Standard Practice for

Emulsified Asphalt Content of Full-Depth Reclamation Mixture Design

AASHTO Designation: PP xxx-18[1]
Technical Section: 2a
Release: Group 3 (Month yyyy)

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1. SCOPE

1.1. This standard for mix design evaluation is used to determine the amount and composition of emulsified asphalt and other additives when using full-depth reclamation (FDR) of asphalt mixtures. The mix design is based on strength and other performance properties.

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- M 85, Portland Cement
- M 216, Lime for Soil Stabilization
- MP XX, Materials for Full-Depth Reclamation Mixtures with Emulsified Asphalt
- T 11, Materials Finer Than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing
- T 27, Sieve Analysis of Fine and Coarse Aggregates
- T 89, Determining the Liquid Limit of Soils
- T 90, Determining the Plastic Limit and Plasticity Index of Soils
- T 176, Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test
- 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 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 Hot Mix Asphalt (HMA) 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*:

- D3549, Standard Test Method for Thickness or Height of Compacted Bituminous Paving Mixture Specimens
- D6857, Standard Test Method for Maximum Specific Gravity and Density of Asphalt Mixtures Using Vacuum Sealing Method

2.3. *Other References*:

- LTPP Seasonal Asphalt Concrete Pavement Temperature Models, LTPPBind 3.1
- *Basic Asphalt Recycling Manual*, Asphalt Recycling and Reclaiming Association and FHWA-HIF-14-001, Annapolis, MD.

3. TERMINOLOGY

3.1. *Full-depth reclamation (FDR)*—the on-site rehabilitation technique in which the full thickness of the asphalt pavement and a predetermined portion of the underlying materials (base, subbase and/or subgrade) is uniformly pulverized and blended with an emulsified asphalt, with or without a combination of additives (lime, cement, aggregate), generating and reusing 100 percent of the reclaimed material, with the resulting pavement serving as a base layer overlaid with a surface treatment or asphalt mixture overlay.

3.2. *Type 1 FDR*— mixtures containing <8 percent passing 0.075 mm (No.200) sieve of the combined material.

3.3. *Type 2 FDR*— mixtures containing ≥8 percent passing 0.075 mm (No.200) sieve of the combined material.

3.4. *reclaimed asphalt pavement (RAP)*—removed and/or processed pavement materials containing asphalt binder and aggregate.

4. SIGNIFICANCE AND USE

4.1. The procedure described in this standard is used to produce FDR that satisfies mix design requirements.

4.2. Specifying an emulsified asphalt alone for FDR may not be satisfactory in producing a good-performing mixture. This method has successfully been vetted and is the baseline design procedure employed on numerous projects.

5. OBTAINING AND PREPARATION OF MATERIALS

5.1. *Core Sampling Existing Pavement for FDR*:

5.1.1. Obtain cores and underlying materials to the planned recycling depth from the areas to be recycled. The material provided must be representative of the material to be recycled.

Where visual differences in the pavement surface are noted or where construction or maintenance records indicate differences, obtain additional cores to evaluate the difference. If these additional cores show significant material differences, perform a separate mix design or verify the mix properties from additional samples.

Note 1—Take cores using a pattern that results in a representative sample of the pavement to be recycled including at or near lane lines, within and between wheel paths, at the pavement edge and within shoulders if shoulders are to be recycled. Provide at least 160 kg (350 lbs) of material per design.

5.1.2. Crush cores at ambient temperature or colder to obtain materials for the mix design.

Note 2—A jaw crusher, laboratory milling machine, or other suitable method is recommended for modeling the particle shape and gradation expected during recycling.

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

Note 3—Consider a cold planer if the pavement section is uniform and a representative section is milled. Obtain samples provided the cold planer (milling machine) produces sufficient coarse material to conduct a mix design. Fine millings may not be acceptable to represent the construction-produced millings from a reclaimer. Only millings that represent the pavement to be recycled shall be collected. If the existing pavement surface is planned to be milled and removed during construction, the pavement shall be milled in a similar manner and removed prior to milling for sampling purposes. Milling and sampling shall only be to the planned recycle depth. The material may be taken from one test location for each mix design to be performed. For example, if a pavement change exists within the limits of the roadway, one test location should be designated separating each area.

5.2. *Test Pit Sampling Existing Pavement for FDR*:

5.2.1. Obtain representative samples of asphalt pavement and underlying materials. The material provided must be representative of the material to be recycled.

Where major visual differences in pavement surface are noted or where construction or maintenance records indicate major differences, obtain additional samples. If these additional samples show significant material differences, either perform a separate mix design or verify the mix properties from the additional samples. The material may be obtained from one test location for each mix design.

5.2.2. Crush the pavement at ambient temperature or colder to obtain materials for the mix design.

Note 4—A jaw crusher, laboratory milling machine, or other suitable method is recommended for modeling the particle shape and gradation expected during recycling.

Note 5—If a portion of the existing pavement surface is planned to be milled and removed during construction, that portion of the pavement shall be removed and discarded prior to the mix design.

5.2.3. Provide at least 160 kg (350 lbs) of material per design.

5.3. *Processing of Recycled Asphalt Pavement (RAP) Materials*:

5.3.1. Sieve the RAP according to T 27, with the exception that drying the RAP to constant mass shall be performed at 40 ± 2°C (104 ± 4°F). If a significant amount of fine uncoated particles are present, perform washed sieve analysis on a representative sample in accordance with T 11.

Process RAP materials to model the gradation expected during recycling. As an alternative, combine RAP materials to meet the gradation band in M XX.

Note 6—Adjustment of the gradation band to local conditions and construction equipment is recommended. The selected gradation shall be chosen to match the expected field gradation as closely as possible, with the exception that a greater top size on the project is expected. Gradations on a project will vary from sample to sample. Slight adjustments in the field to the design emulsified asphalt content are often necessary to obtain optimum mixture performance. Ensure all materials pass the 38.1 mm (1.5 in.) sieve for 150 mm (6 in.) diameter specimens.

6. DETERMINE COMBINED FDR MATERIAL PROPERTIES

6.1. Combine the RAP, batched to the gradation selected in section 5.3, with the underlying material to the proportion found in the field. Perform a washed sieve analysis on a sample of the combined FDR material in accordance with T 11 and T 27 except that the material shall be dried at 40 °C (104 °F).

Note 7—Drying to a constant mass at 40 °C (104 °F) could take several days.

Note 8—If the percent passing the 0.075 mm (No. 200) sieve of the combined FDR material exceeds 20 percent, then the use of a stabilizing additive such as cement or lime may be required to meet the requirements of MP XX.

6.2. Perform T 176 and T 89 & 90 on representative samples of the combined FDR material.

Note 9—Combined FDR mixtures with sand equivalent values < 30 and/or PI > 6 typically require the use of a stabilizing additive such as cement or lime to meet the requirements of MP XX.

6.3. Determine the maximum dry density and the optimum moisture content of the combined FDR material in accordance with T 180, Method D. Use a minimum of four points to determine the optimum moisture content at peak dry density.

Note 10—For materials that do not produce a well-defined optimum moisture curve fix the optimum moisture content between 4 and 5 percent.

7. EMULSIFIED ASPHALT AND ADDITIVES FOR MIX DESIGN

7.1. *Select an emulsified asphalt in accordance with MP XX*:

7.1.1. Obtain 7.6 L (2 gal) of the emulsified asphalt that will be used to produce the FDR mixture. 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.

7.2. *Samples of Other Additives*:

7.2.1. Obtain 2.3 kg (5 lb) of quicklime, hydrated lime, or cement if needed for the mix design.

Note 11—Dry additives are sometimes used to improve early cohesion, strength, and moisture resistance. To limit brittle behavior, the ratio of residual emulsified asphalt to cement should be a minimum of 2.5:1.0 and the quantity of lime should be limited to a maximum of 1.5 percent.

7.2.2. Obtain a sufficient amount of other additives (i.e., corrective aggregate) that will be used to complete the mix design. List the name and source of all additives in the mix design report.

8. DETERMINATION OF DRY AND CONDITIONED STRENGTH

8.1. *Batching FDR Material*:

8.1.1. Select a minimum of four emulsified asphalt contents, evenly spaced, that will bracket the design emulsified asphalt content. Recommended emulsified asphalt contents should be 0.5 percent to 1.0 percent increments covering a range typically between 1 percent and 4 percent, or greater, by dry weight of FDR material. Prepare six specimens 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 cement or lime.

8.1.1.1. For indirect tensile strength testing from T 283, determine the amount of FDR material required to produce a 150 mm (6 in.) diameter and 75 ± 5 mm (2.95 ± 0.2 in.) tall specimen when compacted in the gyratory compactor at 30 gyrations.

8.2. *Preparing Lime Slurry (if required)*:

8.2.1. Prepare slurry by adding the required quantity of additive to water using the ratio expected for the project.

8.2.2. Minimize the amount of additive lost in the form of dust.

8.2.3. Stir until thoroughly mixed, and continuously mix the slurry until it is used to prevent settling.

8.2.4. Cover to reduce water evaporation.

8.3. *Mechanical Mixing*:

8.3.1. Mix samples for testing using a mechanical bucket mixer or laboratory-sized pugmill. If any dry additives are in the mixture, add the additives to the dry FDR and mix thoroughly before adding the water. For mixtures with a sand equivalent value > 30, use 45 to 65 percent of the optimum moisture content determined in 6.3. For mixtures with a sand equivalent value ≤ 30, use 60 to 75 percent of the optimum moisture content determined in 6.3. If slurry is used, add at the desired solids content by weight of dry FDR material and mix thoroughly. Thoroughly mix the FDR material and any additives with water for 60 seconds.

Note 12—During construction dry stabilizing additives are typically added prior to addition of emulsified asphalt. If lime is incorporated a day or more before emulsified asphalt addition, then it shall be added to the wet FDR material a day or more before mixing with emulsified asphalt.

8.3.2. Mix the FDR specimens, conditioned at room temperature between 20 and 25°C (68 and 77°F), thoroughly with any additives and water or slurry, and then mix with emulsified asphalt at the expected delivery temperature. Mixing time with emulsified asphalt should not exceed 60 s.

Note 13—Before mixing the design samples, prepare trial blends with expected moisture, additives and corrective aggregate, if any, to determine that the emulsified asphalt disperses throughout the blend. If an improvement in dispersion is needed, adjust moisture content, staying within the moisture requirements of 8.3.1. If an improvement is still needed, an emulsified asphalt formula change may be needed.

8.4. *Curing Before Compaction*

After mixing, loose specimens shall be cured individually in plastic containers at 40 ± 21ºC (104 ± 2 ºF) for 30 ± 3 minutes. Plastic containers shall be 100 to 180 mm (4 to 7 in.) tall and 150 mm (6 in.) diameter. No further mixing or aeration shall occur during this time.

8.5. *Compacting*:

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

8.5.2. Compact the specimens to 30 gyrations according to T 312 compaction procedures with the exception that the materials and the molds are not heated.

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

8.6. *Curing*:

8.6.1. Extrude the specimens from the molds after compaction. Handle specimens carefully as to not disturb or damage. Remove the paper disks from the top and bottom of the specimens if used.

8.6.2. Place specimens in 60 ± 1°C (140 ± 2°F) forced draft oven with ventilation on sides and top. Place each specimen in a small flat container to account for material loss from the specimens. Cure compacted specimens at 60 ± 1°C (140 ± 2°F) to constant mass but do not heat for more than
48 h and not less than 16 h. Constant mass is defined as 0.05% change in mass or less in 2 hours. After curing, cool specimens at 25 ± 2°C (77 ± 4°F) for a minimum of 12 h and a maximum of
24 h.

8.7. *Sample Conditioning and Testing*:

8.7.1. After curing of specimens, determine the bulk specific gravity of each compacted, cured and cooled specimen according to T 166 Method A or T 331, if required. Since the specimens have already been cured to constant weight under heat, additional drying of the specimens as discussed in Section 6.1 of either T 166 (Method A) or T 331 is not required.

8.7.2. Determine specimen heights according to ASTM D3549. Alternatively, the height can be obtained from the Superpave gyratory compactor readout.

8.7.3. Determine air void contents of the compacted and oven-cured samples at each emulsified asphalt content according to T 269 using the maximum theoretical specific gravity as determined in Section 9.

8.7.4. 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.

8.7.5. 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 pressures) for a time duration required to vacuum saturate samples to 55 to 75 percent. Saturation calculation shall be in accordance with T 283.

8.7.5.1. For the tensile strength test, soak the moisture-conditioned samples in a 25 ± 1°C (77 ± 2°F) water bath for 24 ± 1 h.

8.7.6. Dry samples are tested after a minimum 2-hour temperature conditioning by immersing in a 25 ± 1°C (77 ± 2°F) water bath. Place dry specimens in a leak-proof bag to prevent samples from coming in contact with water. Alternatively, the specimens can be conditioned in an oven at 25 ± 1°C (104 ± 2°F) for a minimum of 2 hours. This testing is performed at the same time that moisture-conditioned specimens are tested.

9. DETERMINING THE THEORETICAL MAXIMUM SPECIFIC GRAVITY

9.1. Batch two FDR material samples according to the gradation used for each mix design for use in determining the theoretical maximum specific gravity value according to either T 209 or ASTM D6857.

9.2. Mix samples according to Section 8.3 using either the highest emulsified asphalt content in the design or the highest and lowest emulsified asphalt contents in the design.

9.3. Follow T 209 or ASTM D6857 with the exception that loose FDR mixtures are cured in a forced draft oven at 60 ± 1°C (140 ± 2°F) to constant mass. Cure for no more than 48 hours and no less than 16 hours. Constant mass is defined as 0.05 percent change in mass or less in 2 h.

9.4. Do not break any agglomerates that will not easily reduce with a flexible spatula.

9.5. If using T 209 use the Supplemental Procedure for Mixtures Containing Porous Aggregate to account for uncoated particles.

9.6. *Testing Two Specimens at the Highest Emulsified Asphalt Content*

9.6.1. Test both specimens at the highest emulsified content in the design.

9.6.2. Back calculate the theoretical maximum specific gravity for the lower emulsified asphalt contents using the following formulas. Calculate the effective specific gravity of the FDR material from the average measured G_{mm} as:

$$G_{FDR} = (100 - P_{br}) / [(100/G_{mm}) - (P_{br}/G_b)]$$

Where: G_{FDR} = Effective specific gravity of FDR material
P_{br} = Percent residual asphalt content from the emulsified asphalt in the mix
G_b = Specific gravity of the residual asphalt

Calculate the theoretical maximum specific gravity for the lower emulsified asphalt contents using the following formula:

$$G_{mm} = 100 / [((100 - P_{br})/G_{FDR}) + (P_{br}/G_b)]$$

Where: G_{mm} = Theoretical maximum specific gravity at desired emulsified asphalt content
P_{br} = Percent residual asphalt content at desired emulsified asphalt content
G_{FDR} = Effective specific gravity of FDR material
G_b = Specific gravity of the residual asphalt

9.7. *Testing Specimens at Highest and Lowest Emulsified Asphalt Content*

9.7.1. Test specimens at the highest and lowest emulsified content in the design. Use straight line interpolation to determine maximum theoretical specific gravity at the other emulsion contents.

10. EMULSIFIED ASPHALT CONTENT SELECTION

10.1 Choose the design emulsified asphalt content that meets the FDR requirements listed in the specification. Report the range of contents that meet the specification requirements.

Note 14—The designer may choose a content that is above the minimum value that meets all the criteria based on knowledge of local construction conditions and sound engineering judgment and experience.

11. REPORT

11.1. Report the following information in the mix design report:

11.1.1. Gradation of RAP and of combined FDR material;

11.1.2. Recommended water content range as a percentage of dry FDR material;

11.1.3. Amount of additive as a percentage of dry FDR material;

11.1.4. Theoretical maximum specific gravity of the mixture at each emulsified asphalt content, G_{mm};

11.1.5. Average air voids and bulk specific gravity at each emulsified asphalt content of T 245 or T 283 samples;

11.1.6. Dry tensile strength at each emulsified asphalt content;

11.1.7. Level of saturation and conditioned tensile strength at each emulsified asphalt content;

11.1.8. Theoretical maximum specific gravity, air void content, dry tensile strength, and conditioned tensile strength at recommended moisture and emulsified asphalt contents;

11.1.9. Optimum emulsified asphalt content as a percentage of dry FDR material, and provide a range of contents that meets the requirements;

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

11.1.11. Emulsified asphalt residue content

11.1.12. Emulsified asphalt penetration of residue.

11.1.13. Notes for the field inspector regarding the possibility of increasing the emulsified asphalt content for finer FDR field gradations or decreasing the content for coarser FDR field gradations compared to mix design gradation;

11.2. *Optional report information*

11.2.1. Certificates of compliance for emulsified asphalt and additive.

12. KEYWORDS

12.1. Full-Depth Reclamation; FDR; reclaimed asphalt pavement; RAP; emulsified asphalt.