## Standard Practice for

# Determination of Optimum Emulsified or Foamed Asphalt Content of Full Depth Reclamation Mixtures

## FLH Designation: T 522

## 1. SCOPE

1.1. This procedure is used to determine the percent of emulsified or foamed asphalt and other needed additives for recycling asphalt concrete and aggregate base materials using Full Depth Reclamation (FDR).

## 2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards:*

- T 11, Materials Finer Than No. 200 (75 µm) Sieve in mineral Aggregates by Washing
- T 27, Sieve Analysis of Fine and Coarse Aggregates
- T 30, Mechanical Analysis of Extracted Aggregate
- T 209, Theoretical Maximum Specific Gravity ($G_{mm}$) and Density of Hot Mix Asphalt (HMA)
- 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

*ASTM Standards:*

- D6857, Maximum Specific Gravity and Density of Bituminous Paving Mixtures Using Automatic Vacuum Sealing Method

## 3. SAMPLING MATERIALS

3.1. *Sampling Existing Pavement Materials*

3.1.1. Obtain pavement cores, auger borings, or test pit samples from the areas to be recycled. Depending upon project length and existing pavement thickness, develop a sampling plan that will provide at least 350 lbs. of RAP and aggregate base for each mix design.

In all cases, the material provided must be representative of the material to be recycled. Where visual differences in the pavement surface are noted, additional cores may be required to evaluate the differences. If these additional samples show significant material differences, a separate mix design should be performed for each identified pavement segment.

3.1.2. Cores are to be cut for the full depth of the asphalt pavement. Sample aggregate base to the depth specified for the full depth reclamation project.

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

**Table 1**—RAP Gradation Requirements

| Sieve Size | Percent Passing |
|---|---|
| 1.5 in. (38 mm) | 100 |
| 1 in. (25 mm) | 85-95 |
| ¾ in. (19 mm) | 75-85 |
| No. 4 (4.75 mm) | 30-40 |
| No. 30 (0.600 mm) | 1-5 |

3.1.4. Milled RAP from the areas and depth to be recycled or other approved means of obtaining RAP samples can be used as an alternative to cores.

3.1.5. 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.

3.1.6. For the aggregate base material obtained, perform a washed sieve analysis in accordance with AASHTO T 11 and AASHTO T 27 and report the obtained gradation.

3.2. *Sampling of Emulsified Asphalt Binder or Asphalt Binder*

3.2.1. Obtain 3 gallons of the emulsified asphalt or 2 gallons of asphalt binder that will be used to produce the recycled mix. Include the name and location of the supplier in the mix design report. Include the grade and properties of the asphalt product used in the mix design report.

3.3. *Sampling of Other Additives*

3.3.1. Obtain 10 lbs. of cement, lime, or other mineral filler if these additives will be used as a part of the mix design.

3.3.2. 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.

## 4. DETERMINING FOAMED ASPHALT CHARACTERISTICS

4.1. For FDR mixtures using foamed asphalt, determine the asphalt expansion ratio and half-life of the asphalt binder to be used.

4.2. Using a laboratory asphalt foaming device designed for the purpose of evaluating asphalt foaming characteristics, determine the asphalt expansion ratio and the half-life of the foamed expansion for asphalt binder temperatures of 320, 338, and 356°F (160, 170, and 180°C) and a range of water contents from 1.5% to 3.5% in increments of 0.5%.

The asphalt expansion ratio is defined as the ratio between the maximum volume achieved in the foamed state and the volume of binder once the foam has completely subsided.

The half-life of the foamed expansion is the time for the foamed asphalt to reduce to half of the maximum volume attained during the foaming process.

4.3. Discharge foamed asphalt into a sufficiently sized container with the capability of measuring the volume of the foam asphalt at various time intervals.

4.4. Measure the maximum volume of the foamed asphalt after being initially discharged into the container.

4.5. Measure the time, in seconds, for the foam to dissipate to half of the maximum volume. Record this time as the half-life of the foamed asphalt.

4.6. Allow the foamed asphalt to completely dissipate. Calculate the expansion ratio by dividing the maximum foamed asphalt volume by the volume of binder after the foam has been dissipated.

4.7. Plot the percent water added versus asphalt expansion ratio and half-life of foamed expansion for each asphalt binder temperature.

## 5. COMBINING RAP AND AGGREGATE BASE MATERIALS

5.1. *Combined Materials*

5.1.1. Combine RAP prepared to the gradation in Table 1 with aggregate base of the gradation determined in 3.1.6 to the planned percentages as determined from the depth of the respective layers. Calculate the combined gradation of RAP and aggregate base.

5.1.2. Batch material to the combined gradation determined in Subsection 5.1.1.

5.1.3. Perform a Modified Proctor test on the combined material in accordance with AASHTO T 180, Method D, to determine optimum moisture content (OMC) at peak dry density of the combined RAP and base material. Materials shall be mixed with the selected amount of water, sealed, and allowed to hydrate for a minimum of 3 hours prior to compaction. The OMC shall be defined by a best-fit curve.

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

6.1. *Specimen Size*

6.1.1. Determine the amount of RAP and aggregate base, before the addition of water, required to produce a 95 ± 5 mm tall specimen when compacting 150 mm diameter specimens with the gyratory compactor at 35 gyrations for testing.

6.1.2. Batch the RAP and aggregate base material according to the proportions established in Subsection 5.1.1 and 5.1.2.

6.1.3. Select a minimum of three emulsified or foamed asphalt contents in either 0.5% or 1.0% increments covering a range typically between 2.0% and 4.0% by dry weight of batched material. Six specimens will be compacted and tested for each emulsified or foamed asphalt content selected. As an option, additional specimens may be batched, compacted, and tested that have varying percentages of other additives such as cement, lime or mineral filler.

In addition, batch two 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 7.

6.2. *Mechanical Mixing*

6.2.1. Place the batched RAP and aggregate in a mixing bowl. Add sufficient water so that the total moisture content of water plus added emulsified asphalt or foamed asphalt will be equal to the OMC as determined in Subsection 5.1.3.

6.2.2. Mix samples for testing using a mechanical bucket mixer or laboratory sized pugmill or a combination of the two. Mix specimens with the required amount of water before addition of emulsified or foamed asphalt. 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.

6.2.3. Mix specimens thoroughly with water first, or water and additives as appropriate, then add the emulsified asphalt or foamed asphalt. Thoroughly mix the material to provide uniform coating. One specimen will be mixed at a time. Mixing time should not exceed 60 seconds.

6.2.4. Transfer mixture to a sealed container and cure at 77 ± 4°F (25 ± 2°C) for 30 ± 3 minutes.

6.3. *Compacting*

6.3.1. Compact the mixture immediately after the curing specified in 6.2.3.

6.3.2. 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.

6.3.3. Compact six specimens at each asphalt content selected 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.

6.3.4. If paper disks are used, place paper disks on the top and bottom of the specimen before compaction and remove paper disks from specimens immediately after compaction.

6.4. *Curing*

6.4.1. 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.

6.4.2. 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.

6.5. *Sample Conditioning and Testing*

6.5.1. After curing of specimens, determine the bulk specific gravity of each compacted, cured and cooled specimen according to AASHTO T 331.

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

6.5.3. Determine air void contents of the compacted and oven-cured samples at each asphalt content according to AASHTO T 269 using the theoretical maximum specific gravity as determined in Section 7.

6.5.4. For each 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.

6.5.5. Perform moisture conditioning on three compacted samples at each asphalt content by applying a vacuum of 13 to 67 kPa absolute pressures (10 to 26 in. of Hg partial 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.

6.5.6. 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.

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

## 7. DETERMINING THE THEORECTICAL MAXIMUM SPECIFIC GRAVITY

7.1. Batch samples according to Subsection 6.1

7.2. Mix samples according to Subsection 6.2.

7.3. Two specimens are required for determination of theoretical maximum specific gravity. Follow AASHTO T 209 with the exception that loose 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 asphalt content in the design and back calculate for the lower 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.

## 8. EMULSIFIED ASPHALT OR FOAMED ASPHALT CONTENT SELECTION

8.1. Choose the design emulsified or foamed asphalt content that meets the requirements listed in the specification. For the foamed asphalt mixture, include the water content and asphalt binder temperature required for proper foaming.

## 9. REPORT

9.1. Report the following information:

9.1.1. Gradation of RAP;

9.1.2. Gradation of aggregate base;

9.1.3. Planned percentages of RAP and aggregate base;

9.1.4. Combined gradation of the blended RAP and aggregate base material;

9.1.5. Foamed asphalt expansion and half-life plots;

9.1.6. Density and OMC from Proctor compaction of the blended material;

9.1.7. Moisture content used in mix design;

9.1.8. Range of emulsified asphalt or foamed asphalt contents used for the mix design;

9.1.9. Density, $G_{mm}$, and air voids at each emulsified asphalt or foamed asphalt content (individual and average values) of AASHTO T 283 samples;

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

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

9.1.12. Tensile strength ratio;

9.1.13. Design emulsified or foamed asphalt content;

9.1.14. Design water content;

9.1.15. Emulsified asphalt or asphalt binder grade, supplier company name and location;

9.1.16. Additive type, company name and location;

9.1.17. Certificates of compliance for emulsified asphalt, asphalt binder, and any additives, as necessary.