PREFACE

Materials Method 5.16 describes New York State Department of Transportation's (NYSDOT's) requirements and policies for the development of Hot Mix Asphalt (HMA) mixture designs, including the responsibilities of the Producer and the Department. This Materials Method (MM) also gives the specific testing details and evaluation procedures to be followed in the HMA mixture design process. Conformance with MM 5.16 assures uniform testing and evaluation of paving mixtures through volumetric analysis of laboratory and plant prepared specimens.

The purpose of the HMA mixture design system is to design HMA mixtures that achieve the fundamental volumetric properties needed to result in maximum pavement performance. It is extremely important that the plant quality control procedures outlined in the Producer's Quality Control Plan are followed to ensure uniform production.

Department personnel may suggest to a Producer methods for improving a mixture design, with the understanding that the suggestions do not bind NYSDOT to accepting material outside of specifications.

Note: This Materials Method (MM) may require the use of hazardous materials and safety sensitive procedures. This MM does not address any of the safety problems associated with its use. It is the responsibility of the user of this MM to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

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NOTES

I. SCOPE

This Materials Method (MM) describes the responsibilities and procedures for the development and review of hot mix asphalt (HMA) mixture designs. This MM outlines a complete procedure for the uniform design of mixtures for 9.5 Top Course, 12.5 Top Course HMA, 19.0 Binder Course HMA, 25.0 Binder Course HMA, or 37.5 Base Course HMA.

II. GENERAL

The mixture design system is based on the Superpave design system and Performance-Graded (PG) binder specification developed through research performed during the Strategic Highway Research Program (SHRP). The Superpave system was developed to address three principal distresses that plague HMA pavement: rutting, fatigue cracking, and low temperature cracking.

The objective of the HMA mix design system is to define an economical blend of PG binder and aggregate yielding a paving mixture having sufficient air voids, voids in the mineral aggregate (VMA) and voids filled with binder (VFB) that will perform satisfactorily over the pavement's service life. The mixture and binder requirements are tailored to accommodate the diverse, but specific, climate and traffic conditions that pavements are exposed to at projects sites across the State. The HMA mixture design procedure is used to establish proper proportions of aggregates, reclaimed asphalt pavement (when applicable), and PG binder to meet the required mixture volumetric properties, given the specific traffic and weather conditions of the project location. Reclaimed asphalt pavement (RAP) may be used in the design and production of any HMA mixture.

The Producer is responsible for preparing the HMA design; NYSDOT is responsible for checking the submitted mixture design for completeness and accuracy. The Regional Director or his representative has final acceptance authority.

A complete HMA mixture design is required for each aggregate source combination, differing aggregate gradations, differing RAP percentages, and a separate job mix formula (JMF) for each plant using the same aggregate at a site having multiple plants.

III. INFORMATION SOURCES

The following is a list of the various sources of information that must be consulted, in addition to this MM, to prepare an HMA Mixture Design. Use the most current version of each of the information sources listed, particularly any AASHTO Provisional Standard that may be reissued as an AASHTO Standard Specification.

1. NYSDOT Standard Specifications - including all Addenda and the Project Proposal.
2. NYSDOT Approved List, Sources of Fine & Coarse Aggregates.

3. NYSDOT Materials Method 5 - Plant Inspector's Manual for Bituminous Concrete Mix Production.
4. NYDOT Approved List – Materials & Equipment
5. NYSDOT Materials Method 28 - Friction Aggregate Control and Test Procedures.
6. NYSDOT Materials Procedure 401 - Quality Control and Quality Assurance Procedures for Hot Mix Asphalt (HMA) Production.
7. NYSDOT Technical Report 01-02 - Using Reclaimed Asphalt Pavement in Superpave Hot Mix Asphalt.
8. AASHTO M 231 - Specification for Weighing Devices Used in the Testing of Materials.
9. AASHTO M 320– Standard Specification for Performance-Graded Asphalt Binder.
10. AASHTO M 323– Standard Specification for Superpave Volumetric Mix Design.
11. AASHTO R 30– Standard Practice for Mixture Conditioning of Hot Mix Asphalt (HMA).
12. AASHTO R 35– Standard Practice for Superpave Volumetric Design for Hot Mix Asphalt (HMA).
13. AASHTO T 11 - Standard Method of Test for Materials Finer Than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing.
14. AASHTO T 27 - Standard Method of Test for Sieve Analysis of Fine and Coarse Aggregates.
15. AASHTO T 84 - Standard Method of Test for Specific Gravity and Absorption of Fine Aggregates.
16. AASHTO T 85 - Standard Method of Test for Specific Gravity and Absorption of Coarse Aggregates.
17. AASHTO T 100 - Standard Method of Test for Specific Gravity of Soils.
18. AASHTO T 166 – Standard Method of Test for Bulk Specific Gravity of Compacted Hot Mix Asphalt Using Saturated Surface-Dry Specimens.
19. AASHTO T 176 - Standard Method of Test for Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test.
20. AASHTO T 209 – Standard Method of Test for Theoretical Maximum Specific Gravity and Density of Hot Mix Asphalt Paving Mixtures.
21. AASHTO T 228 - Standard Method of Test for Specific Gravity of Semi-Solid Bituminous Materials.
22. AASHTO T 245 - Standard Method of Test for Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus.
23. AASHTO T 283 - Standard Method of Test for Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage.
24. AASHTO T 304 - Standard Method of Test for Uncompacted Void Content of Fine Aggregate.
25. AASHTO T 305 - Standard Test Method for Determination of Draindown Characteristics in Uncompacted Asphalt Mixtures.
26. AASHTO T 312 - Standard Method of Test for Preparing and Determining the Density of Hot-Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor.

27. AASHTO T 316 - Standard Method of Test for Viscosity Determination of Asphalt Binder Using Rotational Viscometer.
28. ASTM D 4791 - Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate.
29. ASTM D 5821 - Standard Test Method for Determining the Percentage of Fractured Particles in Coarse Aggregate.
30. AASHTO T 326 – Uncompacted Void Content of Coarse Aggregate (As Influenced by Particle Shape, Surface Texture, and Grading)
31. Asphalt Institute Technical Bulletin - Laboratory Mixing and Compaction Temperatures.

All NYSDOT listed references are available from the New York State Department of Transportation. Contact the Regional Materials Engineer for further information.

All AASHTO listed references are available from:

American Association of State Highway and Transportation Officials
444 North Capitol Street, NW
Suite 225
Washington, D.C. 20001
Phone: (202) 624-5800

All ASTM listed references are available from:

American Society for Testing and Materials
1916 Race Street
Philadelphia, PA 19103-1187
Phone: (215) 299-5400

All Asphalt Institute listed references are available from:

Asphalt Institute
2696 Research Park Drive, P.O. Box 14502
Lexington, KY 40512-4052
Phone: (978) 681-9210

IV. DETAILS OF RESPONSIBILITY

A. Producer

The Producer is responsible for furnishing a complete HMA mixture design to the Department, according to this MM. The mixture's volumetric properties must meet all volumetric criteria.

1. Analysis of Plant Aggregate Gradation

Obtain gradation data, and develop a producible target gradation, meeting all control point criteria.

2. Establishing and Maintaining RAP Stockpiles

For the design and production of HMA mixtures, RAP is a stockpile aggregate material. Include provisions for maintaining RAP stockpiles in the production facility's Quality Control Plan. All aggregate in a RAP stockpile must meet all requirements of Section V.-A.-1., *Aggregate Selection/Requirements*, and be free of contaminants such as traffic loop wires or other debris.

New RAP material may be added to a RAP stockpile, if the aggregate in the material being added to the stockpile meets all of the requirements referenced above. As with other aggregates, RAP should be stockpiled by size. New RAP material that differs in gradation from an existing stockpile should be processed to match the gradation of the existing stockpile before being added, or should be used to form a new stockpile.

Before designing recycled HMA mixtures, establish at least one RAP stockpile. Use this stockpile for the design of recycled HMA mixtures. More than one mixture design may be developed for each stockpile.

3. Obtaining Aggregate and RAP Samples

Obtain representative aggregate and RAP samples according to MM 5, "Plant Inspector's Manual for Bituminous Concrete Mix Production." Obtain a sufficient quantity of aggregate to perform all testing detailed in this MM. A total combined aggregate and RAP mass of 130 kg should be sufficient. RAP samples must be processed to remove all material larger than the scalping screen which will be used during production and dried to a constant weight before being used. Submit a sufficient sample of aggregate and RAP to NYSDOT for mixture design verification.

4. Job Mix Formula (JMF) Development

Develop a JMF through a four-step process consisting of: 1) selecting appropriate materials, 2) developing a design aggregate structure, 3) determining a design PG binder content, and 4) evaluating the resultant mixture's moisture susceptibility using AASHTO T283, if required by RME. The HMA mixture must meet all aggregate quality, mechanical and volumetric property requirements. Develop all JMFs according to this MM. The RAP's binder component must be asphalt binder and free of asbestos and significant contents of solvents, tars, or other contaminating substances.

5. Data Documentation

Document the resultant test data on NYSDOT forms or NYSDOT approved computer-generated forms. The Producer must fill out and sign all forms. The required forms are:

BR 253-257	Superpave Job Mix Formula (specific form will vary with Nominal Maximum Aggregate)
BR 293	Superpave Design PGB Content Compacted Specimen Volumetric Property Summary
BR 294	Superpave Design PGB Content Compacted Specimen Volumetric Property Summary for Recycled Mixtures
BR 295	Superpave Volumetric Property Curves
BR 319	Superpave Design PGB Content Compacted Specimen Density Worksheet
BR 320	Superpave Performance Graded Binder Temperature Viscosity Data
BR 326	Superpave Average Washed Gradation Summary
BR 327	Superpave Batch Masses for Mixture Verification
BR 332	Superpave Design PGB Content Mixture Maximum Specific Gravity Summary - AASHTO T 209

6. HMA Design Submission

Submit the completed HMA mixture design to the Regional Materials Engineer (RME). Include in the mixture design submission:

a. The above listed forms.

b. Sufficient PG binder and aggregate samples if requested by the RME.

7. Production Notification

After the HMA mixture design is assigned verification status, notify the RME by 3:00 pm before initial production. If this notice is not given, mixture verification will not begin, and any material shipped without the appropriate notice will not be accepted.

8. Production Monitoring - Quality Control

Monitor all volumetric properties and aggregate gradations during production according to Section 401 - *Plant Production* of the Standard Specifications.

B. NYSDOT

This section outlines the responsibilities of the RME.

1. HMA Design Review

The RME will review the JMF and associated information for accuracy and completeness according to Section IX, *Verification*. Based on this review, the RME will do one of the following.

a. Assign Verification Status to the design;

b. Will not accept the design for being incomplete;

c. Will not accept the design for not meeting the mixture volumetric criteria or the aggregate consensus property requirements;

d. Lab verify the design to determine whether the design meets the criteria listed in Section IX. *Verification*. The purpose of laboratory verification is to check the Producer's laboratory techniques used to complete the submitted design. After completing the laboratory verification (if required), the RME will either assign Verification Status to the design or will not accept it for not meeting the specified mixture criteria.

2. Production Monitoring - Quality Assurance

For each day of production under Verification Status, the Department personnel will determine the daily production Quality Adjustment Factor (QAF) according to Materials Procedures. At the successful conclusion of mixture production under Verification Status, the RME will assign Production Status to the mixture design.

V. DESIGN PROCEDURE

This section outlines the procedures to be followed by the Producer in preparing the mixture design and by the RME when reviewing mixture designs for volumetric and mechanical properties. For the design and review of recycled HMA mixtures, refer to Section VII, *Recycled Hot Mix Asphalt Design Procedure*. The Producer will develop HMA mixture designs according to AASHTO M 323, AASHTO R 35 and this Materials Method. If different, the requirements in this Materials Method supersede the corresponding AASHTO requirements.

A. Materials Selection

1. Aggregate Selection/Requirements

Aggregates must meet the requirements of Section 401 - *Plant Production*, of the Standard Specifications and additional project-specific consensus requirements for coarse aggregate angularity, fine aggregate angularity, flat-and-elongated particles, and sand equivalent. The aggregate consensus property requirements are based on estimated traffic loadings.

If an individual aggregate component does not meet the aggregate quality requirements, it is not necessarily precluded from use. However, its percentage of use in the total aggregate blend is limited as determined by the law of partial fractions. If an aggregate component's blend proportion is limited due to quality concerns, evaluate the Design Aggregate Structure selected to assure compliance with the aggregate consensus property requirements.

Note: If the coarse aggregate blend percentages are changed during production. Composite samples of the coarse aggregate should be tested to ensure that the minimum percent friction aggregate is present.

Note: Pay particular attention to the coarse aggregate friction aggregate requirements for 12.5 mm and 9.5 mm top courses. The friction aggregate requirements may vary from project to project depending on the traffic volume of a specific project.

2. Performance-Graded Binder Selection

A PG binder (PG XX-YY) is denoted by the range of pavement temperatures, maximum to minimum, over which the binder is expected to provide acceptable performance. The maximum pavement temperature (XX) is equal to the average 7-day maximum pavement temperature 20 mm below the pavement surface. The minimum pavement temperature (-YY) is defined as the minimum pavement surface temperature. Using the Superpave weather database temperature variability is accounted for and a design reliability (or design risk) is assigned for each PG binder.

A primary source, which appears on the Department's Approved List for *Performance-Graded (PG) Binders for Hot Mix Asphalt (HMA) Pavements*, shall certify that the PG binder meets all requirements. This certification shall be provided by the last primary source to alter the PG binder.

Note: The grade of PG binder used on an individual project will be specified in the Contract documents.

Note: A new JMF number is required when a different PG binder grade is used. A new JMF form that references the original design and

indicates the new PG binder to be used is acceptable in lieu of a complete new mix design. The new JMF will be assigned "Verification Status" and require plant verification by the Department.

B. Design Aggregate Structure Selection

This section details the aggregate blend requirements and procedure for determining the estimated design binder content for the aggregate blend. The procedures for developing the aggregate blend are detailed in Section VI. A. *Plant Aggregate Gradation Analysis*.

The aggregate blend submitted must meet all of the aggregate quality requirements (see **Table 2 - Additional Aggregate Criteria**), design control points (see **Table 1 - Design Control Points**), the specified estimated traffic loading and, if a friction course, the friction aggregate criteria for the estimated traffic volume.

1. Mixture Aggregate Consensus Properties

The Producer determines the aggregate consensus properties from **Table 2 - Additional Aggregate Criteria**, and reports the results on BR 253-257, "*Superpave Job mix Formula*,"

Table 1 - Design Control Points

Standard Sieves (mm)	Percent Passing Criteria[1]									
	Nominal Maximum Aggregate Size									
	37.5 mm		25.0 mm		19.0 mm		12.5 mm		9.5 mm	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
50.0		100								
37.5	100	90		100		100				
25.0	90		100	90	100	97				
19.0			90		100	90		100		100
12.5					90		100	90	100	97
9.5							90		100	90
4.75									90	
2.36	41	18	45	22	49	26	58	31	67	32
0.075	6	0	7	1	8	2	10	2	10	2

1. Percent passing rounded to the nearest whole number.

Table 2 - Additional Aggregate Criteria

Design ESALs (million)	Uncompacted Void Content (Percent), minimum				Sand Equivalent (Percent), minimum	Flat-and-Elongated (Percent), maximum
	Coarse Aggregate[1]		Fine Aggregate			
	Depth from Surface[2]					
	≤ 100 mm	> 100 mm	≤ 100 mm	> 100 mm		
< 0.3	45	45	-	-	40	-
0.3 to < 30	45	45	43	40	45	10
≥ 30	47	47	43	43	50	

(1) If the coarse aggregate does not meet the UVC requirements, coarse aggregate angularity results obtained according to ASTM D5821 and the requirements in the previous MM5.16 Interim, dated November 2006, maybe used. Coarse aggregate UVC is not required for crushed stone sources.

(2) If at least 75% of a layer is deeper than 100 mm below the pavement surface, the greater than 100 mm aggregate consensus properties apply for mixture design of that layer. This eliminates the more stringent consensus properties for most 37.5 mm base courses.

Coarse Aggregate Angularity. Coarse aggregate angularity is defined as the percent of voids in loosely compacted aggregate tested according to AASHTO T 326, Method C, using No.1 aggregate sizes as described in §703-02 proportioned to the mix design requirements.

Fine Aggregate Angularity. Fine aggregate angularity is defined as the percent of air voids present in loosely compacted aggregate that passes the 2.36 mm sieve measured on the fine aggregate portion of the blended aggregate by AASHTO T 304, Method C. The criteria are presented as the minimum percent air voids required in loosely compacted fine aggregate.

Note: When the fine aggregate angularity of a natural sand or stone screenings from a crushed gravel source is evaluated, the specific gravity of the Method A blend must be determined for use in the test. When a manufactured sand or stone screenings from a crushed stone source is evaluated, use the specific gravity determined from the sampled material. If the specific gravity was assumed to be the same as the coarse aggregate from the same source, use the assumed value.

Flat-and-Elongated Particles. Flat-and-elongated particles are defined as coarse aggregate particles that have a ratio of maximum to minimum dimensions greater than five. The percentage of flat-and-elongated particles is measured on the portion of the blended aggregate retained on the 9.5 mm sieve by ASTM D 4791. The criteria are presented as the maximum percent allowed by mass of flat-and-elongated particles.

Note: The maximum dimension is defined as the particles maximum length. The minimum dimension is defined as the particles maximum thickness (i.e., if the cross section of the particle is irregularly shaped, the maximum thickness is equal to the length of the short side of a rectangle large enough to contain this shape).

Sand Equivalent. Sand equivalent is defined as the percent of the sand reading to the clay reading measured on the portion of aggregate that passes the 4.75 mm sieve by AASHTO T 176. The criteria are presented as the minimum percent sand equivalent required in the fine aggregate.

Note: Determination of the sand equivalent is not required on a routine basis. The Department believes the aggregates commonly used in New York State will meet the most stringent Superpave consensus sand equivalent requirement. However, if performance problems are encountered the Department may require this testing to be performed.

If any of the aggregate consensus quality requirements are not met for any of the aggregates used in the proposed mixture design, the percent of use for those aggregates is limited in the total aggregate blend as determined by the law of partial fractions as detailed in Appendix 1 Section B.-4. *Aggregate Consensus Properties Determination*.

If the estimated total aggregate consensus property quality (EAQ) is below that specified in **Table 2 - Additional Aggregate Criteria,** reduce the percentage(s) batched for the failing aggregate(s) to bring the EAQ into conformance.

2. Friction Aggregate Requirements.

Friction requirements only apply to surface courses. There are four different friction aggregate requirements depending on the project's estimated traffic volume. Determine the aggregate blend to ensure adequate pavement friction, and report that blend percentage on the BR 253-257, "Superpave Job Mix Formula."

When the coarse aggregate is blended to meet the specified friction aggregate requirements, proportion the blend such that the percent non-carbonate is at least 2.5% (by mass with adjustments to equivalent volumes for materials of different specific gravities) above the minimum required, as determined from the target batching percentages listed on the JMF.

Note: When the coarse aggregate is blended to meet the specified friction aggregate requirement, pay particular attention to the percent non-carbonate material in the friction aggregate. If the friction aggregate being blended is less than 100% non-carbonate, the percent friction aggregate of the blend must be increased proportionally, so the resulting mixture contains at least 2.5% more non-carbonate material than required.

Note: The friction requirements for each project will be specified in the Contract documents. The information included in this section is

provided as a reference only, and does not supersede the criteria specified in the Contract documents.

3. Estimating Design Binder Content

Determine the trial mixture binder content according to Section 7 of AASHTO R 35, and report it on BR 293.

Prepare a trial mixture and gyratory specimens using the aggregate blend and trial mixture binder content according to Section VI. *Specimen Formulation.* Calculate and analyze the specimen volumetric and mechanical data according to Section 9 of AASHTO R 35 using a design air void content of 3.5% instead of 4%. Determine the estimated design binder content.

C. Design PG Binder Content Selection

Submit the test results and data analysis from gyratory compacted specimens for the design aggregate structure at four different PG binder contents. From this data, select the design PG binder content that results in a compacted density of 96.5% of G_{mm} at the design number of gyrations (N_{design}). Under no circumstances shall the PG binder content in the HMA mixture be less than 5.8% for a 9.5 design, 5.2% for a 12.5, 4.5% for a 19.0 design, 4.2% for a 25.0 design, or 3.7% for a 37.5 design. All volumetric and mechanical properties are checked at this PG binder content to ensure that all requirements are met.

1. Selecting PG Binder Contents for Evaluation

Evaluate four PG binder contents according to Section 10 of AASHTO R 35. These include 0.5% below the estimated design PG binder content, the estimated design PG binder content, 0.5% and 1.0% above the estimated design PG binder content. If the trial mixture PG binder content used in V. B. 3. *Estimated Design Binder Content Determination* is within ±0.2% of one of the four binder contents, it may be used and the other three trial binder contents adjusted accordingly (i.e., Trial Mixture PG Binder Content= 5.4%, Estimated Design PG Binder Content = 5.2%, PG Binder Contents for Evaluation = 4.9%, 5.4%, 5.9%, and 6.4%).

Note: If the maximum or minimum trial binder contents are unrealistic, consult with the RME to establish revised design points.

2. Data Analysis and Curve Preparation

Calculate and analyze the specimen volumetric and mechanical data according to Section 9 of AASHTO R 35.

The Producer shall submit a BR 295, "Superpave Volumetric Property Curves," with a separate graphical plot for each of the following relationships:

a. % G_{mm} @ $N_{initial}$ and N_{design} vs. Performance-Graded Binder Content

b. Voids in Mineral Aggregate (VMA) vs. Performance-Graded Binder Content

c. Percent VMA filled with Binder (VFB) vs. Performance-Graded Binder Content

For each graph, plot the average value obtained at each PG binder content and fit the plotted values with a smooth curve to obtain the "best fit" for all values.

3. Design Performance-Graded Binder Content Selection

The design PG binder content is established at 96.5% of G_{mm} (3.5% Air Voids) at N_{design} gyrations. All other volumetric and mechanical properties (see **Table 3 - Superpave Design Criteria** and **Table 4 - Superpave Volumetric Design Criteria**) are checked at this binder content to assure that all criteria are met. Design a mixture such that VMA does not exceed 3.0% above the design minimum criteria (see **Table 4 - Superpave Volumetric Design Criteria**). For 25.0 Binder Course and 37.5 Base Course mixtures with a VMA of 3% or more above the design minimum, perform a draindown test in accordance with AASHTO T 305, with the test results not exceeding 0.3% of the total sample size. If any of the criteria are not met at the selected design PG binder content, modify the design aggregate structure.

Prepare at least two specimens with the selected design aggregate structure at the design PG binder content. Compact the specimens to $N_{maximum}$ gyrations. Determine the average %G_{mm} of the specimens and confirm that it satisfies the design requirement given in **Table 3 - Superpave Design Criteria**. If the requirement is not met at the design PG binder content, a new design aggregate structure is required.

Table 3 - Superpave Design Criteria

Property	Criteria
% Density at $N_{initial}$	See Table 4
% Density at N_{design}	96.5% of G_{mm}
% Density at $N_{maximum}$	$\leq$ 98.0% of G_{mm}
Voids in the Mineral Aggregate, VMA	See Table 4
Voids Filled with Binder, VFB	See Table 4

Table 4 - Superpave Volumetric Design Criteria

<table>
<tr><th rowspan="3">Estimated Traffic ESALs x 10^6</th><th rowspan="3">% G_{mm} @ $N_{initial}$</th><th colspan="2">% Voids Filled with Binder</th><th colspan="5">% Voids in the Mineral Aggregate, minimum</th></tr>
<tr><th rowspan="2">Min.</th><th rowspan="2">Max.</th><th colspan="5">Nominal Maximum Aggregate Size (mm)</th></tr>
<tr><th>9.5</th><th>12.5</th><th>19.0</th><th>25.0</th><th>37.5</th></tr>
<tr><td>< 0.3</td><td>≤ 91.5</td><td>70</td><td rowspan="3">80</td><td rowspan="3">15.0</td><td rowspan="3">14.0</td><td rowspan="3">13.0</td><td rowspan="3">12.0</td><td rowspan="3">11.0</td></tr>
<tr><td>0.3 to < 30.0</td><td rowspan="2">≤ 89.0</td><td rowspan="2">65</td></tr>
<tr><td>≥ 30</td></tr>
</table>

D. Moisture Susceptibility Testing

1. Criteria for Use

Prior to submitting a new design, contact the RME to determine if moisture susceptibility testing will be required. Low moisture susceptibility test results may indicate potential adhesion problems between the binder and aggregate or problems with mix cohesiveness. The RME may require moisture susceptibility testing as part of the mix design submission when there is increased concern regarding the mixture's moisture susceptibility based on the type of aggregate being used or the performance of similar mixes, regardless of aggregate type. The RME should consider test results and performance of similar production status mixes from that producer or aggregate source when determining the need for moisture susceptibility testing for new designs. If the asphalt binder source is changed for a design that was tested for moisture susceptibility due to the type of aggregate, that mixture may be required to be tested again at the RME's discretion.

Note: The Department may sample and test any mix during production to verify the moisture susceptibility requirement is met. If the results do not meet the production requirement, the Producer will need to take corrective action.

2. Procedure

Prepare at least six gyratory compacted specimens, proportioned according to the JMF. Batch and compact all specimens according to Section VI.-C., *Specimen Batching and Compaction*. Specimen quantity depends on the nominal maximum aggregate size.

Determine the tensile strength ratio (TSR) of each specimen according to AASHTO T 283, except the specimens may be fabricated up to 96 hours before TSR testing.

If the TSR of the HMA gyratory specimens is less than 80%, as required in AASHTO M 323, corrective action is required. When corrective action is necessary, any changes made to the design must be noted on the JMF, and all other volumetric and mechanical properties must be evaluated for compliance with requirements. After corrective action has been taken, retest the mixture according to this section.

Note: Corrective action to improve the moisture susceptibility can include the use of anti-strip additives.

VI. SPECIMEN FORMULATION

This section outlines the procedures to develop the design aggregate structure for an HMA mixture. The Producer develops the design aggregate structure. The RME reviews the design aggregate structure for conformance to requirements. This section also outlines the procedure for batching and compaction of HMA mixture test specimens according to AASHTO T 312 and R 30. As many variables as possible have been eliminated to promote precise, accurate, and uniform testing. When formulating specimens for HMA mixtures containing RAP refer to Section VIII, *Recycled Hot Mix Asphalt Specimen Formulation*.

Note: The Producer may determine the coarse aggregate specific gravity on a blend of materials from stockpiles (i.e., 1A's, 1's, and 2's) of the same source, in-lieu of performing tests on each individual stockpile.

Note: Fine aggregate specific gravity testing is not required on stone screenings and manufactured sands from crushed stone sources. The specific gravity of these materials is assumed to be the same as the average coarse aggregate specific gravity from the same source.

A. Plant Aggregate Gradation Analysis

The analysis of aggregate gradations and the blending of aggregate to obtain the desired gradation are important steps in the HMA design process. Select an aggregate gradation that conforms to the control point's criteria and yields a mixture that meets all volumetric requirements.

This section outlines the methods of analyzing aggregate for an HMA mixture design at two types of production facilities: batch plants and drum plants; each requires a different method of analysis. Batch plants incorporate their own aggregate screening system. Drum mix plants control aggregate gradation through the gradation of stockpiles. The requirements for HMA design aggregate analysis for each type of plant system are outlined separately.

1. Batch Plants

Obtain an aggregate history of the materials used at each batch plant, consisting of at least 10 washed gradations performed according to AASHTO T 27 and T 11. Attention must be given to ensure that the gradation history and aggregate samples are representative of normal production.

Create a table, from the aggregate history, showing the percent passing each sieve for each individual aggregate component (i.e., No. 1, No. 1A, screenings, or blended fines). Determine the average gradation of each aggregate component from this table. When aggregate blends are used, document the approximate cold feed blend percentages.

Note: Plants equipped to introduce all fines from the dust collection system or varying amounts of dust collector fines should be carefully analyzed when evaluating the aggregate history. This aspect should be held constant for the gradation history average and when obtaining aggregate samples for the preparation of HMA specimens.

Once the average gradation of each aggregate component is determined from the aggregate gradation history, a combined blend target gradation is prepared by applying the blend proportion to the average gradation history percent passing each sieve for each aggregate component. The actual blend target gradation is the total of this calculation for each sieve size for each aggregate component in the mixture.

For each aggregate component, calculate the average individual percent retained for the size fractions shown in Section VI.-B., and determine the batching masses for the gyratory compacted specimens and mixture maximum specific gravity samples. The details of specimen batching are explained in Section VI.-C.,*Specimen Batching and Compaction*.

The aggregate cold feed blend proportions used to develop the average gradation history can also be used during HMA mixture production. During production, small adjustments to the aggregate cold feed blend proportions are allowed to compensate for variations in aggregate moisture content, slight variations in cold bin aggregate gradations, etc.

The batch plant aggregate stockpiles can be evaluated according to the provisions detailed for drum mix plants. The results of this analysis are used to determine the aggregate consensus properties, and may result in a restriction in the blend proportion of one or more aggregate components. This analysis does not require washed gradations.

2. Drum Mix Plants

Obtain an aggregate history of the materials used at each drum mix plant, consisting of at least 10 **washed** gradations performed according to AASHTO T 11 and T 27. Create a table from the aggregate history, showing the percent passing each sieve for each individual aggregate component (i.e., No. 1, No. 1A, screenings, or blended fines).

Once the average gradation of each aggregate component is determined from the aggregate gradation history, a combined blend target gradation is prepared by applying the blend proportion to the average gradation history percent passing each sieve for each aggregate component. The actual blend target gradation is the total of this calculation for each sieve size for each aggregate component in the mixture.

For each aggregate component, calculate the average individual percent retained for the size fractions shown in Section VI.-B., *Aggregate Preparation* to determine the batch masses for the gyratory compacted specimens and mixture maximum specific gravity samples. The details of specimen batching are explained in Section VI.-C., *Specimen Batching and Compaction*.

B. Aggregate Preparation

Obtain representative aggregate samples according to MM 5. The sample shall be of sufficient quantity to prepare a minimum of sixteen gyratory compacted specimens and sixteen maximum specific gravity samples, and for NYSDOT to prepare a minimum of six gyratory compacted specimens and six maximum specific gravity samples. A total combined aggregate mass of 130 kg should be sufficient. Since additional testing is often required, it is recommended that additional aggregate components be obtained when sampling.

Note: NYSDOT recommends batch plant aggregate samples be obtained from individual hot bins. However, this practice is not required.

Separate aggregate samples to be used in the batching and compaction of gyratory compacted specimens and mixture maximum specific gravity samples into the size fractions listed in **Table 5 - Aggregate Size Fractions**.

Note: At the discretion of the Producer, aggregates may be broken down into individual screen sizes to perform the mixture design. However, NYSDOT will verify the mixture design using the size fractions listed in Table 5 - Aggregate Size Fractions.

Table 5 - Aggregate Size Fractions

Size Fractions
+ 37.5 mm
25.0 mm to 37.5 mm
19.0 mm to 25.0 mm
12.5 mm to 19.0 mm
9.5 mm to 12.5 mm
6.3 mm to 9.5 mm
4.75 mm to 6.3 mm
2.36 mm to 6.3 mm
- 2.36 mm

C. Specimen Batching and Compaction

Prepare at least two gyratory compacted specimens and two mixture maximum specific gravity samples for the design aggregate blend and each PG binder content used to determine the design PG binder content. Condition all mixtures according to AASHTO R 30 and compact all mixtures according to AASHTO T 312.

Note: NYSDOT recommends making three gyratory specimens as a precaution against potential error.

The mixing and compaction temperatures are determined based on the range of temperatures that result in apparent viscosities of 0.17 ±0.02 Pa·s and 0.28 ±0.03 Pa·s respectively when measured according to AASHTO T 316. This information should be available from the refinery or terminal distributing the PG binder.

Note: The manufacturer of modified PG binders may recommend mixing and compaction temperatures different from those determined based on the apparent viscosities listed above.

Note: The Producer may determine the mixing and compaction temperatures graphically according to Asphalt Institute Technical Bulletin, "Laboratory Mixing and Compaction Temperatures."

If the mixing bowl or the short term aging pan is being used for the first time, lightly coat the inside using a similar HMA mixture, before batching, or aging the first specimen. The mixing bowls, compaction molds, and short term aging pans should be clean at the beginning of each HMA mixture design.

1. Batching

Batch the gyratory specimens and mixture's maximum specific gravity samples by aggregate component and size fraction. Doubled batching of specimens is allowed at the Producer's discretion. NYSDOT recommends that the specimens be mixed individually to reduce the potential for error.

Note: The Producer may add minus 0.075 mm size material to account for plant fluctuations. However, the aggregate gradation after the addition must meet all control point criteria. The target value for the 0.075 mm material shown on the JMF should be the actual amount of 0.075 mm material batched, less any additional 0.075 mm material added.

The required gyratory compacted specimen size is 115 mm ±5 mm in height by 150 mm in diameter. The mixture's maximum specific gravity sample size varies depending on the nominal maximum aggregate size of the mixture being tested, as detailed in AASHTO T 209.

Note: The mass of the gyratory specimen depends on the specific gravity of the aggregate.

The specific composition (i.e., the component size fraction batch masses) of each gyratory compacted specimen and mixture maximum specific gravity sample is determined according to the following procedure.

a. Estimate the total gyratory compacted specimen mass required to produce a specimen of the dimensions detailed above. The mixture maximum specific gravity sample size is predetermined based on the nominal maximum aggregate size of the mixture.

b. Determine the specimen's PG binder content (see Section V.-B.-3., *Trial Blend Binder Content Estimation*, or Section V.-C.-1., *Trial Binder Contents Estimation*.

c. Determine the mass of the specimen's PG binder content by multiplying the predetermined PG binder content percentage by the total mass of the specimen from above (i.e., at 5.5% PG binder, then 0.055 x 5000.0 = 275.0 grams of PG binder).

Note: During the selection of the design PG binder content for the selected aggregate structure phase of the mixture design, it is recommended that a constant aggregate batch mass be used for each design point and that the PG binder batch mass be adjusted to simplify the batching procedure. If this procedure is used, the mean of the four selected PG binder contents should be used to determine the aggregate batch mass. The required PG binder batch mass can be determined from Equation 1.

Equation 1:

$$PGBM = \frac{TABM}{1 - PGB_{estimated}} - TABM$$

where:

PGBM	=	Total PG Binder Batch Mass, (g)
TABM	=	Total Aggregate Batch Mass, (g)
PGB $_{estimated}$	=	Estimated Performance-Graded Binder content (-0.5% below the estimated design PG binder content, the estimated design PG binder content, +0.5 and +1.0% above the estimated design PG binder content)

d. Determine total mass of aggregate from Equation 2.

Equation 2:

$$TMA = TSM - PGBM$$

where:

TMA	=	Total Mass of Aggregate, (g)
TSM	=	Total Specimen Mass, (g)
PGBM	=	Total Performance-Graded Binder Mass, (g)

e. Determine the total mass (grams batched) of each individual aggregate component by multiplying its pre-determined blend proportion by the total mass of aggregate in the specimen.

f. For each aggregate component, determine the batch mass for each aggregate size fraction by multiplying the average percent retained in each size fraction by the total mass (grams batched) for that aggregate component. Any difference between the total batch mass and the cumulative grams batched of all size fractions of that component should be compensated for in the size fraction having the most material.

g. Using a scale meeting the requirements listed in **Table 6 - Scale Requirements**, place the batch mass of each aggregate component size fraction into a suitable container. Determine the mass of each material, beginning with the highest percentage material and working toward the lowest percentage material.

Table 6 - Scale Requirements

Test Mass (grams)	Accuracy Requirements
0 - 200	±0.1 g
201 - 2000	±0.05% of test load
2001 and Greater	±1.0 g

h. If the batch mass of each aggregate component was measured individually, combine all aggregate components to determine the total aggregate specimen mass.

Note: If the total mass of aggregate batched is not within ±10.0 grams of target, or the mass of PG binder batched is not within ±1.0 gram of target, discard the specimen.

2. Compaction

The required number of gyrations depends on the estimated traffic loading in millions of 80 kN ESALs, **Table 7 - Design Number of Gyrations**. The design estimated traffic loading will be provided in the Contract documents.

Table 7 – Design Number of Gyrations

Estimated Traffic, Million 80 kN ESALs	**< 0.3**	**0.3 to < 30.0**	**≥ 30.0**
$N_{initial}$	6	8	9
N_{design}	50	75	100
$N_{maximum}$	75	115	160

The Department recommends the following procedure for loading the gyratory compactor mold. Other methods may be used to charge the mold. After short term aging, place the HMA sample onto a sheet of medium mass (23.6 kg) brown craft paper (about 900 mm x 900 mm), roll opposite ends of the paper to form a tube and fold over the ends of the tube to contain the sample. Place the specimen in an appropriate size pan and pierce each end of the closed paper roll with a thermometer. Heat the specimen to mixture temperature, if necessary.

Obtain a gyratory specimen mold and base/top plate, heated to compaction temperature. Place a paper disk in the bottom of the mold. Hold the paper roll vertically over the mold with the lower end slightly below the top of the mold. Drop the sample into the mold from the paper roll in a single drop by releasing the lower end of the paper roll. Level the top of the mix sample and place a paper disk and mold top plate (if required) on top of the mold. Place the mold in the gyratory compactor and compact to the required number of gyrations.

VII. RECYCLED HOT MIX ASPHALT DESIGN PROCEDURE

This section outlines the procedures to be followed by the Producer in preparing the recycled mixture design and by the RME when reviewing recycled mixture designs for volumetric and mechanical properties. The Producer develops the recycled mixture design according to AASHTO M 323 and AASHTO R 35. This section outlines the procedures detailed in these AASHTO Standards. As many variables as possible have been eliminated, to promote precise, accurate, and uniform testing.

The HMA design system is not significantly altered by the inclusion of RAP. The overall process remains the same; however, extra procedures are required to accommodate the use of RAP. RAP is handled as a stockpile material and is subject to all aggregate consensus property requirements. A recycled HMA mixture consists of RAP, virgin aggregate and virgin PG binder.

The maximum RAP blend proportion for 9.5 Top Course, 12.5 Top Course, 19.0 Binder Course, and 25.0 Binder Course nominal maximum size mixtures is 20.0% by weight of the total mixture. The maximum RAP blend proportion for 37.5 Base Course mixtures is 30.0% by weight of the total mixture. No adjustment is made to the PG binder grade to account for the hardness of the RAP binder.

Figure 1 - Superpave Recycled Mixture Diagram

<table>
<tr><td colspan="4">← - Total Mixture - →</td></tr>
<tr><td colspan="2">← - - - - - - - - - - Total Aggregate - - - - - - - - - →</td><td colspan="2">← - - - - - Total Binder Content (P_{tb}) - - - - - - - →</td></tr>
<tr><td rowspan="2">← - - - - Virgin - - - - →
Aggregate</td><td colspan="2">← - - - - - - - Total RAP Content (P_t) - - - - - - - →</td><td rowspan="2">← Virgin PG Binder →
Content (P_b)</td></tr>
<tr><td>← RAP Aggregate →
Content</td><td>← RAP Binder →
Content (P_{rb})</td></tr>
</table>

A. Materials Selection

1. Aggregate Selection

Follow Section V.-A.-1., *Aggregate Selection/Requirements*. All requirements apply to RAP aggregate.

2. Performance-Graded Binder Selection

Select the PG binder according to Section V.-A.-2., *Performance-Graded Binder Selection*.

B. RAP Properties Determination.

1. Obtaining RAP Samples

It is essential that all tests are performed using samples that accurately represent the stockpile from which they are taken. Proper sampling is critical when working with RAP, due to the wide variety of sources from which RAP is obtained. Obtain all samples according to MM 5.

All RAP samples must represent the material that will be introduced into the mixing unit. RAP stockpile samples must be processed to remove all material larger than the scalping screen which will be used during production and dried to a constant mass before analysis or specimen formulation can begin. Samples should be dried immediately before being heated for use. Any samples that are heated and allowed to cool below mixing temperature prior to use must be discarded.

2. RAP Binder Content Determination

Determine the asphalt binder content of each RAP sample as described in Section VIII.-A., *Plant Aggregate Gradation and RAP Binder Content Analysis*.

C. Design Aggregate Structure Selection.

Follow Section V.-B., *Design Aggregate Structure Selection*, except as modified below.

1. Recycled Mixture Aggregate Consensus Properties

Determine the aggregate consensus properties described in Section V.B.1., *Mixture Aggregate Consensus Properties*, for all individual aggregate components, including RAP aggregate recovered by extraction, and report all results on BR 253-257 (as appropriate), *Superpave Design Aggregate Structure Blend Gradation Plot.*

2. Recycled Mixture Friction Aggregate Requirements

Follow Section V. B. 2. *Friction Aggregate Requirements.*

3. EstimatingTotal Design Binder Content.

Determine the trial mixture total binder content (virgin PG binder plus RAP binder) according to Section 7 of AASHTO R 35, as if the mixture did not contain RAP, and report it on BR 277

Determine the RAP blend proportion of the total mixture (Equation 3). Calculate the trial blend virgin PG binder content (Equation 4).

Equation 3

$$P_r = \frac{(1 - P_{tb}) * PB_r}{1 - P_{rb}}$$

where:

PB_r = Blend Proportion of the RAP stockpile, as determined by Aggregate Consensus Properties.
P_r = RAP blend proportion, percent by total mass of mixture,
P_{rb} = RAP binder content, percent by mass of RAP that is binder,
P_{tb} = Total binder content, percent by mass of mixture.

Note: The maximum RAP blend proportion (P_r) is 20.0% (30.0% for 37.5 mm mixes). If P_r is greater than 20.0% (30% for 37.5 mm

mixes), as calculated by Equation 3, a virgin RAP aggregate blend proportion must be chosen, a new Design Aggregate Structure elected, and a new trial batch binder content estimated.

Equation 4

$$P_b = P_{tb} - (P_r * P_{rb})$$

where:

P_b = Virgin Performance-Graded Binder, % by total mass of mixture.

Prepare a trial mixture and gyratory specimens using the aggregate blend, RAP and trial mixture binder content according to Section VI. *Specimen Formulation.* Calculate and analyze the specimen volumetric and mechanical data according to Section 9 of AASHTO R 35 using a design air void content of 3.5% instead of 4%. Determine the estimated design total binder content.

D. Design Total Binder Content Selection

Submit the test results and data analysis from gyratory compacted specimens for the design aggregate structure at four different total binder contents. The RAP blend proportion must be held constant for all four trial blends. Alterations to the total binder content are made by either: increasing the percent virgin PG binder and decreasing the percent virgin aggregate accordingly; or decreasing the percent virgin PG binder and increasing the percent virgin aggregate accordingly. From this data, determine the design total binder content. Select the design total binder content that results in a compacted density of 96.5% of G_{mm} at N_{design} gyrations. Under no circumstances shall the PG binder content in the HMA mixture be less than 5.8% for a 9.5 design, 5.2% for a 12.5, 4.5% for a 19.0 design, 4.2% for a 25.0 design, or 3.7% for a 37.5 design. Check all other volumetric and mechanical properties at this binder content to ensure that all requirements are met.

1. Selecting Total Binder Contents for Evaluation

Evaluate four different total binder contents according to Section 10 of AASHTO R 35. These include 0.5% below the estimated design total binder content, the estimated design total binder content, 0.5% and 1.0% above the estimated design total binder content. If the trial mixture total binder content used in VII. C. 3. *Recycled Hot Mix Asphalt Design Procedure* is within ±0.2% of one of the four binder contents, it may be used and the other three trial binder contents adjusted accordingly. (i.e., Trial Mixture Total PG Binder = 5.4%, Estimated Design Total Binder Content = 5.2%, Total Binder Contents for Evaluation = 4.9%, 5.4%, 5.9%, and 6.4%)

Note: If the maximum or minimum trial binder contents are unrealistic, consult with the RME to establish revised design points.

2. Data Analysis and Curve Preparation

Follow Section V.-C.-2., *Data Analysis and Curve Preparation,* except plot all properties versus total binder content.

3. Design Total Binder Content Selection

The design total binder content is established at 96.5% of G_{mm} (3.5% Air Voids) at N_{design} gyrations. Show this binder content on form BR 295, *Superpave Volumetric Property Curves*. All other volumetric and mechanical properties (see **Table 3 - Superpave Design Criteria**, and **Table 4 - Superpave Volumetric Design Criteria**) are checked at this binder content to assure that all criteria are met. If any of the criteria are not met at the selected design total binder content, a new design aggregate structure is required.

Prepare at least two specimens with the selected design aggregate structure at the design Total Binder Content. Compact the specimens to N_{max} gyrations. Determine the average $\%G_{mm}$ of the specimens and confirm that it satisfies the design requirement given in **Table 3 - Superpave Design Criteria**. If the requirement is not met at the design PG binder content, a new design aggregate structure is required.

E. Moisture Susceptibility Testing

Follow Section V.-D., *Moisture Susceptibility Testing.*

VIII. RECYCLED HOT MIX ASPHALT SPECIMEN FORMULATION

This section outlines the procedures to develop the design aggregate structure for an HMA recycled mixture. The Producer develops the design aggregate structure. The RME reviews the design aggregate structure for conformance to requirements. This section also outlines the procedure for batching and compaction of recycled mixture test specimens according to AASHTO T 312 and R 30. As many variables as possible have been eliminated to promote precise, accurate, and uniform testing.

A. Plant Aggregate Gradation and RAP Binder Content Analysis

Follow Section VI.-A., *Materials Selection*, except as modified herein.

Analyze each sample of RAP, to determine its binder content according to MM 5. Determine the effective specific gravity of the RAP aggregate and use this value as the Bulk specific gravity of the RAP aggregate for calculation purposes.

Note: The ignition oven method may be used to recover RAP aggregate. However, the RME may perform chemical extraction for a specific RAP stockpile, if there is evidence that the ignition oven method causes a change in the aggregate consensus properties of that

stockpile. If chemical extraction confirms that the consensus properties are changed during ignition, chemical extraction will be required.

B. Aggregate and RAP Preparation

Obtain representative aggregate samples according to MM 5. Obtain a sufficient quantity of aggregate for the Producer to prepare a minimum of sixteen gyratory compacted specimens and sixteen maximum specific gravity samples, and for NYSDOT to prepare a minimum of six gyratory compacted specimens and six maximum specific gravity samples. A total combined aggregate and RAP mass of 130 kg should be sufficient. Since additional testing is often required, it is recommended that additional components be obtained when sampling.

Separate aggregate samples to be used in the formulation of gyratory compacted specimens and mixture maximum specific gravity samples into the size fractions listed in **Table 5 - Aggregate Size Fractions**.

Note: At the Producer's discretion aggregates may be broken down into individual screen sizes to perform the mixture design. However, NYSDOT will verify the mixture design using the size fractions listed in Table 5 - Aggregate Size Fractions.

RAP samples used in the formulation of gyratory compacted specimens and mixture maximum specific gravity samples must reflect the material that will be introduced into the mixing unit. Process the RAP to remove all material larger than the scalping screen which will be used during production and heat the RAP sample to mixing temperature. To avoid hardening of the RAP binder, heating times, and temperatures should be kept to a minimum. Once a RAP sample has been heated to mixing temperature, it must be used within one hour. Heating of RAP samples more than once is not allowed.

C. Specimens Batching and Compaction

Follow Section VI.-C., *Specimen Batching and Compaction*, with the following additions.

a. The aggregate gradation history should include the binder content of each RAP sample taken for gradation analysis.

b. During the preparation and specimen formulation process the RAP is handled as a composite material. Do not extract the RAP binder from the RAP aggregate and handle the two materials separately.

c. Batch the RAP as the last aggregate component prior to batching the virgin PG binder.

IX. VERIFICATION

The Regional Materials Engineer (RME) will verify all the mix designs. At a minimum, verification will include a review of the submitted mix design documentation and plant verification during initial production. The RME may also have laboratory mixes prepared and tested to verify the design prior to plant verification.

In addition to submitting a complete HMA mixture design, the Producer may be required to submit the following to the RME:

- A sufficient sample of aggregate for laboratory verification purposes, separated into the size fractions given in **Table 5 – Aggregate Size Fractions**. Place each aggregate size fraction in a separate substantial, sealed container. Label each container with the aggregate source number, aggregate size designation, and size fraction.
- A sufficient quantity of 1 liter PG binder samples from the plant, terminal, or refinery for laboratory verification purposes. The PG binder must be in clean, sealed containers suitable for heating. Label the containers with the grade and the source. If the PG binder is modified in anyway, the samples must be accompanied by the appropriate Materials Safety Data Sheet (MSDS).

Note: When sampling the PG binder, use the approved sampling valve and drain off at least 4 liters from the spout before sampling.

The RME will review the submitted HMA design and either assign Verification Status, require a laboratory verification, or will reject the mixture design. The decision must be made within <u>twenty eight</u> days of the date of submission. When a design is submitted during the paving season, the RME will review and decide within <u>fourteen</u> days of the date of submission. When multiple designs are submitted, each design will be prioritized and given the appropriate review period, and the review period for each mix design will be administered consecutively.

A. Mixture Design Review

1. The RME will review the submitted HMA design to determine if:

a. A complete design has been prepared according to this manual, meeting all volumetric criteria and aggregate consensus property requirements;

Note: If the VMA is 3% or greater than the minimum design for 25.0 and 37.5 mixtures, the mix design may be sent to the Main Office for approval. All the constituents necessary to perform the drain-down test must be included in the shipment.

b. The specific production facility is using the same aggregate source(s) for production as were used for the design;

c. The HMA gradation is representative of actual plant production and the aggregate target values listed on the JMF correspond to the gradation appearing on the BR 253-257 (as appropriate), "*Superpave Job mix Formula*," for the selected aggregate blend;

d. No excessive variation exists in the compacted specimen's bulk specific gravity or the mixture's maximum specific gravity data at the binder contents evaluated;

e. The submitted design was completed according to the appropriate procedures and contains a reasonable PG binder content for the materials used and the design traffic loading level specified.

2. Based on this review, the RME will do one of the following.

a. Assign Verification Status to the design without lab verification and only perform plant verification;

b. Will not assign Verification status to the design for being incomplete;

c. Will not assign Verification status to the design for not meeting the mixture volumetric criteria or the aggregate consensus property requirements;

d. Reject the design because it is not designed using the procedures listed in this MM.

B. Laboratory Verification

The RME may waive the laboratory verification requirement and assign Verification Status to the design. The RME is solely responsible for making this determination.

If laboratory verification is performed, two specimens will be prepared at N_{design} gyrations and calculate air voids for verification. The RME will use the tolerances listed in **Table 8 - Laboratory Verification Tolerances** in determining laboratory verification of a submitted design.

Table 8 - Laboratory Verification Tolerances

Design Criteria	Laboratory Verification Tolerances
Air Voids, V_a	± 1.0%
Voids in the Mineral Aggregate, VMA	$VMA_{Table\ 4}$ - (3.5 - $V_{a(lab)}$) when $2.5 \leq V_{a(lab)} \leq 3.5$ $VMA_{Table\ 4}$ + ($V_{a(lab)}$ - 3.5) when $3.5 < V_{a(lab)} \leq 4.5$

Based on the results of the laboratory verification, the RME will do one of the following:

a. Assign Verification Status to the design;

b. Will not assign Verification status to the design for not complying with the volumetric property requirements.

At this point a complete redesign is required. As a minimum, this will consist of analyzing three distinct aggregate blends and determining the design PG binder content through the analysis of four design points. If the same aggregate sources are used in the redesign, only one additional aggregate blend is required. When a redesign is submitted, the Mixture Design Verification Procedure starts at the beginning of the verification process.

C. Plant Verification

Once the submitted mixture design has been assigned Verification Status by the RME, the Producer must plant verify the design as described below. The production and gradation tolerances shown in MP 401 shall apply during production of a mixture in Verification Status.

1. Initial Production Notification

The Producer must notify the RME and the Contractor by 3:00 pm the day before initial production. If this notice is not given, mixture verification will not begin, and any material shipped to Department projects will not be accepted.

2. Supplying Verification Status Material to Department Projects

HMA produced during the plant verification of a Verification Status design may be supplied to Department projects. All efforts should be made to limit the use of a mixture produced under Verification Status to non-mainline areas; however, mainline is not specifically excluded. The RME will notify the Engineer-In-Charge prior to the shipment of material produced under Verification Status.

3. Quality Control During Verification Status Production

The Producer must monitor all volumetric properties and aggregate gradations during Verification Status according to Section 401, *Plant Production*, of the Standard Specifications. Obtain quality control samples using procedures outlined in Materials Procedure (MP) 401, *Quality Control and Quality Assurance Procedures for Hot Mix Asphalt (HMA) Production*. Compact all specimens to N_{design} gyrations. In addition, prepare two specimens gyrated to N_{max} and determine the % of G_{mm} during Verification Status.

The Producer is authorized to make necessary adjustments during production of a mixture in Verification Status to bring the design into conformance with all specified requirements.

During production under Verification Status, submit a copy of each day's BR 328, *Computation of Volumetric Mix Proportions*, to the RME before

6:00 a.m. the following day. Clearly indicate the total tons of production for each day under Verifications Status.

Note: If the HMA mixture design contains aggregates that do not meet the specified aggregate consensus properties and adjustments are made to the percentages of any aggregate's blend proportion as shown on the JMF to improve the quality of the plant produced mixture, the Producer must recalculate the blend EAQ(s) as outlined in Section V.-B.-1., *Mixture Aggregate Consensus Properties*, to insure total blend still meets the consensus property requirements.

4. Determining QAFs for Verification Status Material

For each day of production under Verification Status, the Department will determine the daily production QAF according to MP 401.

5. Assigning Production Status

Production of a mixture in Verification Status will continue until the end of the third verification day. A verification day is defined as a day when production is greater than or equal to 150 tons. The RME may take action on a mixture in Verification Status based on the criteria outlined below.

a. If the daily QAF yielded by the required tests in accordance with MP 401 is below 1.00 for every verification day, the design will be rescinded, and a complete redesign will be required.

b. If a mixture cannot be properly placed and compacted, exhibits damage from the compaction operation, or exhibits poor performance (i.e., shoving, rutting, flushing, etc.), the RME will immediately suspend production for that project according to Section 105, *Control of Work*, and Section 106, *Control of Material*, of the Standard Specifications. However, a mixture under Verification Status may continue to be placed on another project(s). If a mixture in Verification Status is placed on more than one project and exhibits similar problems on more than one project, the design will be rescinded and a complete redesign is required.

Otherwise, at the successful conclusion of Verification Status, the RME will assign Production Status to the mixture design.

When a design is submitted for review beginning January 1 of each year but does not fulfill the "three verification day" requirement, the design will typically be assigned Production Status on December 31 of the same year. The RME may extend verification status into the following year for designs submitted late in the year.

At any time before the RME assigns Production Status, the Producer may withdraw the design and resubmit a complete redesign.

Mixture Re-design. As a minimum, the redesign must include the determination of the design PG binder content through the analysis of four design points. Copies of the original Mixture Design's JMFs must be included in the re-design. When the re-design is submitted, the Mixture Design Verification Procedure starts at the beginning of the verification process.

APPENDIX 1

VOLUMETRIC ANALYSIS OF RAW MATERIALS AND SUPERPAVE SPECIMENS

A. Definition of Terms

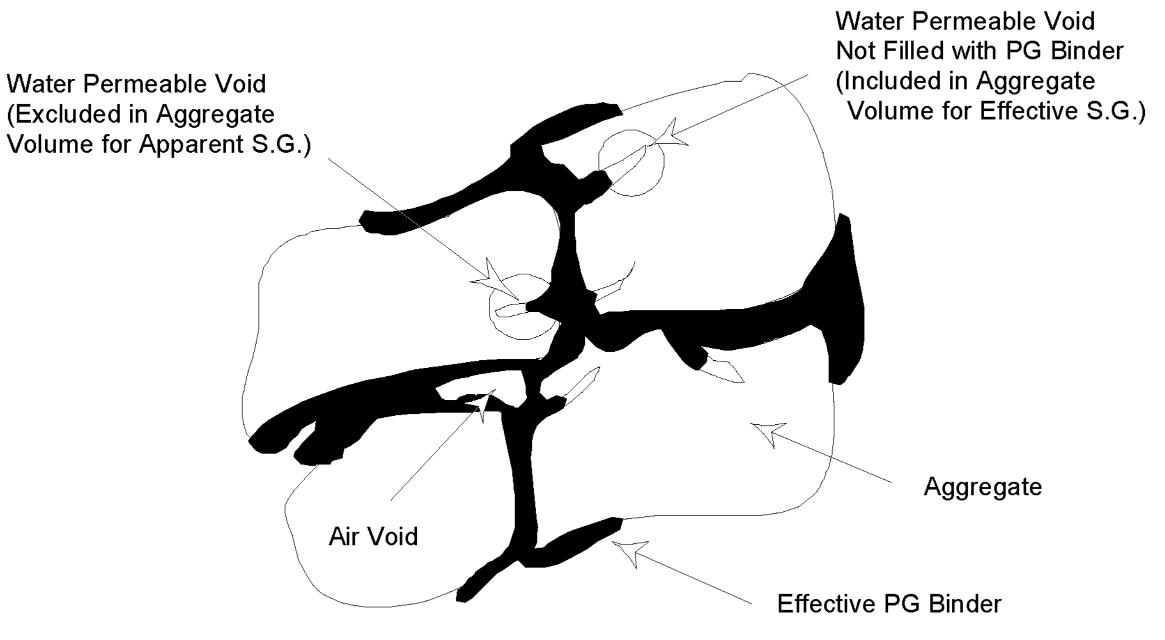
Mineral aggregates are porous and can absorb water and asphalt binder. The degree to which aggregates absorb water and binder varies from source to source. Also, the ratio of water to PG binder absorption varies with each aggregate. Three methods of measuring aggregate specific gravity (S.G.) take these absorption variations into consideration (see Figure A-1): bulk, apparent, and effective specific gravities. They are defined as follows:

Bulk Specific Gravity, G_{sb} - the ratio of the mass measured in air of a unit volume of permeable material (including both permeable and impermeable voids normal to the material) at a stated temperature to the mass measured in air of equal density of an equal volume of water at a stated temperature.

Effective Specific Gravity, G_{se} - the ratio of the mass measured in air of a unit volume of a permeable material (excluding voids permeable to binder) at a stated temperature to the mass measured in air of equal density of an equal volume of water at a stated temperature.

Apparent Specific Gravity, G_{sa} - the ratio of the mass measured in air of a unit volume of an impermeable material at a stated temperature to the mass measured in air of equal density of an equal volume of water at a stated temperature.

Figure A-1 - PG Binder/Aggregate Matrix



Note: The volume of PG binder absorbed by an aggregate is always less than the volume of water absorbed. Consequently, the value for the effective specific gravity of an aggregate should be numerically between its bulk and apparent specific gravities. When the effective specific gravity falls outside these limits, its value is assumed to be incorrect. The calculations, the maximum specific gravity of the total mixture (AASHTO T 209), and the composition of the mixture in terms of aggregate and total PG binder content should be rechecked for the source of error.

The terms Air Voids (V_a), Effective Binder Content (P_{be}), Voids in the Mineral Aggregate (VMA), Voids in the Mineral Aggregate Filled with Binder (VFB) are used throughout this Materials Method, and are defined as follows:

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.

Effective Binder Content, P_{be} - the total PG binder content of a paving mixture minus the portion of PG binder that is absorbed into the aggregate particles.

Voids in the Mineral Aggregate, VMA - the volume of 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 sample.

VMA Filled with Binder, VFB - the ratio of volume of effective binder content, P_{be}, to the volume of voids in the mineral aggregate, VMA, expressed as a percent.

Dust to Effective Binder Ratio - The ratio of the percentage of mineral aggregate passing the 0.075 sieve to the percentage of the effective binder content, P_{be}.

Mixture Maximum Specific Gravity, G_{mm} - The ratio of a mass of a given volume of material to the mass of an equal volume of water. This represents the density of a sample with zero air voids.

Compacted Specimen Bulk Specific Gravity, G_{mb} - The ratio of a mass of a given volume of a compacted specimen (including impermeable air voids) to the mass of an equal volume of water. This represents the density of a sample at the compacted air void content.

B. Analysis Procedures

For all test procedures, use a scale readable to 0.1 g, and accurate to the requirements listed in **Table 8 - Laboratory Verification Tolerances**. Record all masses to the nearest 0.1 g.

1. Individual Material Constituent Specific Gravity Determination

Determine aggregate specific gravity according to AASHTO T 84 and T 85.

The aggregate specific gravities that are used to determine mixture volumetric properties during mixture verification and plant production monitoring will be based on the running average of the last six tests (or less) that were performed on each source. If no previous specific gravity testing has been performed, test the aggregate and use the resultant values.

The apparent specific gravities of the PG binder (AASHTO T 228) and of the mineral filler (AASHTO T 100) may be obtained from the supplier of these materials. PG binder specific gravity at 25°C is needed for hot mix asphalt (HMA) design, but the PG binder specific gravity is generally given at 16°C. To convert this to the specific gravity at 25°C, apply a multiplication factor of 0.9941.

2. Composite Aggregate Bulk and Apparent Specific Gravity Determination

When the total aggregate consists of separate fractions of coarse and fine aggregate and mineral filler, the bulk and apparent specific gravities for the total aggregate are calculated as follows:

$$G_{sb} = G_{sa} = \left[\frac{P_1 + P_2 + \ldots + P_n}{\frac{P_1}{G_1} + \frac{P_2}{G_2} + \ldots + \frac{P_n}{G_n}} \right]$$

where:

G_{sb} = bulk specific gravity for the total aggregate, reported to the nearest 0.001,
G_{sa} = apparent specific gravity for the total aggregate,
P_n = % of individual aggregate components based on total mass of aggregate,
G_n = bulk or apparent (whichever is applicable) specific gravities of aggregates.

Since the bulk specific gravity of mineral filler is difficult to determine, the apparent specific gravity is used instead. The error is usually negligible due to the small quantity of mineral filler in the hot mix asphalt (HMA) mixture.

3. Effective Specific Gravity of Aggregate Determination

The effective specific gravity, G_{se}, of the combined aggregates includes all void spaces in the aggregate particles except those that absorb PG binder. This is based on the mixture maximum specific gravity, G_{mm} determined according to AASHTO T 209.

The G_{se} is calculated as follows:

$$G_{se} = \left[\frac{P_s}{\frac{P}{G_{mm}} - \frac{P_b}{G_b}} \right]$$

where:

G_{se} = effective specific gravity for the total aggregate,
P_s = aggregate, percent by total mass of mixture,
P = total loose mixture, percent by total mass of mixture = 100 percent,
G_{mm} = maximum specific gravity of hot mixture asphalt, AASHTO T 209,
G_b = specific gravity of PG binder at 25°C.

4. Aggregate Consensus Properties Determination

If the coarse aggregate angularity requirements are not met for any of the aggregates used in the proposed mix design, the percentage of use for those aggregates will be limited in the total aggregate blend as determined by the law of partial fractions as detailed below.

$$UVC_T = \frac{[UVC_R * PB_R] + [UVC_1 * PB_1]}{PB_R + PB_1}$$

where:

UVC_T = Total Uncompacted Void Content, reported to the nearest whole number
UVC_1 = Uncompacted Void Content of No. 1 aggregate size
PB_1 = Blend proportion of the No. 1 aggregate size in the mix
UVC_R = Uncompacted Void Content of No. 1 aggregate size in RAP
PB_R = Blend proportion of the RAP in the mix

If the estimated aggregate consensus property quality is below the requirement, reduce the percentage batched for the failing aggregate to bring it into conformance.

5. Superpave Specimen Bulk Specific Gravity Determination

Determine bulk specific gravity according to AASHTO T 166.

The bulk specific gravity test may be performed as soon as the freshly compacted specimens have cooled to room temperature.

Calculate the bulk specific gravity to three decimal places. Specific gravity values that result in a range greater than 0.02 within the same PG binder content shall be considered invalid and shall not be included in the data averaging. Additional Superpave gyratory compacted samples will be required if this situation occurs.

Calculate the bulk specific gravity of the specimen as follows:

$$G_{mb} = \frac{A}{(B - C)}$$

where:

G_{mb} = bulk specific gravity of compacted mixture, reported to the nearest 0.001,
A = mass of the dry specimen in air,
B = mass of the saturated surface dry specimen in air,
C = mass of specimen in water.

6. Mixture Maximum Specific Gravity Determination

Determine Mixture Maximum Specific Gravity according to AASHTO T 209.

Test a minimum of two loose mixture specimens for each design aggregate trial blend or each PG binder content used to determine the design PG binder content. The sample size varies depending on the nominal maximum aggregate size of the mixture being tested and is detailed in the test procedure. Use a sample size of 3.000 kg for 37.5 mm nominal maximum size mixtures. The minimum pycnometer or flask size is 2000 ml (a 2000 g metal pycnometer is recommended). If the capacity of the pycnometer is not large enough to accommodate the required sample size the sample may be split into smaller samples (with a combined mass in excess of the required minimum sample size) and averaged (i.e., an average of four samples).

Maintain a constant minimum vacuum of 30 mm Hg in the pycnometer at all times. This level of vacuum is virtually impossible to maintain by any other means than a precision vacuum pump. The vacuum level should be maintained as close as possible to the required minimum of 30 mm Hg.

Note: NYSDOT recommends the use of a residual pressure manometer to monitor the vacuum achieved during this test.

Mixture maximum specific gravity results differing by more than 0.011 at the same PG binder content shall be considered invalid and run again.

Calculate the specific gravity of the sample as follows:

$$G_{mm} = \frac{A}{A + D - E}$$

where:

G_{mm} = maximum specific gravity of SHMA, reported to the nearest 0.001,
A = mass of dry sample in air,
D = mass of flask filled with airless water at 25°C,
E = mass of flask filled with water and sample at 25°C,

Note: During the selection of the design PG binder content for the selected aggregate structure, the Producer may determine the mixture maximum specific gravity for each PG binder content evaluated using the aggregate's effective specific gravity determined during the selection of the design aggregate structure phase of the mixture design. The mixture maximum specific gravity is calculated using the aggregate's effective specific gravity as follows:

$$G_{mm} = \frac{100}{\frac{P_s}{G_{se}} + \frac{P_b}{G_b}}$$

where:

G_{mm} = mixture's maximum specific gravity
P_s = aggregate content, percent by total mass of mixture
P_b = PG binder content, percent by total mass of mixture
G_{se} = effective specific gravity of aggregate
G_b = PG binder specific gravity

7. Percentage Density ($\%G_{mm}$) and Air Voids (V_a) Determination

Calculate the percentage density and air void content of the specimens using the Superpave gyratory compacted specimen average bulk specific gravity and the average mixture maximum specific gravity for each PG binder content used in the design PG binder content phase of the mixture design, as follows:

$$V_a = 100 - \%G_{mm}$$

$$\%G_{mm} = \frac{G_{mb}}{G_{mm}} * 100$$

where:

$\%G_{mm}$ = percentage compaction, % of the compacted specimens bulk density to the mixtures maximum density, reported to the nearest 0.01%,
G_{mb} = bulk specific gravity of Superpave gyratory compacted specimens,
G_{mm} = maximum specific gravity of SHMA mixture,
V_a = air voids in compacted mixture, % of total volume, reported to the nearest 0.01%.

8. Percent VMA Determination

The VMA is calculated on the basis of the bulk specific gravity of the aggregate (G_{sb}) and is expressed as a percentage of the bulk specific gravity of the compacted paving mixture (G_{mb}). Calculate the VMA as follows:

$$VMA = 100 - \left[\frac{G_{mb} * P_s}{G_{sb}} \right]$$

where:

- VMA = voids in mineral aggregate (% of bulk volume), reported to the nearest 0.1%,
- G_{sb} = bulk specific gravity for the total aggregate,
- G_{mb} = bulk specific gravity of compacted mixture (AASHTO T 166),
- P_s = aggregate, percent by total mass of mixture.

Note: During production, it may be more expedient to use VMA based on the effective specific gravity of the aggregate, because the test method used to determine the bulk specific gravity of the aggregate is variable and time consuming. This alternative method may be used with the RME's approval.

$$VMA_{effective} = 100 - \left| \frac{G_{mb} * P_s}{G_{se}} \right|$$

where:

- $VMA_{effective}$ = effective VMA; or VMA based on G_{se} instead of G_{sb}, reported to the nearest 0.1%
- G_{mb} = bulk specific gravity of compacted mixture,
- P_s = aggregate, percent by total mass of mixture,
- G_{se} = effective specific gravity of total aggregate.

Because the effective specific gravity of the aggregate is smaller than the bulk specific gravity, the "Effective" VMA value will be higher. The Producer should determine an appropriate correction factor to compensate for this difference. The variability of values used in this calculation is less than the conventional approach.

$$VMA = VMA_{effective} * C_f$$

where:

- VMA = voids in the mineral aggregate,
- $VMA_{effective}$ = effective VMA; or VMA based on G_{se} instead of G_{sb},
- C_f = predetermined Correction Factor.

9. Percent VMA Filled with Binder (VFB) Determination

The VFB is calculated on the basis of the Voids in the Mineral Aggregate (VMA) and is expressed as a percentage of the VMA that is filled with PG binder. VFB is calculated as follows:

$$VFB = 100\left[\frac{VMA - V_a}{VMA}\right]$$

where:

- VFB = % VMA filled with PG binder, reported to the nearest 0.1%,
- VMA = Voids in the Mineral Aggregate,
- V_a = Air Voids, percent of total volume.

10. Effective Performance-Graded Binder Content Determination

The effective PG binder content of a paving mixture is the portion of the total PG binder content that remains as a coating on the outside of the aggregate particles, and is the PG binder content on which service performance of a hot mixture asphalt paving mixture depends. The effective PG binder content is calculated as follows:

$$P_{be} = P_b - (G_b P_s)\left[\frac{G_{se} - G_{sb}}{G_{sb} G_{se}}\right]$$

where:

- P_{be} = effective PG binder content, percent by total mass of mixture, reported to the nearest 0.1%
- P_b = binder content, percent by total mass of mixture (for recycled mixtures use P_{tb}),
- G_b = specific gravity of PG binder at 25°C,
- P_s = aggregate, percent by total mass of mixture,
- G_{se} = effective specific gravity of total aggregate,
- G_{sb} = bulk specific gravity of total aggregate.

11. Dust (Minus 0.075 mm Aggregate) to Effective PG Binder Content Ratio

Note: The Dust to Effective PG Binder Content Ratio is not a mix design requirement. If difficulties during placement of the mix occur, the Dust to Effective PG Binder Content Ratio should be checked to assure that it is between the recommended limits.

The dust (minus 0.075 mm aggregate) to effective PG binder content ratio is calculated as follows:

$$P_{0.075\ mm} / P_{be} = \frac{\%P_{0.075\ mm}}{P_{be}}$$

The minus 0.075 mm material must be determined using washed aggregate analysis. Department recommends the ratio to be within the limits of 0.8 to 1.6.

where:

$P_{0.075mm}/P_{be}$	=	minus 0.075 mm aggregate to the effective PG binder content ratio, reported to the nearest 0.1%,
$\%P_{0.075mm}$	=	percent of aggregate passing the 0.075 mm sieve, percent by total mass of aggregate,
P_{be}	=	effective PG binder content, percent by total mass of mixture.

NOTES

APPENDIX 2

LABORATORY EQUIPMENT LIST

All manufacturers and models of equipment mentioned in this Appendix are offered as examples which have been observed to conform consistently to the applicable AASHTO Standards. Calibrate each individual piece of equipment used in the preparation of a HMA mixture design to the applicable AASHTO Standard before use. This is a suggested equipment list only.

General

1. Thermometers - of appropriate quality to meet the requirements of the specific tests.
2. Sieve shaker
3. Fine aggregate splitter
4. Coarse aggregate splitter
5. Scales - meeting the requirements of AASHTO M 231.

Mixture Design and Analysis

1. Superpave gyratory compactors and specimen molds requirements - see under Section IV.-A.., "Producer."
2. Specimen extractor
3. Ovens - of appropriate quality to meet the requirements of the specific tests.
4. Mixer - mechanical mixers are recommended.
5. Bowls - stainless steel bowls are recommended.
6. Steel spoons
7. Sample trays - suitable to run the short-term aging test for both the gyratory specimen and the mixture maximum specific gravity specimen and meet the specified loading requirements.

Mixture Maximum Specific Gravity Determination

1. Vacuum pump with gauge conforming to AASHTO T 209.
2. Pycnometers - for running test according to AASHTO T 209, minimum capacity of 2000 ml, metal pycnometers are recommended.
3. Water tank - a watertight tank equipped with an overflow outlet for maintaining a constant water level, a heater, and circulator are recommended.
4. Residual pressure manometer - recommended but not required.

Flat-and-Elongated Particles Determination

Suitable measuring equipment, a proportional caliper device is recommended.

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Fine and Coarse Aggregate Angularity Determination

1. Cylindrical measure
2. Funnel
3. Funnel stand
4. Glass plate - for calibration

Sand Equivalent Content Determination

1. Graduated plastic cylinder, rubber stopper, irrigator tube, weighted foot assembly, and siphon assembly meeting the requirements of AASHTO T 176.
2. 85 ml tinned box
3. Wide mouth funnel - 100 mm in diameter at mouth.
4. Shaker - either mechanical or manual.

Specific Gravity and Absorption of Coarse Aggregate Determination

1. Wire basket conforming to AASHTO T 85.
2. Water tank - a watertight tank equipped with an overflow outlet for maintaining a constant water level, a heater, and circulator are recommended.

Specific Gravity and Absorption of Fine Aggregate Determination

1. Pycnometer conforming to AASHTO T 84.
2. Metal mold conforming to AASHTO T 84.
3. Tamper

Resistance of Compacted Bituminous Mixtures to Moisture Induced Damage Determination

1. Water bath -60°C ±1°C
2. Breaking head
3. Test press conforming to AASHTO T 245.
4. Suitable load measuring device conforming to AASHTO T 245.
5. Freezer

APPENDIX 3

SUPERPAVE DEFINITION OF TERMS AND ABBREVIATIONS

EAQ	=	estimated total aggregate consensus property quality
ESAL	=	equivalent single axel load
JMF	=	job mix formula
G_b	=	specific gravity of PG binder, at 25°C
G_{mb}	=	bulk specific gravity of compacted mixture
G_{mm}	=	maximum specific gravity of bituminous mixture
G_n	=	bulk or apparent (whichever is applicable) specific gravities of aggregates
G_{sa}	=	apparent specific gravity for the total aggregate
G_{sb}	=	bulk specific gravity for the total aggregate
G_{se}	=	effective specific gravity for the total aggregate
$N_{initial}$	=	initial number of gyrations, determined by traffic loading
N_{design}	=	design number of gyrations, determined by traffic loading
$N_{maximum}$	=	maximum number of gyrations, determined by traffic loading
P	=	% total Superpave hot mix asphalt (HMA) mixture by mass = 100%
P_b	=	PG binder, percent by total mass of mixture
P_{be}	=	effective PG binder content, percent by total mass of mixture
P_n	=	% of individual aggregate components, based on total mass of aggregate mixture
P_r	=	RAP blend proportion, % by total mass of mix
P_{rb}	=	RAP binder content, % by total mass of RAP which is binder
P_s	=	aggregate, percent by total mass of mixture
P_{tb}	=	total binder content, percent by total mass of mixture (RAP mixtures only)
$P_{0.075\ mm}/P_{be}$	=	minus 0.075 mm aggregate to the effective PG binder content ratio
PB_n	=	blend proportions for each stockpile
PB_r	=	blend proportion for aggregate from RAP stockpile
PG	=	performance-graded
$PGB_{estimated}$	=	estimated PG binder content
PGBM	=	total PG binder batch mass
QAF	=	quality adjustment factor
RAP	=	reclaimed asphalt pavement
SHRP	=	Strategic Highway Research Program

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TABM	=	total aggregate batch mass
TSM	=	total specimen mass
TMA	=	total mass of aggregate batched
TSR	=	tensile stress ratio
V_a	=	air voids in compacted mixture, % of total volume
VFB	=	% of VMA filled with effective PG binder
VMA	=	voids the in mineral aggregate (% of bulk volume)
$VMA_{effective}$	=	effective VMA; VMA determined using G_{se}