## Standard Practice for

# Determination of Optimum Emulsified Asphalt Content of Cold In-Place Recycled Mixtures

## FLH Designation: T 524

## 1. SCOPE

1.1. This standard practice is used to determine the percent of emulsified asphalt and other additives to use for recycling asphalt concrete when using Cold In-Place Recycling (CIR) of bituminous pavements.

## 2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards:*

- T 27, Sieve Analysis of Fine and Coarse Aggregates
- T 30, Mechanical Analysis of Extracted Aggregate
- T 166, Bulk Specific Gravity ($G_{mb}$) of Compacted Hot Mix Asphalt (HMA) Using Saturated Surface-Dry Specimens
- T 209, Theoretical Maximum Specific Gravity ($G_{mm}$) and Density of Hot Mix Asphalt (HMA)
- T 245, Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus
- T 269, Percent Air Voids in Compacted Dense and Open Asphalt Mixtures
- T 283, Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage
- T 312, Preparing and Determining the Density of Asphalt Mixture Specimens by Means of the Superpave Gyratory Compactor
- T 331, Bulk Specific Gravity ($G_{mb}$) and Density of Compacted Hot Mix Asphalt (HMA) Using Automatic Vacuum Sealing Method

2.2. *ASTM Standards:*

- D6857, Maximum Specific Gravity and Density of Bituminous Paving Mixtures Using Automatic Vacuum Sealing Method
- D7196, Raveling Test of Cold Mixed Emulsified Asphalt Samples

## 3. OBTAINING AND PREPARATION OF MATERIALS

3.1. *Sampling and Processing of Recycled Asphalt Pavement (RAP) Materials*

3.1.1. Obtain cores from the areas to be recycled. Depending upon project length and existing pavement thickness, develop a coring plan that will provide at least 350 pounds of RAP for each mix design. Additional cores will need to be obtained for more specific asphalt content and gradation analysis if desired.

In all cases, the material provided must be representative of the material to be recycled. If the pavement is not being recycled full depth, cores should be cut to the specified milling depth with the bottom portion being discarded.

Where visual differences in the pavement surface are noted, additional cores may be required to evaluate the difference. If these additional cores show significant material differences, a separate mix design should be performed for each identified pavement segment.

3.1.2. Cut cores to the depth specified for the cold recycled layer.

3.1.3. Crush cores to obtain materials that meet the gradation shown in Table 1.

As an alternative to obtaining and crushing cores, RAP may be obtained by milling. Mill the pavement from areas to be recycled to the specified depth.

3.1.4. Sieve the milled pavement or crushed cores according to AASHTO T 27 with the exception that drying the RAP to constant mass shall be performed at 104 ± 4°F (40 ± 2°C). The washed sieve analysis of AASHTO T 11 is not required.

RAP material will be recombined to meet the gradation requirements shown in Table 1 for additional testing as described in this method.

**Table 1**— RAP Gradation Requirements

| Sieve Size | Percent Passing |
|---|---|
| 1.5 inch (37.5mm) | 100 |
| 1 inch (25.0mm) | 90-100 |
| 3/4 inch (19.0mm) | 85-95 |
| 1/2 inch (12.5mm) | 75-85 |
| No. 4 (4.75mm) | 35-50 |
| No. 16 (1.18mm) | 5-16 |
| No. 200 (75µm) | 0-7 |

## 4. MIX DESIGN BINDER AND ADDITIVES FOR MIX DESIGN

4.1. *Sample of Emulsified Asphalt Binder Agent*

4.1.1. Obtain 3 gallons of the emulsified asphalt that will be used to produce the cold recycled mix. Include the name and location of the supplier in the mix design report. Include the grade and properties of the emulsified asphalt in the mix design report.

4.2. *Sample of Other Additives*

4.2.1. Obtain 5 pounds of quicklime, if quicklime will be used as a part of the mix design.

4.2.2. Obtain a sufficient amount of other additives that will be used to complete the mix design. List the name and source of all additives in the mix design report.

## 5. DETERMINATION OF INDIRECT TENSILE STRENGTH AND TENSILE STRENGTH RATIO

5.1. *Batching RAP Material*

5.1.1. Select a minimum of three emulsified asphalt contents in either 0.5% or 1.0% increments covering a range typically between 1.0% and 4.0% by dry weight of RAP. Batch RAP material for each specimen conforming to the gradation selected for the mix design and meeting the gradation

requirements shown in Table 1. Six specimens will be compacted and tested for each emulsified asphalt content selected. As an option, additional specimens may be batched, compacted, and tested that have varying percentages of other additives such as quicklime.

Determine the amount of RAP material required to produce a 150 mm diameter and 95 ± 5 mm tall specimen when compacted in the gyratory compactor at 35 gyrations.

In addition, batch two RAP material samples for use in determining the theoretical maximum specific gravity value according to AASHTO T 209. Determine the theoretical maximum specific gravity according to Section 6.

5.2. *Mechanical Mixing*

5.2.1. Mix samples for testing using a mechanical bucket mixer, laboratory sized pugmill or a combination of the two. Add moisture that is expected to be added at the milling head, typically 1.5 to 2.5 percent, and mix thoroughly. If any additives (such as lime) are in the mixture, introduce the additives in a similar manner that they will be added during field production.

5.2.2. Mix RAP thoroughly with water first or water and additives as appropriate, then mix with emulsified asphalt at room temperature, 77 ± 4°F (25 ± 2°C). One specimen will be mixed at a time. Mixing time should not exceed 60 seconds.

5.3. *Compacting*

5.3.1. Immediately after mixing, compact the specimens. Compact the specimens at 77 ± 4ºF (25 ± 2ºC).

5.3.2. Compact the specimens using 35 gyrations according to AASHTO T 312 compaction procedures with the exception that the materials and the molds are not heated.

5.3.3. Compact six specimens at each emulsified asphalt content for tensile strength testing; three for unconditioned (dry) tensile strength on cured samples and three for conditioned tensile strength on cured samples for moisture conditioning.

5.4. *Curing*

5.4.1. Extrude the specimens from the molds after compaction. Handle specimens carefully as to not disturb or damage. Carefully remove the paper disks from the top and bottom of the specimens.

5.4.2. Place specimens in 140 ± 2°F (60 ± 1°C) forced draft oven with ventilation on sides and top. Place each specimen in a small container to account for material loss from the specimens. Cure compacted specimens at 140 ± 2°F (60 ± 1°C) to constant mass but do not heat for more than 48 hours and not less than 16 hours. Constant mass is defined as 0.05% change in mass in 2 hours. After curing, cool specimens at ambient temperature a minimum of 12 hours and a maximum of 24 hours.

5.5. *Sample Conditioning and Testing*

5.5.1. After curing of specimens, determine the bulk specific gravity of each compacted, cured and cooled specimen according to AASHTO T 166 Method A or AASHTO T 331, if required.

5.5.2. Determine specimen heights according to AASHTO T 245. Alternatively, the height can be obtained from the SGC readout.

5.5.3. Determine air void contents of the compacted and oven-cured samples at each emulsified asphalt content according to AASHTO T 269 using the theoretical maximum specific gravity as determined in Section 6.

5.5.4. For each emulsified asphalt content tested, separate the specimens into two subsets of three specimens each so the average air void contents of the two subsets are approximately equal.

Perform moisture conditioning on three compacted samples at each emulsified asphalt content by applying a vacuum of 10 to 26 in. of Hg partial pressure (13 to 67 kPa absolute pressure) for a time duration required to vacuum saturate samples to 55 to 75 percent. Saturation calculation shall be in accordance with AASHTO T 283. Soak moisture conditioned samples in a 77 ± 2°F (25 ± 1°C) water bath for 24 ± 1 hours.

5.5.5. Determine tensile strength ratio by AASHTO T 283. Dry or unconditioned samples are tested after a minimum of 45 minutes temperature conditioning by immersing in a 77 ± 2°F (25 ± 1°C) water bath. Place dry specimens in a leak proof bag to prevent samples from coming in contact with water. This testing is performed at the same time that moisture-conditioned specimens are tested.

5.5.6. Report the dry indirect tensile strength and the tensile strength ratio according to AASHTO T 283.

## 6. DETERMINING THE THEORETICAL MAXIMUM SPECIFIC GRAVITY

6.1. Batch samples according to 5.1.

6.2. Mix samples according to 5.2.

6.3. Two specimens are required for determination of theoretical maximum specific gravity. Follow AASHTO T 209 with the exception that loose RAP mixtures are cured in a forced draft oven at 140 ± 2°F (60 ± 1°C) to constant mass. Cure for no more than 48 hours and no less than 16 hours. Constant mass is defined as 0.05% change in mass in 2 hours. Do not break any agglomerates that will not easily reduce with a flexible spatula. Test both specimens at the highest emulsified asphalt content in the design and back calculate for the lower emulsified asphalt contents. Use the dry-back procedure of AASHTO T 209 to account for uncoated particles. ASTM D6857 may be used as an alternative to AASHTO T 209.

## 7. RAVELING TEST

7.1. Mix specimens at the target optimum emulsified asphalt content established. Mix according to ASTM D7196 for lab blended mixtures.

7.2. Cure the specimens for 4 hours at 50°F and 50% relative humidity.

7.3. Abrade the specimens for 15 minutes according to ASTM D7196.

7.4. Record the percent mass loss according to ASTM D7196.

## 8. EMULSIFIED ASPHALT CONTENT SELECTION

8.1. Choose the design emulsified asphalt content that meets the cold mix requirements listed in the specification.

## 9. REPORT

9.1. *Report the following information:*

9.1.1. Gradation of RAP;

9.1.2. Recommended water content range as a percentage of dry RAP;

9.1.3. Amount of additive as a percentage of dry RAP;

9.1.4. Range of emulsified asphalt contents used for the mix design;

9.1.5. Theoretical maximum specific gravity of the mixture at selected emulsified asphalt content, $G_{mm}$

9.1.6. Air voids and bulk specific gravity at each emulsified asphalt content (individual and average values) of AASHTO T 283 samples;

9.1.7. Indirect tensile strength at each emulsified asphalt content (individual and average values);

9.1.8. Level of saturation and conditioned indirect tensile strength at each emulsified asphalt content (individual and average values);

9.1.9. Tensile strength ratio;

9.1.10. Theoretical maximum specific gravity, air void content, tensile strength, tensile strength ratio, and raveling at recommended moisture and emulsified asphalt contents;

9.1.11. Optimum emulsified asphalt content as a percentage of dry RAP;

9.1.12. Emulsified asphalt and additive designation, supplier company name and location;

9.1.13. Emulsified asphalt residue content;

9.1.14. Additive designation, company name and location;

9.1.15. Certificates of compliance for emulsified asphalt and additive.