

DEPARTMENT OF TRANSPORTATION

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**PROVISIONAL METHOD OF TEST FOR MIXTURE DESIGN AND TESTING OF
PARTIAL DEPTH RECYCLING (PDR) OF ASPHALT PAVEMENTS USING
BITUMINOUS RECYCLING AGENTS AND ADDITIVES
EXPIRES 12/31/2024**

A. SCOPE

This test method describes the procedures for mixture design and testing for partial-depth recycling (PDR) of asphalt pavements using bituminous recycling agents and additives.

PDR consists of recycled layers between 0.25 feet minimum and 0.40 feet maximum.

The values stated in either International System of Units (SI units) or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

B. REFERENCES

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| AASHTO R 68 | Standard Practice for Preparation of Asphalt Mixtures by Means of the Marshall Apparatus |
| AASHTO R 76 | Standard Practice for Reducing Samples of Aggregate to Testing Size |
| AASHTO T 11 | Standard Method of Test for Materials Finer Than 75-micron (No. 200) Sieve in Mineral Aggregates by Washing |
| AASHTO T 27 | Standard Method of Test for Sieve Analysis of Fine and Coarse Aggregates |
| AASHTO T 49 | Standard Method of Test for Penetration of Bituminous Materials |
| AASHTO T 59 | Standard Method of Test for Emulsified Asphalts |

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|---------------------|---|
| AASHTO T 209 | Standard Method of Test for Theoretical Maximum Specific Gravity (Gmm) and Density of Hot-Mix Asphalt (HMA) |
| AASHTO T 245 | Standard Method of Test for Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus |
| AASHTO T 265 | Standard Method of Test for Laboratory Determination of Moisture Content of Soils |
| AASHTO T 269 | Standard Method of Test for Percent Air Voids in Compacted Dense and Open Asphalt Mixtures |
| AASHTO T 283 | Standard Method of Test for Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage |
| AASHTO T 308 | Standard Method of Test for Determining the Asphalt Binder Content of Hot Mix Asphalt (HMA) by the Ignition Method |
| AASHTO T 312 | Standard Method of Test for Preparing and Determining the Density of Hot-Mix Asphalt (HMA) Specimens by Means of the Superpave Gyrotory Compactor |
| AASHTO T 315 | Standard Method of Test for Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer (DSR) |
| AASHTO T 329 | Standard Method of Test for Moisture Content of Hot Mix Asphalt (HMA) by Oven Method |
| AASHTO T 331 | Bulk Specific Gravity (Gmb) and Density of Compacted Hot Mix Asphalt (HMA) Using Automatic Vacuum Sealing Method |
| ASTM D2172 | Standard Test Methods for Quantitative Extraction of Asphalt Binder from Asphalt Mixtures |
| ASTM D3203 | Standard Test Method for Percent Air Voids in Compacted Asphalt Mixtures |
| ASTM D5404 | Standard Practice for Recovery of Asphalt from Solution Using the Rotary Evaporator |
| ASTM D7196 | Standard Test Method for Raveling of Cold-Mixed Emulsified Asphalt Samples |
| California Test 105 | Calculations Pertaining to Gradings and Specific Gravities |

California Test 125 Sampling Highway Materials and Products Used in the Roadway Structural Sections

California Test 216 Relative Compaction of Untreated and Treated Soils and Aggregates

California Test 226 Method of Test for Moisture Content of Soils and Aggregates by Oven Drying

C. SIGNIFICANCE AND USE

This method is used in the preparation of the mix design and testing for partial-depth recycling (PDR) of asphalt pavements using bituminous recycling agents and additives. This method includes requirements for:

1. Obtaining field samples
2. Preparing pavement samples
3. Residual asphalt determination for emulsified asphalt
4. Asphalt binder selection and foaming parameters for foamed asphalt
5. Optimum moisture content and maximum density determination
6. Optimum asphalt recycling agent content
7. Obtaining production samples for quality tests
8. Quality testing of production samples
9. Reporting of results

D. APPARATUS

1. Compaction Equipment:
 - A. Gyrotory Compactor - A gyrotory compactor meeting the requirements of AASHTO T 312
 - B. Marshall Compactor – A Marshall compactor meeting the requirements of AASHTO R 68
2. Loading frame - A mechanical or hydraulic testing machine as specified in AASHTO T 283 to provide a range of accurately controllable rates of vertical deformation, including 50 mm/min (2 in./min)
3. Balance - A balance or scale accurate to 0.1 g and having a minimum capacity of 5 kg conforming to AASHTO M 231, Class G2

4. Sieves - Woven-wire cloth sieves that meet the designations required by the specifications and have square openings conforming to AASHTO M 92. Sieves: 1.5 in., 1.25 in., 1.0 in., 0.75 in., 0.5 in., #4, #8, #30, and #200
5. Metal Pans - Pans having a surface area of 75 to 100 in.², approximately 2 in. deep
6. Sieve Shaker - Any mechanical sieve shaking device that meets AASHTO T 27 requirements
7. Mixer - A pugmill style mixer capable of mixing up to 30 kg (66 lbs) of aggregate, sand, and fines as included in the sample of asphalt pavement and base material collected from the job site. The mixer shall also be able to provide an evenly distributed emulsion-coated or foamed asphalt material after 2 minutes of mixing
8. Ovens - A forced draft oven with free circulation of air capable of maintaining a range of temperatures between $40^{\circ} \pm 0.5^{\circ}\text{C}$ and $60^{\circ} \pm 1^{\circ}\text{C}$ ($104^{\circ} \pm 1^{\circ}\text{F}$ and $140^{\circ} \pm 2^{\circ}\text{F}$)
9. Water Bath - A water bath of sufficient size for immersing samples with a 100-mm (4 in.) water cover that can be maintained at $25^{\circ} \pm 1^{\circ}\text{C}$ ($77^{\circ} \pm 2^{\circ}\text{F}$) by suitable methods
10. Water Bath - A water bath of sufficient size for immersing samples with a 100-mm (4 in.) water cover that can be maintained at $40^{\circ} \pm 1^{\circ}\text{C}$ ($104^{\circ} \pm 2^{\circ}\text{F}$) by suitable methods
11. Calipers - Calipers with accuracy to measure the length and diameter of test specimens to the nearest 0.01 mm (0.0004 in.)
12. Thermometer - Thermometer capable of measuring temperatures from 0°C to 50°C (32°F to 122°F)
13. Containers - Airtight containers capable of holding 1.5 kg to 25 kg (3 lbs. to 55 lbs.) of recycled pavement materials
14. Breaking Head Apparatus - A Marshall testing jig meeting the requirements of AASHTO T 245
15. Steel loading strips with a concave surface having a radius of curvature equal to the nominal radius of the test specimen. For specimens 100 mm (4 in.) in diameter, the loading strips shall be 12.7 mm (0.5 in.) wide. The length of the loading strips shall exceed the thickness of the specimens. The edges of the loading strips shall be rounded to the appropriate radius of curvature by grinding

16. Vacuum Container - A vacuum container meeting the requirements of AASHTO T 209
17. Asphalt Foaming Equipment (additional): The laboratory material production method should closely simulate full-scale foamed asphalt production. Laboratory equipment should be capable of producing foamed asphalt at a rate from 50 g to 100 g per second. The laboratory equipment should have a thermostatically controlled chamber or vessel capable of holding at least 10 kg (22 lbs.) of asphalt binder at a temperature from 140°C to 180°C (285°F to 356°F). The laboratory equipment should have a compressed air supply capable of delivering up to 690 kPa (100 psi). The laboratory equipment should have a system for adding up to 5% cold water by weight of asphalt binder.

E. MATERIALS

1. Existing asphalt pavement samples for PDR projects
2. Supplemental aggregates if required in the design
3. Bituminous recycling agent shall be emulsified asphalt or PG graded asphalt binder
4. Additives shall be cement or lime
5. Water

F. OBTAINING FIELD SAMPLES

Obtain existing pavement materials for each mix design as required in the specifications. Samples shall be collected from a minimum of three locations. Samples shall be obtained per specification requirements or in absences thereof, equally spaced along the length of the pavement to be recycled.

Obtain reclaimed asphalt pavement samples from identified representative areas of the project by taking cores or removing slabs to the depth specified for in-place recycling shown in the project plans. Obtain approximately 450 lbs. of sample to be used for mix design.

The approximate number of cores required for each mix design based on the specified partial recycling depth is indicated in the following table:

Minimum Number of Cores required for 450 lbs. of sample based on PDR depth

| PDR depth (ft) | 0.25 | 0.30 | 0.35 | 0.40 |
|---------------------|------|------|------|------|
| 6 in. Diameter Core | 66 | 55 | 47 | 41 |
| 8 in. Diameter Core | 37 | 31 | 26 | 23 |

The approximate total area of pavement slabs required for each mix design based on the specified partial recycling depth is indicated in the following table:

Total Pavement Slab Area required for 450 lbs. of sample based on PDR depth

| PDR depth (ft) | 0.25 | 0.30 | 0.35 | 0.40 |
|------------------------|------|------|------|------|
| Minimum Slab Area (sf) | 14 | 12 | 10 | 8 |

Only the portion of the core representing the specified depth of the PDR shall be used. The excess material beyond the specified depth shall be removed by saw cutting. Slabs shall be reduced in size by saw cutting into sizes which can have excess thickness accurately removed by sawcut. It is recommended that slabs be sawcut into smaller sizes in the field for easier handling.

If pre-milling is specified above the PDR depth, the depth of milling shall be removed using the same process for removing excess material below the PDR depth.

Samples may also be obtained by milling the existing asphalt pavement. Milling depth must be consistent with the project design and milling speed must be the same as that typically followed on recycling projects to ensure that a representative grading is achieved. Use a milling machine with the same tooth configuration as the milling machine to be utilized during production.

All samples shall be properly labeled regarding location, sampling date, etc. Multiple cores from the same location may be grouped, packaged, and stored together.

G. PREPARING PAVEMENT SAMPLES

The suggested sample weights in this procedure are approximate and they may be increased or decreased as necessary to complete the testing described herein.

1. Break down or crush the asphalt pavement cores or slabs using a jaw crusher capable of crushing material passing the 1 in. sieve. Cold planed material shall be screened as required for the mix design.
2. Obtain sufficient samples of the crushed asphalt concrete for the mix design testing required.
3. Obtain representative samples of any required supplemental materials that will be added during the recycling process (i.e., aggregate or supplemental fines to improve gradation).
4. Dry the sampled materials to a constant weight in accordance with AASHTO T 329 at $60^{\circ} \pm 1^{\circ}\text{C}$ ($140^{\circ} \pm 2^{\circ}\text{F}$). If the asphalt concrete samples were obtained by crushing cores or slabs, dry the asphalt concrete and unbound materials separately.
5. For PDR projects with supplemental materials, split portions of the crushed asphalt concrete and blend in proportion to, recycling depth, and in situ density. The combined material is considered as the "recycled material."
6. Perform a sieve analysis on the prepared material in accordance with AASHTO T 11 and AASHTO T 27. The final gradation must meet the gradations shown in the following table:

| Sieve | Medium Gradation % Passing | Coarse Gradation % Passing |
|--------------|---------------------------------------|---------------------------------------|
| 1.25" | 100 | 100 |
| 1.0" | 98 – 100 | 98 – 100 |
| 0.75" | 93 – 97 | 83 – 87 |
| #4 | 48 – 52 | 38 – 42 |
| #8 | 35 – 40 | 25 – 30 |
| #30 | 8 – 12 | 3 – 7 |
| #200 | 1 – 3 | 0.5 – 2 |

7. If the gradation does not meet the gradation in Step 6, follow Asphalt Institute MS-2 Guidelines for fractioning materials. Adjust the fractionated material so the final gradation meets the above gradations.
8. Split out a minimum of two 10 kg (22 lbs.) and seven (for emulsified asphalt) or six (for foamed asphalt) 25 kg (55 lbs.) portions of the recycled material to complete the testing described below.

H. RESIDUAL ASPHALT DETERMINATION FOR EMULSIFIED ASPHALT

The emulsified asphalt used in the mix design shall be as required in the project specifications and shall meet the requirements of Section 94-1.02E of the Standard Specifications.

Laboratory production of the emulsified asphalt mixes must use the same emulsified asphalt from the same supplier that will be used during construction, as chosen by the contractor. If the residual asphalt content is not provided by the manufacturer, determine the residual asphalt content according to AASHTO T 59.

I. ASPHALT BINDER SELECTION AND FOAMING PARAMETERS FOR FOAMED ASPHALT

The asphalt binder used as a recycling agent shall conform to the requirements of the project specifications and shall conform to Section 92 of the Standard Specifications.

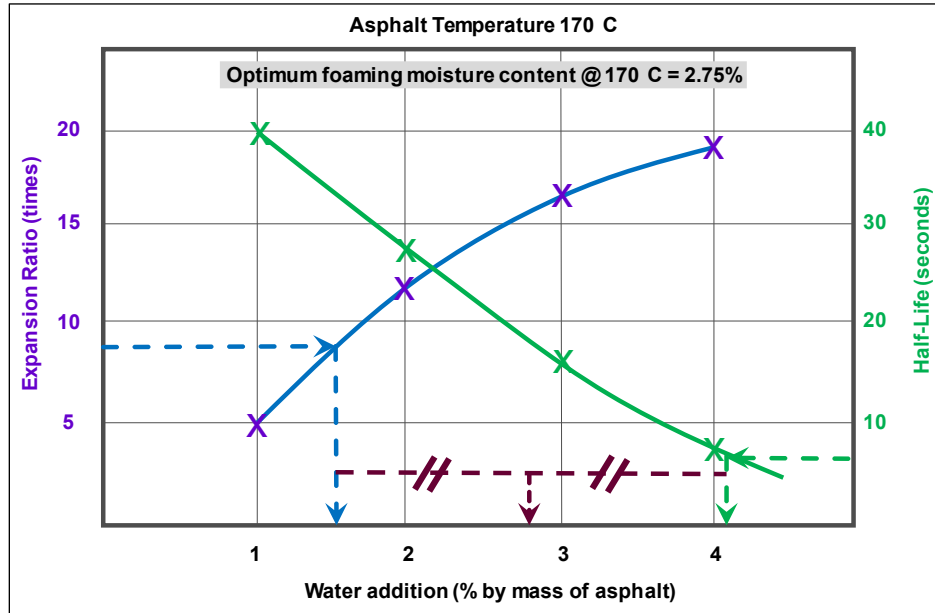
Laboratory production of the foamed asphalt must use the same asphalt binder that will be used during construction, including grade as specified in the project's special provisions and asphalt supplier as chosen by the contractor.

1. Prepare and calibrate laboratory asphalt foaming equipment in compliance with the manufacturer's instructions.
2. Load the asphalt binder into the laboratory foaming equipment and allow the unit to equilibrate temperature for a minimum of 1 hour and a maximum of 4 hours.
3. Select between 3 to 5 asphalt temperatures, depending on the familiarity with the binder source, at 10°C (18°F) increments bracketing the expected optimum temperature. The expected optimum temperature can be determined based on previous experience or a temperature of 160°C (320°F) can be used.

4. For each asphalt temperature, use at least 3 foamed asphalt water percentages between 1.0% and 4.0% in the laboratory asphalt foaming equipment to determine:
 - A. Expansion ratio - The ratio of maximum volume of foamed asphalt relative to the original volume of asphalt. Determine the height of 500 g of neat binder as the baseline. Measure the peak height of the asphalt during foaming and divide by the baseline height to determine the expansion ratio.
 - B. Half-life - The time measured in seconds for the foamed asphalt to subside to half of the maximum volume from the time the foam nozzle shuts off.

Note: The required minimum half-life and expansion ratio will depend on the likely recycled material temperature during construction. If recycling operations will be carried out when the material temperature is above 15°C (60°F), select a water percentage with a minimum expansion ratio of 8:1 and a half-life of at least 6 seconds. If colder temperatures are anticipated (between 10°C and 15°C [50°F and 60°F]), select the asphalt temperature and water percentage with a minimum expansion ratio of 10:1 and half-life of at least 8 seconds.

5. Plot the expansion ratio (primary y-axis) and the half-life (secondary y-axis) for each test temperature used. On each plot, mark the moisture contents required to meet the minimum expansion ratio and half-life requirements. The optimum foaming water content will be the midpoint between these two marks (example in the figure below shows the optimum foaming water content is 2.75%).



6. Choose the temperature and foaming water combination that provides an optimal expansion ratio and half-life for the mix design. If there are not at least two tests performed at temperatures above and below the determined optimum, repeat steps 2 to 5 increasing or decreasing the temperature in 10°C (18°F) increments.
7. If the expansion and half-life at the optimum foamed asphalt water percentage at the optimum temperature do not meet these requirements, select the temperature and foamed asphalt water percentage with the highest expansion ratio and half-life combination. Report all results.

J. OPTIMUM MOISTURE CONTENT AND MAXIMUM DENSITY DETERMINATION

Determine the optimum moisture content and maximum density using one of the following methods:

Method A - Preferred

1. Using a portion of the recycled aggregates, thoroughly mix the prepared materials with the additive as prescribed by the special provisions. (e.g., maximum 1.0% of Type II/V portland cement).
2. Pass the entire sample through a 0.75 in. sieve. Make a note of the percentage of material retained on the 0.75 in. sieve and then discard it.
3. Separate out 6 samples of 1,150 g (for 4 in. diameter mold) of material.
4. Add the starting moisture content to the first split sample and mix thoroughly. Choose a starting moisture content based on experience. For

partial-depth recycled materials, the starting moisture content is typically around 3 percent.

5. Place a paper disk in the bottom of a mold. Do not pre-heat the molds.
6. Add the sample to a mold and rod the material 10 to 15 times with a 5/8 in. rod in a circular motion, making sure to evenly distribute the rodding across the entire sample.
7. Place a paper disk on top of the rodded sample. Compact the specimen at room temperature ($25^{\circ} \pm 2^{\circ}\text{C}$ [$77^{\circ} \pm 4^{\circ}\text{F}$]) using one of the following methods:
 - A. Gyration (AASHTO T 312; 30 gyrations [600 kPa at 1.16°] in a 100 mm diameter mold).
 - B. Marshall (AASHTO T 245; 75 blows per face, in a 4 in. diameter mold).
8. Gently extrude the specimen from the mold and record the mass, height, and diameter of the specimen.
9. Clearly number each specimen.
10. Calculate the bulk density of the specimen using ASTM D3203, Section 6.2. Determine the moisture content per California Test 226.
11. Plot bulk dry density versus moisture content on a graph.
12. Repeat the steps 3 through 10 above on the remaining samples, adding 0.5 to 1.0% moisture by dry weight of recycled materials. A curve is developed indicating the material drops in bulk density with at least two successive moisture content increases. Develop a bulk density versus moisture content curve by plotting successive specimen data until all six specimens are done or until a curve is developed indicating a drop in bulk density.
13. Using the moisture-density relationship, determine the optimum moisture content and maximum dry density from the established curve.
14. Use this optimum moisture content and density for specimen preparation.
15. For emulsified asphalt, determine the water content required to reach optimum moisture content using the following equation:

$$\text{Water content (\%)} = a - (b - c)$$

Where:

- a = optimum moisture content as a percentage of the weight of dry aggregate
- b = estimated emulsified asphalt content as a percentage of the weight of dry aggregate. The final value is determined on completion of the mix design.
- c = residual asphalt content, determined in Section H, as a percentage of the weight of dry aggregate

Method B - Alternative

1. Repeat steps 1 and 2 as described in Method A.
2. Determine the optimum moisture content and maximum density of the prepared mixture according to California Test 216.
3. Use this optimum moisture content and density for specimen preparation.
4. For emulsified asphalt, determine the water content required to reach optimum moisture content using the following equation:

$$\text{Water content (\%)} = a - (b - c)$$

Where:

- a = optimum moisture content as a percentage of the weight of dry aggregate
- b = estimated emulsified asphalt content as a percentage of the weight of dry aggregate. The final value is determined on completion of the mix design.
- c = residual asphalt content, determined in Section H, as a percentage of the weight of dry aggregate

K. SPECIMEN PREPARATION PROCEDURE FOR EMULSIFIED ASPHALT

Prepare specimens for determining the optimum emulsified asphalt residue content by the Marshall stability method or by the indirect tensile strength method. Use the specified additive and additive content. If specimens are being prepared for "Report Only Indirect Tensile Strength Test" purposes, then follow the procedure in Section L.

1. Pass the entire sample through a 0.75 in. sieve. Record the percentage of oversized material and then discard it.

2. Quarter the material into 4 bulk samples. This requires approximately 25 kg (55 lbs.) of material.
3. Determine an appropriate range of residual asphalt contents by mass of dry aggregate to assess the mix design. For example: 2.1%, 2.3%, 2.5%, and 2.7% or 2.0%, 2.5%, 3.0%, and 3.5%.
4. Place one bulk sample into the pug mill, add the additive at the selected rate by weight of the dry aggregate (do not exceed 1%), and the water content calculated in Section J.
5. Add the first emulsified asphalt residue content determined in step 3 before mixing.
6. Mix the material for 4 minutes.
7. Remove the material from the pug mill and place into a bowl, covered by a lid or damp cloth to prevent evaporation of the mixing moisture.
8. Determine the mass of wet material needed to achieve the maximum dry density of the mix as determined in Section J to conform with the height requirements of AASHTO T 245.
9. Split the processed material into 8 samples at the mass determined and place each into a covered container to prevent evaporation of the mixing moisture. Place any unused material into a covered container.

Note: If compacting with a vibrating hammer, the processed material should be split into 16 samples to allow compaction in 3 lifts.

10. Place a paper disk in the bottom of a mold. Do not pre-heat the molds.
11. Add one of the split samples into a mold and rod the material 10 to 15 times with a 5/8 in. rod in a circular motion, making sure to evenly distribute the rodding across the entire sample.
12. Place a paper disk on top of the rodded sample. Compact the specimen at room temperature ($25^{\circ} \pm 2^{\circ}\text{C}$ [$77^{\circ} \pm 4^{\circ}\text{F}$]) using one of the following methods:
 - A. Gyration (AASHTO T 312; 30 gyrations [600 kPa at 1.16°] in a 100 mm diameter mold).
 - B. Marshall (AASHTO T 245; 75 blows per face, in a 4 in. diameter mold).
13. The target final specimen height should be $63.5 \pm 2.5 \text{ mm}$ ($2.5 \pm 0.1 \text{ in.}$).
14. Gently extrude the specimen from the mold and record the mass of the specimen.

15. Repeat steps 10 through 14 six additional times within 30 minutes of adding the water portion to the recycled material and additive.
16. Number each specimen clearly.
17. Repeat steps 4 through 16 three times with the three remaining emulsified asphalt residue contents.
18. Cure the compacted specimens and one remaining uncompact sample in a forced draft oven at $40^{\circ} \pm 1^{\circ}\text{C}$ ($104^{\circ} \pm 2^{\circ}\text{F}$) for 72 hours. If, after the 72-hour cure, the specimens have not reached constant mass (0.05% change in 2 hours), allow the samples to continue to cure until constant mass is reached checking each additional hour. Record the additional time required for cure.

Note: During curing, specimens must not be stacked or touching, and allowance must be made for air circulation around each specimen.

19. Remove the specimens from the oven and allow to cool to ambient temperature ($25^{\circ} \pm 2^{\circ}\text{C}$ [$77^{\circ} \pm 4^{\circ}\text{F}$]). When cooled, record the mass, diameter, and height of each specimen according to AASHTO T 269.
20. Determine the maximum theoretical specific gravity of the uncompact sample according to AASHTO T 209. Determine air voids in accordance with ASTM D3203.

L. SPECIMEN PREPARATION PROCEDURE FOR “REPORT ONLY” INDIRECT TENSILE STRENGTH TESTS FOR EMULSIFIED ASPHALT

1. Prepare 1 bulk sample. This requires approximately 6 kg (13 lbs.) of material.
2. Place the bulk sample into the pug mill, add the additive at the selected rate by weight of the dry aggregate (do not exceed 1%), and the water content calculated in Section J.
3. Add the optimum emulsified asphalt residue content determined in Section M, Step 6 below.
4. Complete Steps 6 through 16 in Section K.
5. Complete Steps 18 through 20 in Section K.

M. SPECIMEN PREPARATION PROCEDURE FOR FOAMED ASPHALT

Prepare specimens for determining the optimum foamed asphalt content by the indirect tensile strength or Marshall stability method. Use the specified additive and additive content. If specimens are being prepared for "Report Only Marshall Stability Tests" purposes, then follow the procedure in Section N.

1. Pass the entire sample through a 0.75 in. sieve. Record the percentage of oversized material and then discard it.
2. Quarter the material into 4 bulk samples. This requires approximately 25 kg (55 lbs.) of material.
3. Determine an appropriate range of foamed asphalt contents by mass of dry aggregate to assess in the mix design. For example, 2.1%, 2.3%, 2.5%, and 2.7% or 2.0%, 2.5%, 3.0%, and 3.5%.
4. Place one bulk sample into the pug mill, add the additive at the selected rate by weight of the dry aggregate (do not exceed 1%), and 75% of the water content calculated in Section J.
5. Mix the material for 3 minutes.
6. Add the first foamed asphalt content determined in step 3 while mixing and continue mixing for 30 seconds after the asphalt nozzle has switched off. Add the remaining 25% water to achieve the optimum moisture content and mix for an additional 30 seconds.
7. Remove the material from the pug mill and place into a bowl, covered by a lid or damp cloth to prevent evaporation of the mixing moisture.
8. Determine the mass of wet material needed to achieve the maximum dry density of the mix as determined in Section J to conform with the height requirements of AASHTO T 245.
9. Split the processed material into 8 samples at the mass determined and place each into a covered container to prevent evaporation of the mixing moisture. Place any unused material into a covered container.
10. Place a paper disk in the bottom of a mold. Do not pre-heat the molds.
11. Add one of the split samples into a mold and rod the material 10 to 15 times with a 5/8 in. rod in a circular motion, making sure to evenly distribute the rodding across the entire sample.
12. Place a paper disk on top of the rodded sample. Compact the specimen at room temperature ($25^{\circ} \pm 2^{\circ}\text{C}$ [$77^{\circ} \pm 4^{\circ}\text{F}$]) using one of the following methods:

- A. Gyration (AASHTO T 312; 30 gyrations [600 kPa at 1.16°] in a 100 mm diameter mold).
 - B. Marshall (AASHTO T 245; 75 blows per face, in a 4 in. diameter mold).
13. The target final specimen height should be 63.5 ± 2.5 mm (2.5 ± 0.1 in.).
14. Gently extrude the specimen from the mold and record the mass of the specimen.
15. Repeat steps 10 through 14 six additional times, and within 30 minutes of adding the water portion to the recycled material and additive.
16. Number each specimen clearly.
17. Repeat steps 4 through 16 three times with the three remaining foamed asphalt contents.
18. Cure the compacted specimens and one remaining uncompact sample in a forced draft oven at $40^\circ \pm 1^\circ\text{C}$ ($104^\circ \pm 2^\circ\text{F}$) for 72 hours. If after the 72-hour cure, the specimens have not reached constant mass (0.05% change in 2 hours), allow the samples to continue to cure until constant mass is reached checking each additional hour. Record the additional time required for cure.
- Note: During curing, specimens must not be stacked or touching, and allowance must be made for air circulation around each specimen.
19. Remove the specimens from the oven and allow to cool to ambient temperature ($25^\circ \pm 2^\circ\text{C}$ [$77^\circ \pm 4^\circ\text{F}$]). When cooled, record the mass, diameter, and height of each specimen according to ASTM D3203.
20. Determine the maximum theoretical specific gravity of the uncompact sample according to AASHTO T 209. Determine air voids in accordance with ASTM D3203.

N. SPECIMEN PREPARATION PROCEDURE FOR “REPORT ONLY” MARSHALL STABILITY TESTS FOR FOAMED ASPHALT

1. Prepare 1 bulk sample. This requires approximately 6 kg (13 lbs.) of material.
2. Place the bulk sample into the pug mill, add the additive at the selected rate by weight of the dry aggregate (do not exceed 1%), and 75% of the water content calculated in Section J.
3. Add the optimum foamed asphalt content determined in Section Q, Step 6 below.

4. Complete Steps 5 through 16 in Section M.
5. Complete Steps 18 through 20 in Section M.

O. DETERMINING OPTIMUM EMULSIFIED ASPHALT RESIDUE CONTENT USING MARSHALL STABILITY

Determine the optimum emulsified asphalt residue content by the Marshall stability and retained Marshall stability.

1. Use the specimens prepared in Section K.
2. Randomly separate the 7 specimens from each emulsified asphalt residue content into 2 groups of 3 specimens each plus one and condition them as follows:
 - A. For the dry test and one remaining specimen: Place specimens in a conditioning chamber or temperature-controlled room at $25^{\circ} \pm 2^{\circ}\text{C}$ ($77^{\circ} \pm 4^{\circ}\text{F}$) for 22 hours. Transfer the specimens to a second conditioning chamber set at $40^{\circ} \pm 1^{\circ}\text{C}$ ($104^{\circ} \pm 2^{\circ}\text{F}$) for 2 hours. Alternatively, place the specimens into individual impermeable plastic bags, seal them, and then place them in a water bath at $40^{\circ} \pm 1^{\circ}\text{C}$ ($104^{\circ} \pm 2^{\circ}\text{F}$) for 2 hours.
 - B. For the wet test: Place specimens on a rack in a water bath with a temperature of $25^{\circ} \pm 2^{\circ}\text{C}$ ($77^{\circ} \pm 4^{\circ}\text{F}$) for 23 hours. Transfer the specimens to a second water bath with a temperature of $40^{\circ} \pm 1^{\circ}\text{C}$ ($104^{\circ} \pm 2^{\circ}\text{F}$) for 1 hour. Remove the specimens from the water and damp dry them according to AASHTO T 166.

Note: Water level must be a minimum of 100 mm (4.0 in.) above the top of the specimens and specimens must not be stacked or touching.

3. Determine the Marshall stability of the three dry-test and three wet-test specimens according to AASHTO T 245. Record the peak breaking loads. Record the internal temperature of each specimen with an infrared thermometer. Determine the moisture content of one randomly selected dry and wet specimen from each mix according to AASHTO T 265.
4. Calculate the average wet Marshall stability ($MStab_{wet}$) and dry Marshall stability ($MStab_{dry}$) of each subset and record the results.
5. Calculate the retained Marshall stability of each subset and record the results:

$$\text{Retained Marshall stability} = M\text{Stab}_{\text{wet}} / M\text{Stab}_{\text{dry}}$$

6. Select an emulsified asphalt residue content that exceeds the minimum specified $M\text{Stab}_{\text{dry}}$ result that also meets the retained Marshall stability requirement.
7. Determine the bulk specific gravity of the one remaining untested specimen according to ASTM D3203 (specimen dimensions) or AASHTO T 331.
8. Do not adjust the additive content above 1% to achieve the Marshall stability requirements.

Note 1: If the minimum Marshall stability cannot be achieved with any of the emulsified asphalt residue contents and 1% additive, the gradation should be checked and adjusted, and the testing repeated.

Note 2: If the $M\text{Stab}_{\text{wet}}$ result meets the specified minimum, but the retained Marshall stability does not, this may indicate that the additive is dominating the result.

P. DETERMINING THE MARSHALL STABILITY OF FOAMED ASPHALT SPECIMENS FOR "REPORT ONLY" PURPOSES

Determine the Marshall stability and retained Marshall stability of foamed asphalt specimens for "Report Only" purposes.

1. Use the specimens prepared in Section N.
2. Randomly separate the 7 specimens from each emulsified asphalt residue content into 2 groups of 3 specimens each plus one and condition them as follows:
 - A. For the dry test and one remaining specimen: Place specimens in a conditioning chamber or temperature-controlled room at $25^{\circ} \pm 2^{\circ}\text{C}$ ($77^{\circ} \pm 4^{\circ}\text{F}$) for 22 hours. Transfer the specimens to a second conditioning chamber set at $40^{\circ} \pm 1^{\circ}\text{C}$ ($104^{\circ} \pm 2^{\circ}\text{F}$) for 2 hours. Alternatively, place the specimens into individual impermeable plastic bags, seal them, and then place them in a water bath at $40^{\circ} \pm 1^{\circ}\text{C}$ ($104^{\circ} \pm 2^{\circ}\text{F}$) for 2 hours.
 - B. For the wet test: Place specimens on a rack in a water bath with a temperature of $25^{\circ} \pm 2^{\circ}\text{C}$ ($77^{\circ} \pm 4^{\circ}\text{F}$) for 23 hours. Transfer the specimens to a second water bath with a temperature of $40^{\circ} \pm 1^{\circ}\text{C}$ ($104^{\circ} \pm 2^{\circ}\text{F}$) for 1 hour. Remove the specimens from the water and damp dry them according to AASHTO T 166.

Note: Water level must be a minimum of 100 mm (4.0 in.) above the top of the specimens and specimens must not be stacked or touching.

3. Determine the Marshall stability of the three dry-test and three wet-test specimens according to AASHTO T 245. Record the peak breaking loads. Record the internal temperature of each specimen with an infrared thermometer. Determine the moisture content of one randomly selected dry and wet specimen from each mix according to AASHTO T 265.
4. Calculate the average wet Marshall stability ($MStab_{wet}$) and dry Marshall stability ($MStab_{dry}$) and record the results.
5. Calculate the retained Marshall stability and record the results:

$$\text{Retained Marshall stability} = MStab_{wet} / MStab_{dry}$$

6. Determine the bulk specific gravity of the one remaining untested specimen according to ASTM D3203 (specimen dimensions) or AASHTO T 331.

Q. DETERMINING OPTIMUM FOAMED ASPHALT CONTENT USING INDIRECT TENSILE STRENGTH

Determine the optimum foamed asphalt content by the indirect tensile break strength and tensile strength ratio.

1. Use the specimens prepared in Section M.
2. Randomly separate the 7 specimens from each foamed asphalt content into 2 groups of 3 specimens each plus one and condition them as follows:
 - A. For the dry test and one remaining specimen: Place specimens in a conditioning chamber or temperature-controlled room at $25^{\circ} \pm 2^{\circ}\text{C}$ ($77^{\circ} \pm 4^{\circ}\text{F}$) for 24 hours.
 - B. For the wet test: Place specimens on a rack in a water bath with a temperature of $25^{\circ} \pm 2^{\circ}\text{C}$ ($77^{\circ} \pm 4^{\circ}\text{F}$) for 24 hours. Remove the specimens from the water and damp dry them according to AASHTO T 166.

Note: Water level must be a minimum of 100 mm (4.0 in.) above the top of the specimens and specimens must not be stacked or touching.

3. Determine the indirect tensile strength (ITS) of the 3 dry-test and 3 wet-test specimens according to AASHTO T 283. Record the peak breaking loads. Record the internal temperature of each specimen with an infrared thermometer. Determine the moisture content of one randomly selected

dry and wet specimen from each foamed asphalt content according to AASHTO T 265.

4. Calculate the average wet (ITS_{wet}), and dry (ITS_{dry}) of each subset and record the results.
5. Calculate the tensile strength ratio (TSR) of each subset and record the results:

$$TSR = ITS_{wet} / ITS_{dry}$$

6. Select a foamed asphalt content that exceeds the specified minimum ITS_{wet} requirement that also meets the minimum TSR requirement.
7. Determine the bulk specific gravity of the one remaining untested specimen according to ASTM D3203 (specimen dimensions) or AASHTO T 331.
8. Do not adjust the additive content above 1% to achieve the minimum wet strength.

Note 1: If the minimum wet strength cannot be achieved with any of the foamed asphalt contents and 1% additive, the gradation should be checked and adjusted, and the testing repeated.

Note 2: If the ITS_{wet} result meets the specified minimum, but the TSR does not, this may indicate that the additive is dominating the result.

R. DETERMINING THE INDIRECT TENSILE STRENGTH OF EMULSIFIED ASPHALT SPECIMENS FOR “REPORT ONLY” PURPOSES

Determine the indirect tensile break strength and tensile strength ratio of emulsified asphalt specimens for “Report Only” purposes.

1. Use the specimens prepared in Section L.
2. Randomly separate the 7 specimens from each emulsified asphalt residue content into 2 groups of 3 specimens each plus one and condition them as follows:
 - A. For the dry test and one remaining specimen: Place specimens in a conditioning chamber or temperature-controlled room at $25^{\circ} \pm 2^{\circ}\text{C}$ ($77^{\circ} \pm 4^{\circ}\text{F}$) for 24 hours.
 - B. For the wet test: Place specimens on a rack in a water bath with a temperature of $25^{\circ} \pm 2^{\circ}\text{C}$ ($77^{\circ} \pm 4^{\circ}\text{F}$) for 24 hours. Remove the specimens from the water and damp dry them according to AASHTO T 166.

Note: Water level must be a minimum of 100 mm (4.0 in.) above the top of the specimens and specimens must not be stacked or touching.

3. Determine the indirect tensile strength (ITS) of the 3 dry-test and 3 wet-test specimens according to AASHTO T 283. Record the peak breaking loads. Record the internal temperature of each specimen with an infrared thermometer. Determine the moisture content of one randomly selected dry and wet specimen from each emulsified asphalt residue content according to AASHTO T 265.
4. Calculate the average wet (ITS_{wet}), and dry (ITS_{dry}) ITS and record the results.
5. Calculate the tensile strength ratio (TSR) and record the results:

$$TSR = ITS_{wet} / ITS_{dry}$$

6. Determine the bulk specific gravity of the one remaining untested specimen according to AASHTO T 269 (specimen dimensions) or AASHTO T 331.

S. RAVELING AND COATING TESTS FOR EMULSIFIED ASPHALT

At optimum emulsified asphalt content, perform the following additional tests on three replicate specimens prepared using the procedure described in Section K:

1. Raveling test per ASTM D7196
2. Coating Test per AASHTO T 59

If the raveling test fails at the optimum emulsified asphalt content, repeat the test on specimens prepared at the optimum emulsified asphalt content plus 0.25%.

T. OBTAINING PRODUCTION SAMPLES FOR QUALITY TESTS

1. Windrow after processing prior to paving
2. Obtain samples per CT 125
3. Thoroughly mix field samples prior to compacting test specimens.

U. QUALITY TESTING OF PRODUCTION SAMPLES

1. A minimum of 6 samples shall be compacted for each quality test. If multiple quality tests are to be performed, compact as many multiple samples of 6 as required.
2. All production samples shall be compacted within 2 hours of mixing by the recycler.

3. Compact samples as follows:
 - A. Gyration (AASHTO T 312; 30 gyrations [600 kPa at 1.16°] in a 100 mm diameter mold).
 - B. Marshall (AASHTO T 245; 75 blows per face, in a 4 in. diameter mold).
4. Compacted samples shall be cured a maximum of 30 hours at ambient temperature, prior to the 72-hour oven cure.
5. Cure the compacted specimens and one remaining uncompacted sample in a forced draft oven at $40^{\circ} \pm 1^{\circ}\text{C}$ ($104^{\circ} \pm 2^{\circ}\text{F}$) for 72 hours. If after the 72-hour cure, the specimens have not reached constant mass (0.05% change in 2 hours), allow the samples to continue to cure until constant mass is reached checking each additional hour. Record the additional time required for cure.

Note: During curing, specimens must not be stacked or touching, and allowance must be made for air circulation around each specimen.

6. Remove the specimens from the oven and allow to cool to ambient temperature ($25^{\circ} \pm 2^{\circ}\text{C}$ [$77^{\circ} \pm 4^{\circ}\text{F}$]). When cooled, record the mass, diameter, and height of each specimen according to AASHTO T 269.
7. Production samples may be handled and transported as follows:
 - A. Compacted samples shall be placed in the curing oven within 30 hours of compaction.
 - B. Samples shall be protected by wrapping in plastic wrap or placed in a protective container such as a modified plastic concrete cylinder mold immediately after compaction.
 - C. Within a protective container, samples shall:
 - a. Be placed flat on the bottom of the container.
 - b. Not stacked.
 - c. Each sample shall be separated from each other and the container walls by rags, paper towels or other suitable materials which will not damage the samples.
 - D. Transport time of compacted samples shall be limited to 4 hours. The transportation time shall not be considered as part of the 72-hour cure period. Place transported samples immediately into oven for 72-hour cure period.

V. REPORTING OF RESULTS

Report results on the Mix Design Forms.

When required, submit test results electronically in accordance with the DIMEXML format and guidance documents found at the following link:

<https://dime.dot.ca.gov/index.php?r=help/submittestresult>

W. HEALTH AND SAFETY

It is the responsibility of the user of this test method to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. Prior to handling, testing, or disposing of any materials, testers must be knowledgeable about safe laboratory practices, hazards and exposure, chemical procurement and storage, and personal protective apparel and equipment.

Refer to the Safety Manual for your Laboratory.

End of Text
(California Test 315 contains 23 pages)