WEST VIRGINIA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
MATERIALS CONTROL, SOILS AND TESTING DIVISION

MATERIALS PROCEDURE

GUIDE TO DESIGNING HOT-MIX ASPHALT USING THE SUPERPAVE VOLUMETRIC DESIGN METHOD

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1. PURPOSE

1.1 To establish an approved Superpave volumetric design method, test procedures, and evaluation criteria for hot-mix asphalt (HMA). If reclaimed asphalt pavement (RAP) is used in the design, refer to Materials Procedure (MP) 401.02.24 for additional guidelines.

2. SCOPE

2.1 This procedure is applicable to design tests conducted for the purpose of establishing mixture proportions for HMA using the Superpave mix design method. Superpave designs previously approved under the March 2000 version of this MP may continue to be used only if they were designed and approved within the volumetric and gradation parameters of Table 1, Table 2, and Table 3, and the quality control requirements of MP 401.02.29 can continue to be maintained.

2.2 Any approved mix design that exhibits poor field performance may be rejected from further use by the Division.

3. REFERENCED DOCUMENTS

3.1 *AASHTO Standards:*

- M 323, Superpave Volumetric Mix Design
- R 30, Mixture Conditioning of Hot Mix Asphalt (HMA)
- R 35, Standard Practice for Superpave Volumetric Design for Hot Mix Asphalt (HMA)
- 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 30, Mechanical Analysis of Extracted Aggregate

- T 84, Specific Gravity and Absorption of Fine Aggregate
- T85, Specific Gravity and Absorption of Coarse Aggregate
- T 166, Bulk Specific Gravity of Compacted Hot Mix Asphalt (HMA) Using Saturated Surface-Dry Specimens
- T 176, Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test
- T 209, Theoretical Maximum Specific Gravity and Density of Hot Mix Asphalt (HMA)
- T 269, Percent Air Voids in Compacted Dense and Open Asphalt Mixtures
- T 283, Resistance of Compacted Hot Mix Asphalt (HMA) to Moisture Induced Damage
- T 304, Uncompacted Void Content of Fine Aggregate
- T 308, Determining the Asphalt Binder Content of Hot Mix Asphalt (HMA) by the Ignition Method (Test Method A)
- T 312, Preparing and Determining the Density of Hot Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor

3.2 *ASTM Standards*

- D 4791, Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate

3.3 *Material Procedures*

- MP 401.02.24, Guide To Designing Hot-Mix Asphalt with Reclaimed Asphalt Pavement
- MP 401.02.29, Guide for Quality Control and Acceptance Requirements for Superpave Hot-Mix Asphalt

4. TESTING REQUIREMENTS

4.1 The laboratory performing the design shall be a Division approved laboratory. To obtain Division approval, a laboratory must demonstrate that they are equipped, staffed and managed, for batching and testing HMA in accordance with this MP. This shall be accomplished by submitting a copy of their latest report of inspection by the AASHTO Materials Reference Laboratory (AMRL) to the District Materials Section. The laboratory must also submit a letter detailing the actions taken to

correct any deficiencies noted in the test procedures listed below. The District will forward this information to Materials Control, Soils and Testing Division (MCS&T). It is also required that the design laboratory request to be included on AMRL's routine schedule of inspections, which is usually every 18 to 24 months in order to maintain their approval status.

4.1.1 AASHTO Test Procedures

- T 30, Mechanical Analysis of Extracted Aggregate
- T 84, Specific Gravity and Absorption of Fine Aggregate
- T85, Specific Gravity and Absorption of Coarse Aggregate
- T 166, Bulk Specific Gravity of Compacted Hot Mix Asphalt (HMA) Using Saturated Surface-Dry Specimens
- T 209, Theoretical Maximum Specific Gravity and Density of Hot Mix Asphalt (HMA)
- T 283, Resistance of Compacted Hot Mix Asphalt (HMA) to Moisture Induced Damage (specimens prepared using T 312)
- T 308, Determining the Asphalt Binder Content of Hot Mix Asphalt (HMA) by the Ignition Method (Test Method A)
- T 312, Preparing and Determining the Density of Hot Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor

4.2 The laboratory is required to have a technician who has attended and successfully completed a Division approved Superpave mix design class. In addition to the class that is offered through the West Virginia University Asphalt Technology Program, hands-on Superpave mix design classes offered by the Asphalt Institute, National Center for Asphalt Technology (NCAT), National Asphalt Pavement Association (NAPA), Chicago Testing Laboratory, and various state DOTs have been approved. Also, Superpave design classes offered by all of the state DOTs that border West Virginia are approved. Classes offered by other state DOTs may be evaluated for approval as needed. Proof of successful completion of all class requirements (including a written examination) must be provided. Approval of an older design class that did not require a written examination will be on a case-by-case basis including a review of the designer's experience. MCS&T will maintain a list of the approved design laboratories and design technicians.

4.3 The mix design properties shall meet the requirements of Table 1, and shall consist of the following:

4.3.1 Percent Air Voids: T 269

4.3.2 Percent Voids in Mineral Aggregate (VMA): R 35

4.3.3 Percent Voids Filled With Asphalt (VFA): R 35

4.3.4 Fines to effective asphalt (FA) ratio: R 35

4.3.5 Tensile Strength: T 283

TABLE 1—Superpave Method Volumetric Mix Design Criteria

Design air void content, percent				4.0		
Fines-to-effective asphalt (FA) ratio[(Note 1)]				0.6 – 1.2		
Tensile strength ratio, percent (T 283)[(Note 2)]				80 (minimum)		
	Nominal Maximum Size, mm (in.)					
	37.5 (1½)	25 (1)	19 (¾)	12.5 (½)	9.5 (⅜)	4.75 (No.4)
Percent Voids in Mineral Aggregate (VMA)[(Note 3)]	11.5	12.5	13.5	14.5	15.5	16.5
Percent Voids Filled with Asphalt (VFA)	65 – 75	68 – 76	70 – 78	72 – 79	74 – 80	75 – 81

Note 1: When the design aggregate gradation falls within the coarse graded requirement of Table 4, the FA ratio criteria shall be 0.8 – 1.6. For all 4.75 mm (No. 4) mixes, the FA ratio shall be 0.9 - 2.0.

Note 2: Test specimens shall be compacted using a gyratory compactor in accordance with T 312. If the 80 percent minimum tensile strength ratio is not met, a new design will be required. A Division approved antistripping additive, such as hydrated lime conforming to the requirements of M 303 or a liquid antistripping additive, may be added to the mixture if needed. The additive must be identified on the T400SP Form. T 283 shall be waived when a new mix design is developed using all of the aggregate sizes and sources of a previously approved mix design that has met the required tensile strength ratio of at least 85 percent. This waiver information should be noted on the submitted design package along with the previously approved design T400SP number to inform the MCS&T why T 283 test data has not been included. If the approved design contained an antistripping additive, then the new design must also contain this additive. MCS&T may request the tensile strength ratio be checked at any time on any design that is shown to exhibit signs of stripping.

Note 3: Mixtures designed with the VMA exceeding the minimum value by more than two percent may be susceptible to flushing and rutting, especially when used on pavements subjected to slow moving traffic conditions. They may also be difficult to compact as they often have a tendency to shove under the roller.

4.4 The mix design shall be developed using the volumetric design guidelines provided in M 323 and R 35 with the exception of any variations or additions that are noted in this MP. All laboratory prepared design test specimens shall be conditioned in an oven for 2 hours ± 5 minutes in accordance with R 30. The gyratory compaction criteria shall be in accordance with Table 2 based on the projected 20-year design traffic ESAL value supplied in the contract documents. If the traffic ESAL value is not supplied in the contract documents, contact the District to obtain this information. The design PG Binder shall normally be selected in accordance with Section 401.2 of the Standard Specifications. However, the laboratory's mix designer should refer to the contract documents to see if a nonstandard binder grade has been specified for the project.

TABLE 2 - Gyratory Compaction Criteria[(Note 4)]

20-Year Projected design ESALs (millions)	Compaction Parameters	
	Gyration Level-1	Gyration Level-2
	N_{design} for Binder < PG 76-XX	N_{design} for Binders ≥ PG 76-XX or Mixes Placed Below Top Two Lifts[(Note 5)]
< 0.3	50	50
0.3 to < 3	65	65
3 to < 30	80	65
≥ 30	100	80

Note 4: Unless otherwise specified in the contract documents, a PG 64-22 binder shall be used in mixtures located below the top two pavement lifts. The use of a different binder grade must be approved by the Engineer.

Note 5: The Gyration Level-2 criteria for mixes placed below the top two lifts applies only to mainline paving. Multi-lift base failure and other pavement repairs shall fall under the criteria of Gyration Level-1 unless otherwise specified in the contract documents.

4.5 The design gradation shall meet the requirements of Table 3 for the specified mix type. Table 4 shall be used to distinguish between the gradation criteria for each mix type. The percent passing each sieve listed in Table 3, from one sieve larger than the nominal maximum size down to the 75 µm (No. 200), shall be included in all gradation calculations.

TABLE 3– Design Aggregate Gradation Requirements for Superpave Mixtures (Note 7)

Type of Mix	**37.5**	**25**	**19** (Patch & Level)	**12.5**	**9.5** (Scratch)	**4.75** (Scratch)
Standard Sieve Size	**Nominal Maximum Size**					
	37.5 mm (1 ½ inch)	**25 mm** (1 inch)	**19 mm** (3/4 inch)	**12.5 mm** (1/2 inch)	**9.5 mm** (3/8 inch)	**4.75 mm** (No. 4)
50 mm (2")	100					
37.5 mm (1½")	90 – 100	100				
25 mm (1")	90 max	90 – 100	100			
19 mm (3/4")		90 max	90 – 100	100		
12.5 mm (1/2")			90 max	90 – 100	100	100
9.5 mm (3/8")				90 max	90 – 100	95 – 100
4.75 mm (No.4)			(Note 6)		90 max	90 – 100
2.36 mm (No.8)	15 – 41	19 – 45	23 – 49	28 - 58	32 - 67	
1.18 mm (No.16)						30 – 60
600 µm (No.30)						
300 µm (No. 50)						
75 µm (No.200)	0.0 – 6.0	1.0 - 7.0	2.0 – 8.0	2.0 - 10.0	2.0 - 10.0	6.0 – 12.0

Note-6: When a 19 mm mix is specified for use as a heavy duty surface mix, it shall be designed as a fine graded mix with the additional requirement of a minimum of 47% passing the 4.75 mm (No.4) screen. The allowable tolerance limit shall be the JMF ± 5% on the 4.75 mm (No.4) sieve, but not below the minimum requirement.

Note 7: For quality control of the mixture the allowable tolerances for each JMF shall be the specified design control points shown in Table-3 with the exception that a 4.75 mm mix shall have a tolerance limit of the JMF ± 5% on the 1.18 mm (No. 16) sieve and all other mix types shall have a tolerance limit of the JMF ± 6% on the 2.36 mm (No.8) sieve. These tolerances shall also be applied to the mix design and shall be documented on the T-400SP Form. The tolerances shall not fall outside of the specified control points of Table-3.

TABLE 4–Coarse and Fine Graded HMA Criteria

Mixture Nominal Maximum Size	Coarse Graded % Passing / Sieve Size	Fine Graded % Passing / Sieve Size
37.5 (1½)	< 47% / 9.5 mm	≥ 47% / 9.5 mm
25 (1)	< 40% / 4.75 mm	≥ 40% / 4.75 mm
19 (¾)	< 47% / 4.75 mm	≥ 47% / 4.75 mm
12.5 (½)	< 39% / 2.36 mm	≥ 39% / 2.36 mm
9.5 (3/8)	< 47% / 2.36 mm	≥ 47% / 2.36 mm
4.75 (No. 4)	No distinction between coarse and fine grading	

4.6 The aggregate used in the mix design shall meet the requirements of Sections 702.3, 702.4, 703.1, 703.2, and 703.3 of the Standard Specifications with exceptions and additions as noted in Table 5. If a mix contains reclaimed asphalt pavement (RAP), the asphalt must be removed from the RAP for gradation analysis by the ignition oven method (T 308) or a solvent extraction process (T 164). If the T 164 solvent extraction test method is used, a non-chlorinated solvent may be substituted for the standard specified solvent, and the test method may be modified as per the recommendations of the solvent supplier. The solvent must be a product that has been tested for use in extracting asphalt from HMA. The RAP aggregate shall be proportionally blended into the samples submitted to MCS&T as described in Section 4.8. The RAP used for designing a mix must come from the plant stockpile from which it will be produced.

4.7 Test results for fine aggregate angularity, recorded on Design Attachment Number 13, shall be submitted along with the mix design package. Testing shall be conducted in accordance with T 304 (Method A) on a sample blended in accordance with the methods described in Section 4.8.1 and 4.8.2. This testing may be performed by a WVDOH certified asphalt technician or aggregate inspector. The name of the testing laboratory and the technician conducting the test shall be indicated on the worksheets.

4.8 Other than the exception noted in Section 4.9, to obtain final approval of the mix design, coarse and fine aggregate samples must be submitted to the MCS&T through the District Materials Section. These samples will be tested and used as part of the overall approval process for the mix design, therefore, they should be submitted well in advance of the earliest anticipated use of the mix. The aggregate property requirements of Table 5 shall be applied to the blend of coarse and fine aggregates within the mixture.

4.8.1 For each mix design, a minimum 30,000 gram sample (40,000 gram sample for a 37.5 mm mix) of the coarse and fine aggregates shall be blended to the mix design

proportions. The blended sample shall then be separated into plus 4.75 mm (No. 4) and minus 4.75 mm (No. 4) portions. The fine aggregate sample shall then be further prepared in accordance with Section 4.8.2. Mixtures shall be designed in accordance with the criteria set forth in Table 1, 2 and 3 unless otherwise indicated in a special provision or as a note in the contract documents.

4.8.2 Fine Aggregate Sampling Procedure: The minus 4.75 mm (No. 4) portion of the blended aggregate sample shall be split into two separate samples. One of these split samples shall be bagged and labeled as the unwashed portion of the fine aggregate blended sample. The other split sample shall be washed, oven dried, and graded to remove all plus 2.36 mm (No. 8) and minus 150 µm (No. 100) material. This washed sample shall then be split and placed into two sample bags. One bag shall be labeled as washed fine aggregate specific gravity sample and the other shall be labeled as washed fine aggregate angularity sample.

4.9 If a new mix design uses the exact aggregate design structure and sources as a previously approved mix design, the aggregate evaluation used to accept the previous mix design will apply to the new mix design. A note of the testing waiver along with the T400SP lab number from the previous design shall be included in the remarks of the T400SP worksheet submitted along with the documentation of the new mix design.

TABLE 5 – Aggregate Consensus Property Requirements

20 Year Projected Design ESALs (millions)	Coarse Agg. Angularity (% Minimum) ASTM D5821 (Note 8)		Fine Agg. Angularity (% Minimum) AASHTO T304, Method A (Note 10)		Fine Agg. Sand Equivalent AASHTO T176	Coarse Agg. Flat and Elongated ASTM D4791
	Top Two Pavement Lifts (Note 9)	Below Top Two Pavement Lifts	Top Two Pavement Lifts	Below Top Two Pavement Lifts	% Minimum	% Maximum (Note 13)
< 0.3 (Note 11)	55 / -	- / -	-	-	40	-
0.3 to < 3 (Note 11)	75 / -	50 / -	40	40	40	10
3 to < 10	85 / 80	60 / -	45	40	45	10
10 to < 20 (Note 12)	90 / 85	80 / 75	45	40	45	10
20 to < 30	95 / 90	80 / 75	45	40	45	10
≥ 30	100/100	100/100	45	45	50	10

Note 8: "85/80" denotes that a minimum of 85 percent of the coarse aggregate has one fractured face and a minimum of 80 percent has two fractured faces.

Note 9: The referenced "top two pavement lifts" does not include a scratch course or patching-and-leveling course that may be placed between these lifts. When a scratch or patching-and-leveling course is placed between the top two lifts, the aggregate requirements for the mix shall fall under the "top two pavement lifts" criteria.

Note 10: For design traffic levels of 3 million ESALs or greater, any mix composed of a 100 percent crushed aggregate blend that will be used in the top two lifts of the pavement structure will be acceptable with an FAA value of 43 percent or greater. The 43 percent FAA criteria shall also apply to the 30 million or grater traffic level for mixtures below the top two lifts. It shall also apply to 100 percent crushed aggregate blends that contain no more than 15 percent RAP.

Note 11: The minimum requirement for coarse aggregate angularity for any Section 402 skid resistant mix design with a projected ESAL value of 0.3 to less than 3 million shall be 85/80. For skid resistant mix design with a projected ESAL value of less than 0.3 million it shall be 75/-.

Note 12: The 10 to less than 20 million design ESAL aggregate criteria only applies to Section 402 skid resistant mix designs.

Note 13: Flat and elongated particles in coarse aggregates shall be tested in accordance with D 4791 with the exception that the material passing the 9.5 mm (⅜ in.) sieve and retained on the 4.75 mm (No. 4) sieve shall be included. The aggregate shall be measured using the ratio of 5:1, comparing the length (longest dimension) to the thickness (smallest dimension) of the aggregate particles.

4.10 At the beginning of each paving season in subsequent years the aggregate consensus properties of Table 5 shall be tested on blended aggregate samples prepared in accordance with Section 4.8. These tests may be conducted by a WVDOH certified asphalt technician or aggregate inspector. These test results shall be submitted to the District Materials Section for the purpose of maintaining approval of the mix design. The name of the testing laboratory, date tested, and signature of the technician conducting the tests shall be indicated on the worksheets. These test results must be submitted before the mix is used on any Division project each year.

4.10.1 During the time that the annual aggregate consensus testing is being performed, the Division may periodically request that a duplicate set of blended aggregate samples be prepared for submittal to MCS&T for testing. The Division will identify the mix design in advance so that sufficient material is obtained for preparation of duplicate samples. Nonconforming test results on these samples will require further investigation by the Division. No corrective action will be required by the Contractor unless the investigation concludes that it is necessary. If corrective action is required, the contractor will be notified, and further use of the mix design shall be discontinued until the Division has determined that the problem has been properly addressed.

4.11 If the aggregate consensus property test results submitted to the Districts meet specification requirements, the District shall forward the results to MCS&T for the purpose of maintaining approval of the mix design. If any of the required aggregate tests fail to meet specification requirements, retesting by the contractor will be permitted, and the District shall submit a sample of the blended aggregate to MCS&T to verify the consensus property test that failed.

4.12 If the mix is comprised of 100 percent crushed blended aggregates that contain no more than 15 percent RAP, and it met both the coarse and fine aggregate angularity requirements, the flat-and-elongated requirement, and the sand equivalent requirement during the initial design approval, and any annual follow-up testing, then retesting each year by MCS&T will not be required. However, fine aggregate samples of mixes containing rounded natural sand and/or greater than 15 percent RAP must be prepared by a certified asphalt technician in accordance with Section 4.8 and 4.8.1, and a sample of sufficient size required for testing the fine aggregate angularity shall be submitted to MCS&T on an annual basis.

4.13 Full mix design testing will not be required when a mix design is developed using the exact aggregate structure, sources, and compaction level as a prior Division approved design, along with a different neat binder grade. The designer may instead select to make a set of bulk specific gravity test specimens and a maximum specific gravity test specimen with the approved aggregate structure and the new binder grade at the optimum asphalt content of the approved design. Since these samples are laboratory produced design specimens, they must be oven aged for 2 hours ± 5 minutes before testing in accordance with R 30 (Mix Conditioning of HMA) as specified in R 35 (Superpave Volumetric Design for HMA). Mix and compaction temperature will be based on the requirements of the new binder grade. The percent air voids must be 4.0 ± 0.3 percent. The voids-in-mineral aggregate must be within ± 0.5 percent of the original approved job mix formula design target (but not outside of the limits of this MP). All other mix design criteria must be within the limits specified in this MP. If the mix design meets all of these requirements then this test data may be submitted along with a new T400SP form for approval as a new mix design. A copy of the approved T400SP on which this new design is based should also be included. If the mix design fails to meet all of the requirements then a new mix design must be developed.

5. REPORT

5.1 The T-400SP JMF form shall include the design property information required in Section 401.4 of the Standard Specification. JMF submittals shall include all Superpave mix design software printouts from the specimen compaction and analysis covering the required mix properties. In addition, if not automatically generated through the mix design software, the following information must be included.

5.1.1 A summary sheet (Superpave Package Attachment #1) showing the optimum asphalt content determination plus the design properties compared to the design criteria of Table 1. This attachment shall be signed and dated by the mix design technician.

5.1.2 Worksheet for calculating the effective gravity of the blended aggregates (Attachment #4 or #4A).

5.1.3 Worksheets showing calculations for maximum specific gravities of the mix at the different asphalt contents (Attachment #5). For any mix that contains any single coarse aggregate component with the water absorption of 1.5 percent or greater, follow the supplemental procedure of T 209 to determine if a dry-back is necessary. Because the dry-back procedure is addressing an aggregate coating issue, this same supplemental procedure shall be used on quality control and verification samples of mixes containing these high absorptive aggregates to determine if the dry-back procedure is necessary.

5.1.4 Worksheet for calculating the bulk and apparent specific gravities of the total aggregate, and the percent VMA in the compacted mixture (Attachment #6 or #6A).

5.1.5 Worksheet for determining the maximum specific gravity of the mixture, including the dry-back procedure when required (Attachment #7). Note that AASHTO R-35 specifies that the maximum specific gravity shall be based on the average of at least two tests.

5.1.6 Worksheets showing calculation for bulk and apparent specific gravities and absorption of the coarse and fine aggregates used in the mix design (Attachments #8 or #8A).

5.1.7 The 0.45 power gradation chart (Attachment #9) developed for each mix design. This chart shall include the maximum density line, aggregate control points, and a gradation plot showing each screen used in the design.

5.1.8 A worksheet showing the calculations for the combined aggregate of the mix design (Attachment #10).

5.1.9 Worksheets showing the washed sieve analysis results for each aggregate used in the mix design (Attachment #11).

5.1.10 A worksheet showing the calculations for the fine aggregate angularity test (Attachment #13).

5.1.11 A worksheet showing the calculations for absorbed asphalt and effective asphalt content (Attachment #14).

5.1.12 The temperature-viscosity chart for the asphalt used in the mix design. A supplier issued chart or document containing the mix and compaction temperature recommended for the specific grade of asphalt will be acceptable.

5.2 The entire printed JMF package shall be submitted to the local District Materials Section in which the HMA plant is located. After reviewing, the District shall attach a memo to the JMF package requesting approval of the design and submit it to the MCS&T Asphalt Section.

5.2.1 The JMF package can also be submitted electronically by scanning it into an Adobe Acrobat Reader file and e-mailing the file to the appropriate District Materials Section and the MCS&T Asphalt Section. After reviewing the JMF package, the District will send an e-mail to the MCS&T Asphalt Section verifying that the JMF package has been reviewed. The District will also note any problems that they find with the JMF. The MCS&T Asphalt Section will conduct a final review on the design package and assign a laboratory number to each approved mix design. MCS&T will contact the mix designer if there are any problems or concerns with the JMF package that will delay final approval. An electronic copy of the approved T400SP form shall be e-mailed to the District and Producer for distribution.

5.3 All applicable mix design worksheets can be found on the MCS&T's web page under the "Toolbox" heading at the following link:

http://www.transportation.wv.gov/highways/mcst

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