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METHOD OF TEST FOR MIXTURE DESIGN AND TESTING OF PARTIAL DEPTH RECYCLING OF ASPHALT PAVEMENTS USING BITUMINOUS RECYCLING AGENTS AND ADDITIVES

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.

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

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-µm (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 59	Standard Method of Test for Emulsified Asphalts
AASHTO T 166	Standard Method of Test for Bulk Specific Gravity (G_{mb}) of Compacted Asphalt Mixture Using Saturated Surface-Dry Specimens
AASHTO T 265	Standard Method of Test for Laboratory Determination of Moisture Content of Soil
AASHTO T 269	Percent Air Voids in Compacted Dense and Open Asphalt Mixtures

AASHTO T 312	Standard Method of Test for Preparing and Determining the Density of Asphalt Mixture Specimens by Means of the Superpave Gyratory Compactor
ASTM D7196	Standard Test Method for Raveling Test of Cold-Mixed Emulsified Asphalt Samples
CT 125	Method of Test for Sampling Highway Materials and Products Used in the Roadway Structural Sections
CT 226	Method of Test for Determination of Moisture Content of Soils and Aggregates by Oven Drying
CT 372	Method of Test for Resistance of Cold Recycled Pavement Materials to Moisture-Induced Damage
MS-2	Asphalt Mix Design Methods

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 for mix design
2. Preparing pavement samples for mix design
3. Asphalt binder selection and foaming parameters for foamed asphalt as recycling agent
4. Optimum moisture content and maximum density determination
5. Optimum recycling agent content determination
6. Reporting of results

D. APPARATUS

1. Gyratory Compactor – A gyratory compactor meeting the requirements in accordance with AASHTO T 312 and 100 mm ± 0.25 mm diameter molds.
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 in accordance with AASHTO M 231, Class G2.

4. 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 ASTM E11. Nonstandard sieve frames shall conform to the requirements of ASTM E11 as applicable. Sieves: 1½ in., 1¼ in., 1.0 in., ¾ in., ½ in., No. 4, No. 8, No. 30, and No. 200.

   Note: Other sieve sizes may be inserted/needed to protect required sieves from being overloaded and damage.

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 is in accordance with AASHTO T 27 requirements.

7. Mixer - A pug mill style mixer capable of mixing up to 30 kg (66 lb) 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°C ± 0.5°C and 60°C ± 1°C (104°F ± 1°F and 140°F ± 2°F).

9. Water Bath – A water bath of sufficient size, capable of maintaining a uniform temperature of 25°C ± 0.5°C (77°F ± 0.9°F), and immersing samples with a minimum of 100 mm (4 in.) of water above their surface. The thermometer for measuring the temperature of the water bath shall be in accordance with the requirements of AASHTO M 339M/M 339 with a temperature range of at least 20 to 30°C (68 to 86°F) with an accuracy of ±0.13°C (±0.22°F).

10. Calipers - Calipers with accuracy to measure the length and diameter of test specimens to the nearest 0.01 mm ($^4/_{10000}$ in.).

11. Containers - Airtight containers capable of holding 1.5 to 25 kg (3 to 55 lb) of recycled pavement materials.

12. Steel Loading Strips – 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 (½ 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.

13. 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 to 100 g per second. The laboratory

equipment should have a thermostatically controlled chamber or vessel capable of holding at least 10 kg (22 lb) of asphalt binder at a temperature from 140 to 180°C (285 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 the weight of asphalt binder.

E. MATERIALS

1. Existing asphalt pavement samples for PDR projects
2. Supplementary aggregates if specified
3. Recycling agent shall be one of the following:

   3.1 Emulsified asphalt: shall be as required in the project special provision 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 residue asphalt content is not provided by the manufacturer, determine the residual asphalt content in accordance with AASHTO T 59.

   3.2 Foamed asphalt: PG grade binder prior to foaming 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 performance grade as specified in the project's special provisions and asphalt binder supplier as chosen by the contractor.

4. Additives shall be cement
5. Water

F. OBTAINING FIELD SAMPLES FOR MIX DESIGN

Obtain reclaimed asphalt pavement samples for each mix design as required in the specifications. Samples shall be collected from the specified locations listed in the project special provision, or if not listed, from a minimum of three locations, equally spaced along the length of the pavement to be recycled.

Obtain reclaimed asphalt pavement samples from identified representative areas of the project by milling, taking cores, or removing slabs to the depth specified for in-place recycling shown in the project plans. Obtain

approximately 450 lbs. of reclaimed asphalt pavement 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:

TABLE 1
Minimum Number of Cores Required for 450 lb 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:

TABLE 2
Total Pavement Slab Area Required for 450 lb of Sample Based on PDR Depth

PDR Depth (ft)	0.25	0.30	0.35	0.40
Minimum Slab Area (ft^2)	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 FOR MIX DESIGN

The suggested sample weights in this procedure are approximate and 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. Milling or cold planned 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 supplementary aggregates if specified that will be added during the recycling process.
4. Dry the sampled materials to a constant weight in accordance with California Test 125.
5. If supplementary aggregates are specified, 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:

TABLE 3
Requirements for Final Gradation

Sieve Size	Percentage Passing	
	Medium Gradation	Coarse Gradation
1¼"	100	100
1"	98 – 100	98 – 100
¾"	93 – 97	83 – 87
No. 4	48 – 52	38 – 42
No. 8	35 – 40	25 – 30
No. 30	8 – 12	3 – 7
No. 200	1 – 3	0.5 – 2

7. If the gradation does not meet the gradation in Step 6, follow Asphalt Institute MS-2 Section 3.3. for fractioning materials. Adjust the fractionated material so the final gradation meets the above gradations.
8. Split out at least two 10 kg (22 lb) and seven 25 kg (55 lb) portions of the recycled material to complete the testing described below.

H. ASPHALT BINDER SELECTION AND FOAMING PARAMETERS FOR FOAMED ASPHALT AS RECYCLING AGENT

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 three and five 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 three foaming water percentages between 1.0 % and 4.0 % by weight of binder 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 Figure 1 below shows the optimum foaming water content is 2.75 % for a specified minimum expansion ratio of 8 and half-life of 6).

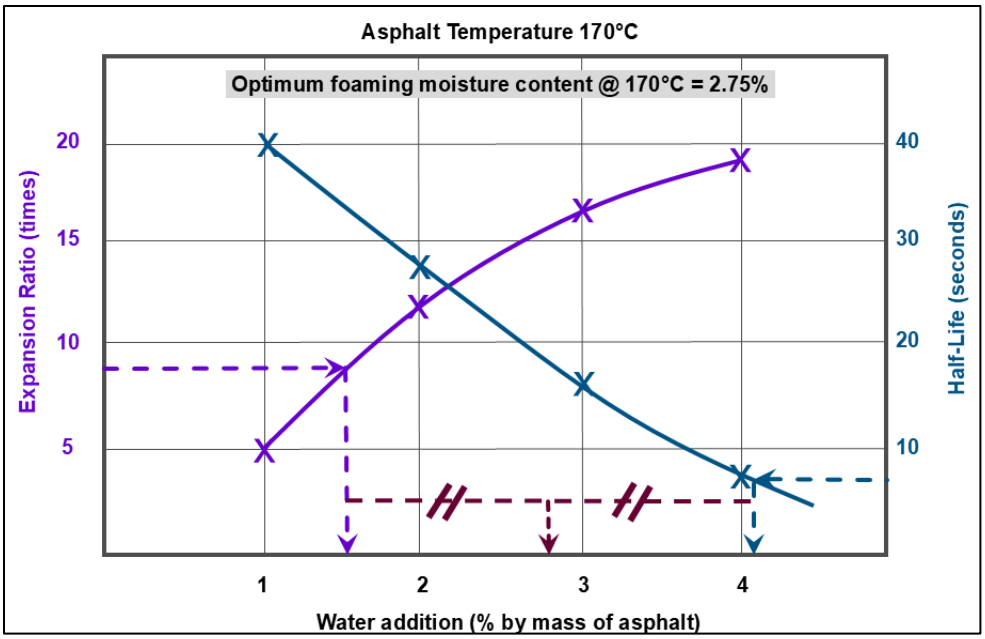

FIGURE 1. Example of determining the optimum foaming water content

6. Choose the temperature and foaming water combination that provides an optimum 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.

I. OPTIMUM MOISTURE CONTENT AND MAXIMUM DENSITY DETERMINATION

Determine the optimum moisture content and maximum density:

1. Using a portion of the recycled aggregates, thoroughly mix the pavement samples prepared in section G with the additive as prescribed by the special provisions. (e.g. 1.0 % cement).
2. Pass the entire sample through a ¾ in. sieve. Make a note of the percentage of material retained on the ¾ in. sieve and then discard it.
3. Separate out six samples of 1,150 g (for 100 mm diameter mold) of material.
4. Choose a starting moisture content based on experience. Add the starting moisture content to the first split sample and mix thoroughly. For PDR materials, the starting moisture content is typically around 3 %.

5. Do not pre-heat the molds.
6. Add the sample to a mold, level the material in the mold, and rod the material 10 to 15 times with a ⅝ in. rod in a circular motion, making sure to evenly distribute the rodding across the entire sample.
7. Compact the specimen at room temperature (25°C ± 2°C [77°F ± 4°F]) using 30 gyrations in a gyratory compactor per AASHTO T 312 Section 9.
8. Gently extrude the specimen from the mold and record the mass, height, and diameter of the specimen.
9. The target final specimen height should be measured in accordance with AASHTO T 269 Section 6.2.2 and should be 63.5 ± 2.5 mm (2½ ± 1/10 in.). If necessary, adjust the mass determined in Step 3 to meet the specimen height requirements.
10. Clearly number each specimen.
11. Calculate the bulk density of the specimen in accordance with AASHTO T 269 Section 6.2.2. Determine the moisture content in accordance with California Test 226.
12. Repeat steps 3 through 11 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. Plot bulk dry density versus moisture content on a graph.
14. Using the moisture-density relationship, determine the optimum moisture content and maximum dry density from the established curve.
15. Use this optimum moisture content and density for specimen preparation.
16. If emulsified asphalt is used as a recycling agent, 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

J. SPECIMEN PREPARATION FOR OPTIMUM RECYCLING AGENT CONTENT

Prepare specimens for determining the optimum recycling agent content by the indirect tensile strength method. Use the specified additive and additive content.

1. Pass the entire sample through a ¾ in. sieve. Record the percentage of oversized material and then discard it.
2. Quarter the material into four bulk samples. This requires approximately 25 kg (55 lb) of material.
3. Determine an appropriate range of recycling agent 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 %).
   - 4.1 If emulsified asphalt is used as recycling agent, add the water content calculated in Section I. Add the first emulsified asphalt residue content determined in step 3 before mixing. Mix the material for 4 minutes.
   - 4.2 If foamed asphalt is used as a recycling agent, mix the material for 3 minutes. Add the first 75 % 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.
5. 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.
6. Determine the mass of wet material needed to achieve the maximum dry density of the mix as determined in Section I, to conform with the height requirements of California Test 372.
7. Split the processed material into eight 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.
8. Do not pre-heat the molds.
9. Add one of the split samples into a mold and rod the material 10 to 15 times with a ⅝ in. rod in a circular motion, making sure to evenly distribute the rodding across the entire sample.
10. Compact the specimen at room temperature (25°C ± 2°C [77°F ± 4°F]) using 30 gyrations in a gyratory compactor in accordance with AASHTO T 312 Section 9.

11. Gently extrude the specimen from the mold and record the mass of the specimen.
12. The target final specimen height should be measured in accordance with AASHTO T 269 Section 6.2.2 and should be 63.5 ± 2.5 mm (2½ ± ⅒ in.). If necessary, adjust the mass determined in Step 6 to meet the specimen height requirements.
13. Repeat steps 8 through 12 six additional times, all within 30 minutes of adding the water portion to the recycled material and additive.
14. Number each specimen clearly.
15. Repeat steps 4 through 16 three times with the three remaining recycling agent contents.
16. Cure the compacted specimens and one remaining uncompacted sample in a forced draft oven at 40°C ± 1°C (104°F ± 2°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.
17. Remove the specimens from the oven and allow to cool to ambient temperature (25°C ± 2°C [77°F ± 4°F]). When cooled, record the mass, diameter, and height of each specimen according to AASHTO T 269 Section 6.2.2.

K. DETERMINING OPTIMUM RECYCLING AGENT CONTENT

Determine the optimum recycling agent content by the indirect tensile strengths (ITS):

1. Use the specimens prepared in Section J.
2. Randomly separate the seven specimens from each recycling agent content into two groups of three specimens each plus one and condition them as follows:
    A. For the ITS_{dry} test: Place specimens in a conditioning chamber or temperature-controlled room at 25°C ± 2°C (77°F ± 4°F) for 24 hours.
    B. For the ITS_{wet} test: Place specimens on a rack in a water bath with a temperature of 25°C ± 2°C (77°F ± 4°F) for 24 hours. Remove the specimens from the water and damp dry them in accordance with AASHTO T 166.

Note: Water level must be a minimum of 100 mm (4 in.) above the top of the specimens and specimens must not be stacked or touching.

3. Determine the indirect tensile strength (ITS) of the three dry-test and three wet-test specimens according to California Test 372. 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 recycling agent content in accordance with AASHTO T 265.
4. Calculate the average ITS_{dry}, and ITS_{wet} of each subset and record the results.
5. Select a recycling agent content that exceeds the specified minimum ITS_{dry} and ITS_{wet} requirements.
6. Do not adjust the cement content above 1 % to achieve the minimum wet strength.

Note: 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.

L. DETERMINING RAVELING RESISTANCE

At optimum recycling agent content, perform the following test on three replicate specimens prepared using the procedure described in Section J:

1. Raveling test in accordance with ASTM D7196.
2. If the raveling test fails at the optimum recycling agent content, repeat the tests on specimens prepared at the selected recycling agent content plus 0.25 %.

M. ADDITIONAL TESTS FOR EMULSIFIED ASPHALT AS RECYCLING AGENT

At optimum recycling agent content, perform the following test on three replicate specimens prepared using the procedure described in Section J.

1. Coating test in accordance with AASHTO T 59.

N. REPORTING OF RESULTS

Report results on the mix design forms.

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

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

O. 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 13 pages)