.1 Discussion—For borderline cases, a bituminous paving mixture shall be designated an open bituminous paving mixture if the calculated percent air voids, based on either 6.1 or 6.2, is 10 % or more.

4. Significance and Use

4.1 The percent of air voids in a bituminous mixture is used as one of the criteria in the design methods and for evaluation of the compaction imparted in bituminous paving projects.

5. Sampling

5.1 Samples for testing shall consist of specimens from laboratory molded mixtures or cores from field compacted mixtures.

6. Procedure

6.1 For dense bituminous paving mixtures, determine the bulk specific gravity of the compacted mixture by Test Method D 1188, by Test Method D 2726, or by Test Method D 6752. Determine the theoretical maximum specific gravity by Test Method D 2041 or by Test Method D 6857 on a comparable bituminous mixture to avoid the influence of differences in gradation, asphalt content, and so forth.

6.2 For open bituminous mixtures, determine the density of a regularly shaped specimen of compacted mixture from its dry mass (in grams) and its volume (in cubic centimetres). Obtain the height of the specimens by Test Method D 3549. Measure the diameter of the specimen at four locations and average.
Calculate the volume of the specimen based on the average height and diameter measurement. Convert the density to bulk specific gravity by dividing by \( 0.9707 \) g/cm\(^3\) or 997 kg/m\(^3\), the density of water at 25°C (77°F). Determine the theoretical maximum specific gravity by Test Method D 2041 on a comparable bituminous mixture to avoid the influence of differences in gradation, asphalt content, etc.

6.3 For borderline cases, a bituminous paving mixture shall be designated an open bituminous paving mixture if the calculated percent air voids, based on either 6.1 or 6.2, is 10% or more.

6.4 For referee purposes, determine both the bulk specific gravity and the theoretical maximum specific gravity on aliquot portions of the same sample of compacted bituminous paving mixture.

7. Calculation

7.1 Calculate the percent air voids in a compacted bituminous paving mixture as follows:

\[
\text{Percent air voids} = 100 \left( 1 - \frac{\text{bulk specific gravity}}{\text{theoretical maximum specific gravity}} \right)
\]

(1)

8. Precision and Bias

8.1 The precision of this test method depends on the precision of test methods for bulk specific gravity and theoretical maximum specific gravity. It is computed by a procedure described in Practice D 4440. Since the computation for percent air voids in 7.1 involves the quotient of bulk specific gravity divided by the theoretical maximum specific gravity, the quotient formula is used:

\[
\sigma_{xy} = \sqrt{\frac{\sigma_x^2 \sigma_y^2}{\sigma_{xy}^4} + \frac{\sigma_x^2 + \sigma_y^2}{\sigma_{xy}^2}}
\]

(2)

where:

\( \sigma_x \) = standard deviation for determining precision limits of test results based on the quotient of test results from Test Method D 1188, D 2726, or D 6752, and Test Method D 2041 or D 6857,

\( \mu_x \) = mean (average) of \( x \) standard test results (bulk specific gravity, Test Method D 1188, D 2726, or D 6752),

\( \gamma \) = mean (average) of \( y \) standard test results (theoretical maximum specific gravity, Test Method D 2041 or D 6857),

\( \sigma_y \) = standard deviation from the precision statement of \( y \) standard test results (bulk specific gravity, Test Method D 1188, D 2726, or D 6752), and

\( \sigma_{xy} \) = standard deviation from precision statement of \( y \) standard test results (theoretical maximum specific gravity, Test Method D 2041 or D 6857).

8.2 Criteria for judging the acceptability of percent air voids test results would be presented in the form:

<table>
<thead>
<tr>
<th>Operator Precision</th>
<th>Standard Deviation ( \sigma_{xy} )</th>
<th>Acceptable Range of Two Results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( 2.8 \sigma_{xy} )</td>
<td></td>
</tr>
</tbody>
</table>

APPENDIX

(Nondemandatory Information)

X1. EXAMPLE CALCULATION OF PRECISION

X1.1 Assume the following precision data:

Bulk specific gravity, \( x \)

<table>
<thead>
<tr>
<th>Average</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.485</td>
<td>0.067</td>
</tr>
</tbody>
</table>

Theoretical maximum specific gravity, \( y \)

<table>
<thead>
<tr>
<th>Average</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.523</td>
<td>0.004</td>
</tr>
</tbody>
</table>

Then using the equation in 8.1:

\[
\sigma_{xy} = \sqrt{\frac{(2.523)^2 (0.007)^2 + (2.423)^2 (0.004)^2}{(2.523)^4}}
\]

\[= 0.00316 \quad (X1.1)\]

This value is in terms of air voids; therefore it should be multiplied by 100 to convert it into percentage. Therefore:

\[
\sigma_{xy} = 0.00316(100) = 0.32 \%
\]

(1.12)