
Standard Practice for

Designing Stone Matrix Asphalt (SMA)

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1. SCOPE

- 1.1. This standard practice covers the design of Stone Matrix Asphalt (SMA) using the Superpave Gyratory™ Compactor (SGC). The SMA design is based on the volumetric properties of the SMA in terms of air voids (V_a), voids in the mineral aggregate (VMA), and the presence of stone-on-stone contact.
- 1.2. The values stated in SI units are to be regarded as the standard. The U.S. Customary units in parentheses are for information only.
- 1.3. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. REFERENCED DOCUMENTS

- 2.1. *AASHTO Standards:*
- MP 8, Stone Matrix Asphalt (SMA)
 - R 30, Mixture Conditioning of Hot-Mix Asphalt (HMA)
 - T 19M/T 19, Bulk Density (“Unit Weight”) and Voids in Aggregate
 - T 27, Sieve Analysis of Fine and Coarse Aggregates
 - T 84, Specific Gravity and Absorption of Fine Aggregate
 - T 85, Specific Gravity and Absorption of Coarse Aggregate
 - T 166, Bulk Specific Gravity of Compacted Hot-Mix Asphalt Using Saturated Surface-Dry Specimens
 - T 209, Theoretical Maximum Specific Gravity and Density of Hot-Mix Asphalt Paving Mixtures
 - T 283, Resistance of Compacted Hot-Mix Asphalt (HMA) to Moisture-Induced Damage
 - T 305, Determination of Draindown Characteristics in Uncompacted Asphalt Mixtures
 - T 312, Preparing and Determining the Density of Hot-Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor
- 2.2. *Asphalt Institute Publication:*
- MS-2, *Mix Design Methods for Asphalt Concrete and Other Hot-Mix Types*

3. TERMINOLOGY

3.1. *Definitions:*

3.2. *stone matrix asphalt (SMA)*—a hot-mix asphalt (HMA) consisting of two parts, a coarse aggregate skeleton and a rich asphalt binder mortar. The mixture must have an aggregate skeleton with coarse aggregate-on-coarse aggregate contact (generally referred to as stone-on-stone contact). The coarse aggregate is generally considered to be that fraction of the aggregate retained on the 4.75-mm (No. 4) sieve but may be designated as other sizes.

3.3. *air voids (V_a)*—the total volume of the small pockets of air between the coated aggregate particles throughout a compacted paving mixture, expressed as a percent of the bulk volume of the compacted paving mixture (Note 1).

Note 1—Term defined in the Asphalt Institute Manual MS-2, *Mix Design Methods for Asphalt Concrete and Other Hot-Mix Types*.

3.4. *voids in the mineral aggregate (VMA)*—the volume of the intergranular void space between the aggregate particles of a compacted paving mixture that includes the air voids and the effective binder content, expressed as a percent of the total volume of the specimen (Note 1).

3.5. *voids in the coarse aggregate (VCA)*—the volume between the coarse aggregate particles. This volume includes filler, fine aggregate, air voids, asphalt binder, and fiber (if used).

3.6. *SMA mortar*—a mixture of asphalt binder, filler [material passing the 0.075-mm (No. 200) sieve], and stabilizing additive.

3.7. *stabilizing additive*—either cellulose or mineral fiber.

4. SUMMARY OF THE PRACTICE

4.1. *Materials Selection*—Asphalt binder, aggregate, mineral fillers, and stabilizing additives that meet the applicable specification are selected.

4.2. *Selecting Optimum Gradation*—The three recommended trial aggregate gradations from the selected aggregates are blended. The dry-rodded unit weight for the coarse aggregate for each trial gradation is determined in accordance with T 19/T 19M. For each trial gradation, an initial trial asphalt binder content is selected and at least two specimens are compacted in accordance with T 312. Where no previous history is available, an initial trial asphalt binder content between 6.0 and 6.5 percent is recommended. The gradation is selected to ensure that minimum VMA requirements and stone-on-stone contact are achieved.

4.3. *Selecting Design Binder Content*—Replicate specimens are compacted in accordance with T 312 at three binder contents. The design binder content is selected on the basis of satisfactory conformance with the requirements of Section 10 (Note 2).

Note 2—When an SMA mix cannot be designed within the minimum binder content requirements, the guidelines given in Table X1.11 can be used to establish minimum binder content requirements based on the combined-aggregate bulk specific gravity.

- 4.4. *Evaluating Moisture Susceptibility*—The moisture susceptibility of the mixture, designed and compacted in accordance with T 312 with the SGC to a V_a content of 6.0 ± 1.0 percent, is evaluated in accordance with T 283.
- 4.5. *Evaluating Draindown*—The mixture is evaluated for sensitivity to asphalt binder draindown in accordance with T 305. If the mixture fails the moisture susceptibility or draindown tests, it must be modified so that the specification requirements are met.

5. TEST SPECIMENS

- 5.1. *Number of Samples*—A total of nine samples are initially required; at least three samples at each of the three trial gradations are produced. Each sample is mixed with the trial asphalt binder content, and two of the three samples for each trial gradation are compacted. The remaining sample of each trial gradation is used to determine the theoretical maximum density according to T 209.
- 5.2. *Preparation of Aggregates*—Dry aggregates to a constant mass at 105°C to 110°C (221°F to 230°F), and separate the aggregates by dry-sieving into the desired size fractions. The following size fractions are recommended:
- 37.5 mm ($1\frac{1}{2}$ in.) to 25.0 mm (1 in.),
 - 25.0 mm (1 in.) to 19.0 mm ($\frac{3}{4}$ in.),
 - 19.0 mm ($\frac{3}{4}$ in.) to 12.5 mm ($\frac{1}{2}$ in.),
 - 12.5 mm ($\frac{1}{2}$ in.) to 9.5 mm ($\frac{3}{8}$ in.),
 - 9.5 mm ($\frac{3}{8}$ in.) to 4.75 mm (No. 4),
 - 4.75 mm (No. 4) to 2.36 mm (No. 8),
 - 2.36 mm (No. 8) to 0.075 mm (No. 200), and
 - Passing 0.075 mm (No. 200).
- 5.3. *Determination of Mixing and Compaction Temperatures:*
- 5.3.1. The temperature to which the asphalt binder must be heated to produce a viscosity of 170 ± 20 cSt shall be the mixing temperature.
- 5.3.2. The temperature to which the asphalt binder must be heated to produce a viscosity of 280 ± 30 cSt shall be the compaction temperature.
- Note 3**—While the temperatures given in Sections 5.3.1 and 5.3.2 are appropriate for neat asphalt binders, the selected temperatures may not be applicable to modified asphalt binders. In those cases, it is recommended that the manufacturer's guidelines for mixing and compaction temperatures be used.
- 5.4. *Preparation of Mixtures:*
- 5.4.1. A mechanical mixing apparatus shall be used.
- 5.4.2. An initial batch shall be mixed for the purpose of “buttering” the mixing bowl and stirrers. This batch shall be emptied after mixing, and the sides of the bowl and stirrers shall be cleaned of mixture residue by scraping with a small limber spatula but shall not be wiped with a cloth or washed clean with solvent, except when a change is to be made in the asphalt binder or at the end of a design.

- 5.4.3. Into separate pans for each test specimen, weigh sufficient material to produce compacted samples of the desired volume, approximately 4700 g. Mix the aggregate in each pan. Place the aggregate in an oven and heat to a temperature not exceeding the mixing temperature established in Section 5.3 by more than approximately 28°C (50°F). Heat the asphalt binder to the established mixing temperature. The stabilizing additive is added to the heated aggregate prior to the introduction of the asphalt binder.

Note 4—It is recommended that the stabilizing additive be manually mixed with the heated aggregate. This procedure is needed to ensure an even distribution of the stabilizing additive during the laboratory mixing process. The use of stabilizing additives generally requires slightly longer mixing times.

- 5.4.4. Form a crater in the dry blended aggregate and stabilizing additive, and weigh the preheated required amount of asphalt binder into the crater. Care must be exercised to prevent loss of the mix during mixing and subsequent handling. At this point, the temperature of the aggregate and asphalt binder shall be within the limits of the mixing temperature established in Section 5.3. Mix the aggregate and asphalt binder rapidly until the aggregate is thoroughly coated.

- 5.5. *Compaction of Specimens*—The compaction temperature is determined in accordance with Section 5.3. Laboratory samples of SMA are short-term conditioned in accordance with R 30 and then compacted for 100 gyrations.

Note 5—When aggregates have a Los Angeles Abrasion loss value greater than 30 percent, the desirable number of SGC design gyrations is 75.

6. SELECTION OF TRIAL GRADATIONS

- 6.1. The trial gradations must be selected to be within the desired specification range as defined in MP 8. To design an SMA mixture, it is recommended that at least three trial gradations be initially evaluated. It is suggested that one of the trial blends fall along the coarse limits, one along the fine limits, and one in the middle of the gradation bands as defined in MP 8. When the bulk specific gravities of the different aggregates to be used in the mixture vary by more than 0.2, the trial blend gradations should be based upon volumetric percentage. An example problem illustrating how to blend aggregates based on volume is given in Appendix X1.1.

7. SELECTION OF TRIAL BINDER CONTENT

- 7.1. As a starting point, for aggregates with bulk specific gravities approximately equal to 2.75, a binder content of approximately 6.0 percent or greater, by mass, needs to be selected. If the bulk specific gravity of the coarse aggregate exceeds 2.75, the trial binder content can be reduced by approximately 0.1 percent for each specific-gravity increment of 0.05 above 2.75. If the bulk specific gravity of the coarse aggregate is below 2.75, the trial binder content can be increased approximately 0.1 percent for each specific gravity increment of 0.05 below 2.75 (see Table X1.11).

8. DETERMINATION OF VCA IN COARSE-AGGREGATE FRACTION OF MIXTURE

- 8.1. For best performance, the SMA must have a coarse-aggregate skeleton with stone-on-stone contact. The stone fraction is that portion of the total aggregate blend retained on the 4.75-mm (No. 4) sieve for 12.5-mm ($1/2$ -in.) and 19-mm ($3/4$ -in.) SMA. For the 9.5-mm ($3/8$ -in.) nominal-maximum aggregate size SMA, the stone fraction is that portion of the total aggregate blend retained on the 2.36-mm (No. 8) sieve. The condition of stone-on-stone contact within an SMA is