Colorado Procedure 85-13

Standard Method of Test for

Asphalt Cement Content of Asphalt Mixtures by the Nuclear Method

(This procedure is based upon AASHTO T 287-06. AASHTO T 287-06 or any subsequent revision may not be used in place of this procedure.)

1. SCOPE

1.1 This method covers the determination of the asphalt cement content of asphalt concrete mixtures with a nuclear asphalt content gauge.

1.2 The values stated in English units are to be regarded as the standard. The metric equivalents of English units may be approximate.

1.3 This test method involves potentially hazardous materials, operation and equipment. This method does not address the safety concerns associated with its use. All operators will be trained in radiation safety prior to operating nuclear gauges.

2. REFERENCED DOCUMENTS

2.1 *Colorado Procedures:*

- CP 30 Sampling of Aggregates
- CP 32 Reducing Field Samples of Aggregate to Testing Size
- CP 41 Sampling Hot Mix Asphalt
- CP 43 Determining Moisture (Water) or Volatile Distillates Content of Bituminous Paving Mixtures
- CP 55 Reducing Field Samples of Hot Mix Asphalt to Testing Size

2.2 *Colorado Laboratory Procedures:*

- CP-L 5115 Preparing and Determining the Density of Bituminous Mixture Test Specimens Compacted by the Superpave Gyratory Compactor

2.3 *AASHTO Procedures:*

- T 40 Sampling Bituminous Materials

2.4 *Manufacturer's Instruction Manual*

3. SIGNIFICANCE AND USE

3.1 This method is used for rapidly determining the asphalt content of asphalt paving mixtures. Testing can be completed in a matter of minutes so that adjustments, if necessary, can be made in the asphalt metering system with a limited amount of mix production. The procedure is useful in the determination of asphalt content only, as it does not provide extracted aggregate for gradation analysis.

3.2 This procedure determines the asphalt binder content of a test sample by comparing the measured asphalt binder content with previously established correlation data. The asphalt binder content is expressed as a percentage of the mass of the asphalt mixture.

3.3 Accurate results are dependent upon proper correlation of the nuclear gauge to the material being tested. This procedure is sensitive to the type and gradation of the aggregate, hydrated lime and the percentage and source of the asphalt binder.

3.4 This procedure measures the total amount of hydrogen in a sample, including hydrogen present in the form of water. Unless the test sample is completely free of moisture, the percentage of moisture must be determined as outlined in Subsection 10.2 and a correction shall be made to compensate for the moisture.

3.5 This procedure may be used with reclaimed asphalt pavement (RAP) incorporated into the mixture, if approved by the Region Materials Engineer, provided that the RAP is of uniform gradation, asphalt content, and asphalt type. When RAP is used, the RAP should be mixed in the correlation samples at the same rate that will be used in the asphalt concrete mixture being tested.

4. APPARATUS

4.1 Nuclear Asphalt-Content (AC) Gauge.

4.1.1 Variability of the AC Gauge at 6 percent asphalt content shall be no greater than 0.05 percent for a 4-minute count.

4.1.2 The variability of the AC Gauge is determined from the slope of the correlation curve and the standard deviation of the count rate. Variability is calculated as follows:

$$v = \frac{s.d.}{s}$$

Where:

v = AC Gauge variability, in percent asphalt,
s.d. = Standard Deviation, in counts per automatically timed period,
s = Slope, in counts per percent asphalt.

The standard deviation is calculated from 20 individual automatically timed readings (per manufacturer's instructions for operation of the equipment). Counts are taken on a sample with asphalt cement content within ± 0.5 percent of the mix design.

4.1.3 The range of control mix shall be between 2 and 14 percent asphalt cement by weight.

4.2 Sample Pans - Three or more stainless-steel pans. Dimensions as specified by the gauge manufacturer. Sample pans with excessive asphalt cement residue, visible damage, or deformity shall not be used. When cleaning agents are used on the sample pans they shall be washed with water and dried prior to use.

NOTE 1: The residue left by the cleaning agents may contain hydrogen that can affect nuclear gauge readings.

4.3 Balance - Capable of weighing to 15 kg (33 lb), readable to 0.1 g.

4.4 Oven - Capable of heating to 350ºF ± 5º (177ºC ± 3º).

4.5 Straightedge - Steel, approximately 18 in. (450 mm) in length.

4.6 Plywood - 3/4 in. (20 mm) or heavier, or metal plate 3/8 in. (10 mm) or heavier having an area slightly larger than the top of the sample pans or wooden survey stake longer than the width of the sample pan.

4.7 Assorted spoons, spatulas, and mixing bowls.

4.8 Thermometer - Temperature range of 50ºF to 500ºF (10ºC to 300ºC).

5. PRECAUTIONS

5.1 The nuclear asphalt-content gauge may be sensitive to outside influence and therefore:

5.1.1 Any other source of neutron radiation shall be kept at least 33 ft (10 m) from the equipment.

5.1.2 The space within 3 foot of the AC gauge shall be kept free of hydrogenous materials such as coffee cups, water, oil, WD40, asphalt, or plastic materials.

5.1.3 All personnel shall be kept at least 3 feet away from the AC gauge during testing.

5.1.4 The AC gauge shall not be located within 3 ft of any water supply tanks, fuel tanks, or other liquid containers subject to fluctuating liquid levels.

5.2 Moving the AC gauge to a different location may cause a change in the background radiation measurements. New background measurements and possibly a new correlation will be necessary prior to use.

6. SAMPLING

6.1 Obtain samples of aggregate in accordance with CP 30. Reduce samples of aggregate to testing size according to CP 32.

6.2 Obtain samples of asphalt binder in accordance to AASHTO T 40.

6.3 Obtain samples of the freshly produced HMA in accordance with CP 41. Reduce samples of HMA to testing size according to CP 55.

7. STANDARDIZATION

7.1 All nuclear devices are subject to long-term aging of the radioactive source, detectors, and other electronic systems, which may change the relationship between count rate and asphalt content. Because of this aging, new correlation curves shall be run each construction season. Changes in the surroundings of the asphalt content gauge (Subsection 5.1.1 to 5.2) may also produce increases or decreases in count rate. In order to minimize these effects, background counts must be taken at least once per day.

7.2 Turn the Asphalt Content Gauge on and allow a 20 minute warm up period before using the gauge. Perform a background test of at least 8 minutes with an empty chamber and record the background count on the Nuclear Asphalt Content Gauge Log.

For Troxler gauges a variation of less than or equal to 1 percent from the previous background count is acceptable. If the variation is greater than 1 percent, check for conditions identified in Subsection 5.1.1 to 5.2 and repeat the test. If the variation remains, follow Subsection 7.4.

For CPN gauges a CHI value (acronym from gauge display) of 1.00 ± 0.25 is acceptable. If the CHI value is outside the range check for conditions identified in Subsection 5.1.1 to 5.2 and then repeat the test. If the CHI value remains outside the range follow Subsection 7.4.

7.3 Verify gauge stability by performing a statistical stability test on all new or repaired AC Gauges prior to use and once per month when the gauge is in use. A failing statistical stability test should be repeated after ensuring that the chamber is empty and checking for the conditions identified in Subsections 5.1.1 to 5.2. If the test still fails, follow Subsection 7.4.

7.4 If an AC Gauge has failed either the background test or the statistical stability test, contact the On-Site Radiation Safety Officer, or contact the manufacturer of the gauge for guidance.

NOTE 2: If the equipment is being used either continuously or intermittently during the day, it is best to leave the power on during the day to prevent having to repeat the background count. This may also provide more stable and consistent results.

8. CORRELATION PAN PREPARATION

8.1 This method is sensitive to the type of aggregate, percentage and source of asphalt cement, aggregate gradation, and all additives, including hydrated lime. Accordingly, a correlation must be developed for each mix type. The correlation will be established with three or more points. A baseline dry aggregate count must also be taken to determine whether changes in aggregate properties are affecting the asphalt cement content determinations.

8.1.1 Sample the aggregate at the plant in accordance with Subsection 6.1. The aggregate shall be oven dried at 300ºF ± 15º (149ºC ± 8º) to constant weight. The aggregate may be a composite generated from individual components by percentage of weight according to the mix design or a cold feed combined aggregate sample (without hydrated lime added) from an HMA production facility. The cold feed combined aggregates' conformance to the mix design gradation targets shall be verified prior to correlation. Enough aggregate shall be obtained for a minimum of one dry aggregate and three mix samples. Approximately 65 lb (30 kg) total will be required.

8.1.2 Hydrated lime, if required by the mix design, shall be added to the aggregate in the laboratory.

8.2 Dry Aggregate Count:

8.2.1 A dry aggregate count should be made often enough to ensure that changes in aggregate do not occur unnoticed (approximately once per week). If a change greater than ± 0.5 percent occurs, a new correlation shall be run.

8.2.2 Place the dry hot aggregate in a tared sample pan in two equal layers.

8.2.3 Use a spatula to distribute the aggregate uniformly, so that the coarse and fine aggregate do not segregate.

NOTE 3: Too much spading can cause the fines to migrate to the bottom, resulting in excessive sample weight.

8.2.4 Raise and drop the pan approximately one inch, four times. Be sure that the pan bottom strikes evenly.

8.2.5 Fill the pan with the second layer slightly above the top rim.

8.2.6 Raise and drop the pan approximately one inch, four times.

8.2.7 Place a straightedge firmly across the rim and use a sawing motion to strike off the surface of the sample, so that it is flush with the rim. Gaps between the straight edge and the sample shall be filled with fine aggregate and the sample leveled. Do not compact the sample. Obtain and record the temperature and weight of the sample.

8.2.8 Obtain a 16-minute sample count following the gauge manufacturer's instructions. This count will be used to determine if changes occur in the aggregate used during construction.

8.3 There are two methods used to prepare the sample pans used for correlation. Method A is used when each laboratory prepares and tests the pans. Method B is used when the sample pans are prepared in the Contractor's lab and then used for the correlation curve generation in a CDOT lab. The Region Materials Engineer will designate which method will be used.

Method A

8.3.1 Heat all bowls, sample pans, tools, aggregate, and asphalt binder to the mixing temperature listed in CP-L 5115 for the asphalt binder being used. An initial or "butter" mix is required to condition the mixing equipment. Mix a minimum of three asphalt concrete samples to cover the approximate range of the design asphalt content. Mix one at the design asphalt content, one at 1.0 percent above and one at 1.0 percent below, or at other percentages as required to cover the range of expected use. Use the same source, grade and type of asphalt binder that will be used in the asphalt concrete mixture to be tested. All elements of the mix design must be utilized, including hydrated lime.

NOTE 4: It is recommended that the design optimum asphalt content sample be mixed and placed in the sample pan first to determine the test weight for all samples.

8.3.2 Fill the sample pan one-half full, evenly distributing the sample in the pan.

8.3.3 Level the asphalt concrete mixture with a trowel or spatula.

8.3.4 Fill the remainder of the pan so that the asphalt concrete mixture is mounded above the top of the pan. Record the weight of the asphalt concrete mixture in the pan. This is the weight that all correlation and test samples will be measured.

8.3.5 Use a metal plate, plywood, or survey stake to consolidate the asphalt concrete mixture until it is even with the top edge of the pan. Make sure that excessive voids are not visible in the corners of the pan. All specimens shall be compacted at a temperature between 250ºF - 300ºF (121ºC - 149ºC).

NOTE 5: For AC gauges that do not have temperature compensation capability, obtain and record the temperature of the sample. This is the temperature ± 10ºF (± 6ºC) at which all samples and correlation pans will be measured.

8.3.6 Prepare the remainder of the correlation sample pans following the procedures of 8.3.1 thru 8.3.5. Use the same weight of asphalt concrete mixture in each pan.

Method B

8.3.7 CDOT personnel will witnesses the Contractor's laboratory prepare the correlation sample pans following the procedures of 8.3.1 thru 8.3.6.

8.3.8 When CDOT personnel cannot witness the Contractor's laboratory prepare the correlation sample pans; CDOT personnel will prepare a sample at optimum AC content following the procedures of 8.3.1 thru 8.3.5.

8.3.8.1 At the completion of procedures 9.1 thru 9.5 the CDOT prepared sample pan will be tested following the procedures of 10.9 and 10.10. If the gauge result varies by more than 0.20% from the optimum AC content, a new gauge correlation is required.

9. CORRELATION GENERATION:

9.1 Follow the gauge manufacturer's procedures to start a new correlation.

NOTE 6: Most gauge manufacturers use the term calibration instead of correlation for preparing a correlation curve.

9.2 Place the sample pan in the gauge and set the count time for a 16-minute count.

Proceed following manufacturer's instructions for operation of the equipment and the sequence of operation.

9.3 Repeat Subsection 9.2 for the remainder of the correlation samples.

9.4 Prepare a correlation curve by plotting the correlation asphalt concrete mixture sample readings versus asphalt content on linear graph paper, choosing convenient scale factors for counts and asphalt content. Connect the points with a straight line. On most gauges the equation (slope and intercept) for this line is generated internal to the gauge. A correlation will be considered acceptable if the correlation factor is greater than or equal to 0.9990.

$$\text{Correlation factor} = \sqrt{1 - \frac{\sum_i (Y_i - \hat{Y}_i)^2}{\sum_i (Y_i - \bar{Y})^2}}$$

Where:

Y_i = Actual percent asphalt values for each sample,

$\hat{Y}_i$ = Calculated percent asphalt values from curve,

$\bar{Y}$ = Mean value of the actual percentages asphalt,

i = Number of correlation samples.

9.5 At the conclusion of procedure 9.4 perform an additional background count to compare with the original background count performed in Subsection 7.2. A variation of greater than 1.0 percent from the previous background count is unacceptable.

NOTE 7: The formula to calculate the slope and intercept of a straight line is

$$y = mx + b$$

The slope, m, is calculated using the following equation.

$$\text{Slope}(m) = \frac{y_2 - y_1}{x_2 - x_1}$$

The intercept, b, is calculated using the following equation.

$$b = y_1 - mx_1$$

Where for Troxler Gauges:

x_1 = Measured count of Point 1/1000,
x_2 = Measured count of Point 2/1000,
y_1 = Percent AC of Point 1,
y_2 = Percent AC of Point 2.

Where for CPN Gauges:

x_1 = Percent AC of Point 1,
x_2 = Percent AC of Point 2,
y_1 = Measured count of Point 1,
y_2 = Measured count of Point 2.

10. DETERMINING ASPHALT CONTENT OF HMA SAMPLES

10.1 Sample the HMA in accordance with Section 6.3.

10.2 The sample portion to be tested should provide approximately 17.6 lb. (8 kg) per test unit.

10.3 The test sample shall be checked for moisture content. The percentage moisture determined must be subtracted from the asphalt content percentage as indicated by the nuclear AC gauge. Determine the amount of moisture in the mixture in accordance with CP 43 and CP 55.

10.4 Adjust the test sample temperature to 250°F - 300°F (121°C - 149°C).

10.5 Fill the sample pan one-half full; evenly distribute the sample in the pan.

10.6 Level the asphalt concrete mixture with a trowel or spatula.

10.7 Fill the remainder of the pan until the weight of the asphalt concrete mixture in the pan is equal to plus or minus 5 grams of the mass of mix in the samples used for correlation in Subsection 8.3.4. Record the weight of the asphalt concrete mixture in the pan.

10.8 Use a metal plate, plywood, or survey stake to compact the asphalt concrete mixture until it is even with the top of the pan.

NOTE 8: For AC gauges that do not have temperature compensation capability, obtain and record the temperature of the sample. The starting test temperature shall be 180°F to

290°F (82°C to 143°C) and within ± 10°F (± 6°C) of the correlation temperature.

10.9 Place the sample in the gauge. Set the gauge to take a single 16-minute count. Follow the manufacturer's instructions to obtain sample asphalt content.

10.10 Correct asphalt content for moisture content.

11. REPORT

11.1 The results are reported on the following CDOT forms:

11.1.1 CDOT Form #772, Nuclear Asphalt-Content Gauge Log (Example in Chapter 800).

11.1.2 CDOT Form #599, Nuclear Asphalt-Content Correlation (Example in Chapter 800).

11.1.3 CDOT Form #106, Asphalt Tests (Example in Chapter 800).