

**2360 SPECIFICATION  
SUPERPAVE HOT MIX ASPHALT (TYPE SP) Rev. 1/7/99**

**2360.1 DESCRIPTION.**

This work consists of the construction of one or more pavement courses of Superpave hot plant mixed asphalt-aggregate mixture on the approved prepared foundation, base course or existing surface in accordance with the specifications and in conformity with the lines, grades, thicknesses and typical cross sections shown on the plans or established by the Engineer.

**A Design Criteria**

The type(s) of mixture shall be delineated in the Special Provisions and are identified as Type SP-9.5, Type SP-12.5, or Type SP-19.0. The mixtures are further identified as Type SP xx.x wear and Type SP xx.x non-wear.

**A1 20 Year Design ESAL's (Specified in the Special provisions)**

Mainline Design ESAL's \_\_ - \_\_ million  
Shoulder Design ESAL's \_\_ - \_\_ million

The requirements for type SP HMA mixtures are based on the 20 year design traffic level of the project, expressed in 80 kN Equivalent Single Axle Loads (ESAL's). The seven traffic levels are shown in Table 2360-1.

**Table 2360-1  
Superpave Traffic Levels**

Traffic Level	20 Year Design ESAL's (1 x 10 <sup>6</sup> ESAL's)
1	$\leq 0.3$
2	$0.3 \leq 1$
3	1 to $\leq 3$
4	3 to $\leq 10$
5	10 to $\leq 30$
6	30 to $\leq 100$
7	$> 100$

**A2 Mixture and PG Asphalt binder (Specified in the Special Provisions)**

Mainline non-wear	Type SP - xx.x	PG__-__
Mainline wear	Type SP - xx.x	PG__-__
Shoulder	Type SP - xx.x	PG__-__

**B Minimum Lift thickness**

SP-9.5 wear : Minimum Lift thickness = 40 mm  
SP-12.5 wear or nonwear: Minimum Lift thickness = 50 mm  
SP-19.0 nonwear only : Minimum Lift thickness = 75 mm

**2360.2 MATERIALS**

The Superpave HMA shall be composed of a combination of aggregate (coarse, fine or mixtures thereof), mineral filler, if required, and performance graded asphalt binder material.

**A Asphalt Binder Material ..... AASHTO MP-1**

Asphalt binder material shall meet the requirements of PG asphalt binder testing tolerances, sampling rates, testing procedures, and acceptance criteria based on Mn/DOT Technical Memorandum No.97-17-CME-03 and AASHTO MP-1. The PG asphalt binder cannot be modified with air blowing procedures unless it is approved by the Mn/DOT Bituminous Office. The Contractor shall not use petroleum distillates such as fuel oil, diesel fuel or other fuels in the asphalt binder tanks. A statement shall be provided by the supplier for recommended laboratory mixing and compaction temperatures and field maximum mixing and compaction temperatures.

**B Additives**

An additive is any material added to a asphalt mixture or material, such as mineral filler, hydrated lime, asphalt additives, antistripping, and similar products that do not have a specific pay item. When a Contract requires additives, compensation is included with the pay items for the appropriate mixture. If the Engineer directs the Contractor to incorporate additives, the compensation will be as Extra Work, at the unit price specified in the proposal. The Department will not compensate the Contractor for additives incorporated at the Contractor's option.

Additives shall not be incorporated into the mixture without approval of the Bituminous Engineer. Anti-foaming agent shall be added to asphalt cement at the manufacturer's recommended dosage rate. Mineral filler and hydrated lime may be added in a quantity not to exceed 5 percent and 2 percent, respectively, of the total mass of the aggregate. The combination of mineral filler and hydrated lime shall not exceed 5 percent of the total mass of aggregate. The Engineer will approve or disapprove methods for addition of additives.

**B1 Mineral Filler ..... 3145**

**B2 Hydrated Lime ..... ASTM C977**

Hydrated lime used in asphalt mixtures shall meet the requirements of ASTM C977 and have

a maximum of eight percent unhydrated oxides (as received basis). The method of introducing and mixing the hydrated lime and aggregate shall be subject to approval by the Engineer prior to beginning mixture production.

**B3 Liquid Anti-Stripping Additive**

When a liquid anti-strip additive is added to the asphalt binder, blending shall be completed before the asphalt binder is mixed with the aggregate. Liquid antistrip additives that modify the asphalt binder, such that it fails to meet the Performance Grade (PG) requirements, shall not be used. No paving will be allowed until the asphalt binder / additive blend has been tested and the results meet the criteria in 2360.2A. The Company adding the additive will be responsible for testing the binder / additive blend to ensure compliance with the standard specification for performance graded asphalt binder AASHTO MP-1 .

**B4 Coating and Anti-Stripping Additive ..... 3161**

**C Gradation Requirement**

The coarse and fine aggregate shall be combined in such proportions to produce an asphalt mixture meeting all of the requirements defined in this specification and shall conform to the gradation as defined in Table 2360-2. Gradation testing shall be conducted in accordance with AASHTO T-11 (-0.075 mm (#200) wash) and T-27.

**Table 2360-2  
Aggregate Gradation Broad Bands**

Sieve Size	Superpave Mixture (Percent Passing)					
	SP-9.5 (3/8") Nominal size		SP-12.5 (1/2") Nominal size		SP-19.0 (3/4") Nominal size	
mm (inch)	Min.	Max.	Min.	Max.	Min.	Max.
25.0 ( 1 )	-	-	-	-	100	-
19.0 (3/4)	-	-	100	-	90	100
12.5 (1/2)	100	-	90	100	-	90
9.5 (3/8)	90	100	-	90	-	-
4.75 (#4)	-	90	-	-	-	-
2.36 (#8)	32	67	28	58	23	49
0.075 (#200)	2	8	2	8	2	7

**C1 Gradation Restricted Zone:**

The recommended design gradation, identified in Table 2360-2 should avoid the restricted zones specified in Table 2360-3.

**Table 2360-3**

**Recommended Aggregate Gradation Restricted Zone**

Sieve Size within Restricted Zone	Boundaries of Restricted Zone Superpave Mixture (Percent Passing)					
	SP-9.5 Nominal size		SP-12.5 Nominal size		SP-19.0 Nominal size	
	Min.	Max.	Min.	Max.	Min.	Max.
2.36 mm (#8)	47.2	47.2	39.1	39.1	34.6	34.6
1.18 mm (#16)	31.6	37.6	25.6	31.6	22.3	28.3
0.60 mm (#30)	23.5	27.5	19.1	23.1	16.7	20.7
0.30 mm (#50)	18.7	18.7	15.5	15.5	13.7	13.7

**D Consensus Aggregate Properties:**

All consensus aggregate properties are based upon the design ESAL's for mainline or shoulder mixtures as specified in the special provisions. The aggregate blend shall meet the following consensus properties.

**D1 Coarse Aggregate Angularity (CAA) ..... ASTM D 5821**

The coarse aggregate blend shall meet the coarse aggregate angularity requirement defined in Table 2360-4.

**Table 2360-4  
Coarse Aggregate Angularity  
(Minimum Percent Fractured Faces)**

Traffic Level	Depth of Pavement from Surface			
	≤ 100 mm (4 in)		>100 mm (4 in) & Shoulders	
	One or More Fractured Faces (%)	Two or More Fractured Faces (%)	One or More Fractured Faces (%)	Two or More Fractured Faces (%)
1	55	-	-	-
2, 3	75	-	50	-
4	85	80	60	-
5	95	90	80	75
6, 7	100	100	100	100

**D2 Fine Aggregate Angularity (FAA) ..... ASTM C1252 Method A**

The fine aggregate blend shall meet the fine aggregate angularity requirement for the composite aggregate blend as defined in Table 2360-5.

**Table 2360-5  
Fine Aggregate Angularity**

Traffic Level	Depth of Pavement from Surface	
	≤ 100 mm (4 in)	>100 mm (4 in) & Shoulders
	Minimum Uncompacted Void Content (%)	Minimum Uncompacted Void Content (%)
2,3	40	40
4,5	45	40
6,7	45	45

**D3 Flat and Elongated Particles..... ASTM D 4791**

The maximum amount of flat and elongated particles by mass for the coarse aggregate + 9.5mm (3/8 in) blend shall not exceed 10% for all projects with traffic level 3 or above. Flat and Elongated particles are the percentage of coarse aggregate, as defined in ASTM D 4791, where the ratio of length to width or width to thickness is greater than three to one.

**D4 Clay Content..... AASHTO T 176**

The fine aggregate blend shall have a sand equivalent value meeting the requirements defined in Table 2360-6

**Table 2360-6  
Clay Content**

Traffic Level	Sand Equivalent Minimum (%)
1,2,3	40
4,5	45
6,7	50

**E Source Specific Aggregate Properties:**

Individual aggregate components shall be tested and meet the following quality requirements:

**E1 Los Angeles Abrasion (Toughness Test) ..... AASHTO T 96**

The Los Angeles Rattler loss on the coarse aggregate fraction (material retained on the 4.75 mm (#4) sieve shall not exceed 40 percent for any individual source used within the mix. An aggregate proportion which passes the 4.75 mm (#4) sieve and exceeds 40 percent LAR loss on the coarse aggregate fraction is prohibited from use in the mixture. Tested on class A, B, C, D, and E aggregates as defined in 3139.

**E2 Magnesium Sulfate (Soundness Test) ..... AASHTO T 104**

The magnesium sulfate soundness loss on the coarse aggregate fraction (material retained on the 4.75 mm (#4) sieve) shall not exceed the following for any individual source used within the mix:

- a) No more than 14 % loss on the 19 mm (3/4") to 12.5 mm (1/2") and larger fractions.
- b) No more than 18% loss on the 12.5 mm (1/2") to 9.5 mm (3/8") fraction.
- c) No more than 23% loss on the 9.5 mm (3/8") to 4.75 mm (#4) fraction.
- d) No more than 18% for the composite loss (Applies only if all three size fractions are tested).

An aggregate proportion which passes the 4.75 mm (#4) sieve and exceeds the loss requirements listed above on the coarse aggregate fraction is prohibited from use in the mixture.

**E3 Total Spall and Lumps (Deleterious Materials Test) .... Mn/DOT Lab Manual 1209**

Spall is defined as shale, iron oxide, unsound charts, pyrite, highly weathered and/or soft phyllite and argillite (may be scratched with a brass pencil), and other materials having similar characteristics. Spall is measured on the total sample.

Lumps are defined as loosely bonded aggregations and clayey masses. If the percent of lumps measured in the stockpile or cold feed exceed the values listed below, asphalt production shall cease and compliance shall be determined by dry batching. This procedure may be repeated at any time at the discretion of the Engineer.

**Table 2360-E3  
Spall Material and Lumps**

Traffic Level	Total Spall in fraction retained on the 4.75 mm (#4) sieve	Maximum Shale Content of fraction passing 4.75 mm (#4) sieve.	Maximum percent Lumps in fraction retained on 4.75 mm (# 4) sieve.
1 , 2	5.0	5.0	0.5
3	2.5	5.0	0.5
4 - 7	1.0	5.0	0.5

**E4 Insoluble Residue (Soundness Test) ..... Mn/DOT Lab Manual 1221**

The minus 75 µm (#200) sieve size portion of the insoluble residue shall not exceed 10%. Tested on class B only as defined in 3139.

**E5 Aggregate Specific Gravity ..... AASHTO T84 and T85, Mn/DOT modified.**

Testing shall be conducted on all aggregate used in the mixture.

**E6 Fine Aggregate and Mineral Filler:**

All material passing the 4.75 mm (#4) sieve and retained on the 0.075 mm (#200) sieve shall be considered as fine aggregate. The material passing the 0.075 mm (#200) sieve shall be considered as mineral filler.

**E7 Recycled Asphaltic Pavement Materials (RAP)**

The Contractor may use a maximum of 10% RAP in a Superpave mix subject to the following conditions.

1. The Contractor is responsible for the design of Superpave mixtures that incorporate RAP. Compliance with composite aggregate consensus properties include 2360.2C and 2360.2D.
2. Source aggregate properties described in section 2360.E5 shall be determined by testing a representative chemically extracted RAP sample.
3. The percent asphalt binder content in the RAP must be determined according to Mn/DOT lab manual method 1851 or 1852 on file in the Bituminous Office.
4. RAP containing any objectionable material, i.e. road tar, metal, glass, wood, plastic, brick, fabric or any other material having similar characteristics will not be permitted for use in the HMA mixture.

**F Mixture Requirements:**

The aggregate fractions shall be sized, graded and combined in such proportions that the resulting mixture will meet the grading and physical properties (2360.2C, 2360.2D, and 2360.2E) of the approved mix design. The gradation shown on the mix design shall be within the range specified in Table 2360-2. Gradation is a design and acceptance / process control requirement.

**F1 Aggregate Restrictions**

Class B carbonate aggregate shall be limited in Superpave mixtures as follows:

**Table 2360-F1  
Aggregate Restriction**

Traffic Level	Maximum % - 4.75 mm (#4)		Maximum % + 4.75 mm (#4)	
	Final Lift	All other Lifts	Final Lift	All other Lifts
1-3	90	90	100	100
4	80	80	50	100

5-7	50	80	0	100
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**F2 Gyrotory Compaction:**

The design mixture shall be compacted in accordance with AASHTO TP-4. The number of gyrations shall be as defined in Table 2360-7.

**Table 2360-7  
Superpave Design Gyrotory Compactive Effort**

Traffic Level	$N_{initial}$	$N_{design}$	$N_{maximum}$
1	6	50	75
2,3	7	75	115
4	8	90	140
5	8	100	160
6,7	9	125	205

**F3 Volumetric Criteria:**

The design air void content of the mixture at design shall be 4.0% at the design number of gyrations ( $N_{design}$ ) for mixtures placed in the upper 100 mm (4 in) of the finished surface. The design air void content of the mixture at design shall be 3.0% at the design number of gyrations ( $N_{design}$ ) for mixtures placed at depths more than 100 mm (4 in.) from the surface and on all (wear and nonwear) shoulders that do not carry traffic. Volumetric criteria for  $N_{initial}$ ,  $N_{design}$ , and  $N_{max}$  are design and acceptance / process control requirements.

**Table 2360-8  
Mixture Densification Criteria**

Gyration Level	Criteria for % $G_{mm}$ ( $\leq$ 100 mm (4 in.) from Surface)	Criteria for % $G_{mm}$ ( $>$ 100 mm (4 in.) from Surface) & Shoulders
$N_{initial}$	$< 89.0^{(1)}$	$< 90.0$
$N_{design}$	$= 96.0$	$= 97.0$
$N_{maximum}$	$< 98.0$	$< 99.0$

(1) Traffic level 1 maximum increase to 91.5 and traffic level 2 maximum increase to 90.5.

**F4 VMA Criteria:**

The voids in the mineral aggregate (VMA) of the mixture during design and production shall meet the minimum criteria as shown in Table 2360-9 at the design number of gyrations. VMA shall be calculated according to procedures outlined in the Asphalt Institute's Superpave SP-2 manual. VMA is a design and acceptance / process control requirement.

**Table 2360-9  
VMA Criteria**

Type Mix Nominal size	Coarse Mixture % Pass 2.36mm (#8)	VMA (%) Minimum	Fine Mixture % Pass 2.36 mm (#8)	VMA (%) Minimum
SP-9.5	≤ 47	14.5	> 47	15.0
SP-12.5	≤ 39	13.5	>39	14.0
SP-19.0	< 35	12.5	>35	13.0

**F5 VFA Criteria:**

The voids filled with asphalt (VFA) criteria of the mixture at design shall be as shown in Table 2360-10 at the design number of gyrations. VFA is a design requirement.

**Table 2360-10  
VFA Criteria**

Traffic Level	Design VFA % ≤ 100 mm (4 in) from surface	Design VFA % >100 mm (4 in) & Shoulders
1	70.0 - 80.0	75 - 85
2, 3	65.0 - 78.0	70 - 83
4 - 7	65.0 - 75.0 <sup>(1)</sup>	70 - 80 <sup>(2), (3)</sup>

(1) 9.5 mm mixtures upper limit increase to 76.0%

(2) 9.5 mm mixtures upper limit increase to 82.0%

(3) 12.5 mm mixtures upper limit increase to 81.0%

**F6 Fines to Effective Asphalt Ratio Requirement:**

The effective asphalt binder content shall be calculated in accordance with the Asphalt Institute method in MS-2 (sixth edition, chapter 4). The Fines to effective asphalt content by mass shall be 0.6 to 1.2 except, in mixtures whose gradation passed beneath the restrict zone as shown in Table 2360-3, the fines to effective asphalt content by mass shall be 0.8 to 1.6.

**F7 Moisture Damage Susceptibility:**

The retained tensile strength ratio of the mixture (150 mm (6 in) specimens) shall be 80.0 % or greater and shall be tested in accordance with ASTM D-4867, Mn/DOT modified. The Department will test a resubmitted mix once. Subsequent requests must be accompanied by mixture containing an antistrip agent or an aggregate composition change.

## **2360.3 MIXTURE DESIGN**

### **A Mixture Design General**

The asphalt mix may be designed using one of the following Contractor trial mix design options. Review and approval of mixture designs will be performed in the District lab where the project is located. The addition of aggregates and materials not included in the original mixture Submittal is prohibited.

It shall be the Contractor's responsibility to design the Superpave asphalt mixture in accordance with AASHTO TP-4, June 1997 or the Asphalt Institute's Superpave Mix Design Manual SP-2 (2-hour short term aging period is used for volumetric), such that it meets the requirements of this specification. The Contractor shall follow 2360.3B, 2360.3C, or 2360.3D for mix design and verification.

Proportion changes which exceed 10% of any single stockpile aggregate, from the original mix design Submittal, will be considered a new mix design. New mix designs must meet all material requirements as described in 2360.2 and 2360.3.

### **B Laboratory Mixture Design ( Option 1 )**

Test results and documentation as described in section 2360.3E shall be submitted with the materials described below for consideration by the Department Bituminous Engineer or District Materials Engineer to verify compliance with these specifications and to issue a Department approved HMA Paving Recommendation.

#### **B1 Aggregate sample**

At least 15 working days prior to the start of asphalt production, the Contractor shall submit to the Bituminous Engineer or the District Materials Engineer a 35 kg (75 lb) sample of representative aggregate retained on the 4.75 mm (# 4) sieve and a 15 kg (35 lb) sample of material passing the 4.75 mm (#4) sieve. These samples will be tested for each source, class, type, and size of virgin and non-asphaltic salvage aggregate source used in the mix design.

Aggregates that require the magnesium sulfate soundness test shall be submitted to the Bituminous Engineer or District Materials Engineer at least 30 calendar days prior to the start of asphalt production.

#### **B2 Mixture sample**

At least 7 working days prior to the start of asphalt production, the Contractor shall submit in writing a proposed Job Mix Formula (JMF) for each combination of aggregates to the Bituminous Engineer or District Materials Engineer for review and approval. This proposed JMF must be

signed by a level II Quality Management mix designer. For each JMF submitted, the Contractor shall include test data to demonstrate conformance to material properties as specified in Section 2360.2. The proposed JMF shall be submitted on forms approved by the Department. In addition, the Contractor shall submit a 50 kg (110 lb) uncompacted sample plus two Gyratory briquettes compacted at the optimum asphalt binder content and gyrations conforming to the JMF for laboratory examination and evaluation.

### **B3 Tensile Strength Ratio sample**

Mixture or Gyratory specimens, that represent the mixture at optimum asphalt content, shall be submitted at least 7 days prior to actual production for verification of moisture sensitivity retained tensile strength ratio (TSR). Material submitted for TSR verification may be tested for maximum specific gravity  $G_{mm}$  compliance in addition to TSR results. Failure to meet the  $G_{mm}$  tolerance will result in rejection of the submitted mix design. A new mix design Submittal will be required and will be subject to provisions described in 2360.3E. One of the following options may be used to verify that the tensile strength ratio (TSR) meets the requirements as described in 2360.2F7.

Option 1) The Contractor will batch material at the design proportions including optimum asphalt. Immediately (before curing) split sample and allow samples to cool to room temperature. Submit 25 kg (55 lb) of mixture to the district lab for curing and test verification. Both groups will use a 2 hour cure time ( $\pm 15$  minutes) at 135 ° C and follow remaining procedures in ASTM D 4867-92, Mn/DOT modified.

Option 2) The Contractor batches, cures (as indicated in option #1), compacts, and submits 6 Gyratory specimens at the required 6.5 - 7.5% air void content and 8200 grams of uncompacted mixture.

### **C Produced Mixture Design ( Option 2 )**

Test results and documentation as described in section 2360.3E shall be submitted with materials described below for consideration by the Department Bituminous Engineer or District Materials Engineer to verify compliance with these specifications and issuance of a Department approved HMA Paving Recommendation.

### **C1 Aggregate Sample**

At least 15 working days prior to supplying mixture to a Department Project, the Contractor shall submit to the Bituminous Engineer or the District Materials Engineer a 35 kg (75 lb) sample of representative aggregate retained on the 4.75 mm (#4) sieve and a 15 kg (35 lb) sample of material passing the 4.75 mm (#4) sieve. These samples will be tested for each source, class, type, and size of virgin and non-asphaltic salvaged aggregate source used in the mix design.

Aggregates that require the magnesium sulfate soundness test shall be submitted to the

Bituminous Engineer or District Materials Engineer at least 30 calendar days prior to the start of asphalt production.

## **C2 Mixture Sample**

At least 3 working days prior to supplying mixture to a Department project, the Contractor shall provide the Bituminous Engineer or District Materials Engineer with the data and samples of material from at least four consecutive quality control test results, as shown in 2360.4E, representing the most recent Quality Management certified production of the mixture for review and approval. The Contractor shall supply sufficient material or Gyratory specimens as described in option 1 for verification of Tensile Strength Ratio. If these test results show the mixture to be in compliance with the requirements of 2360.2F a paving recommendation may be issued based on previously produced material. Compliance shall include the moving average of 4 test results compared to the warning limits and each single test result as compared to twice the warning limits shown in Table 2360-11.

## **D Laboratory Mixture Design / Initial Production Test Strip Verification ( Option 3 )**

### **D1 Laboratory Mix Design**

The Contractor shall meet the requirements shown in 2360.3B, 2360.3B1, and 2360.3B3; this excludes 2360.3B2.

### **D2 Initial Production test Strip Verification**

For initial use of a Type SP mix design at a particular plant, full-scale production and placement of the mix shall be limited to 500 metric tons (550 tons) for each mix type in order to demonstrate the capability of producing, placing, and compacting the mix as specified. During this period, the Contractor shall take a minimum of 2 separate sets of mixture samples which will be used for extraction gradation analysis and determination of volumetric properties. These samples shall be 50 kg (110 lb) total to be split with between the Contractor and Department. Production will cease until mixture properties are tested and evaluated by both the Contractor and the Department. Results must be within the allowable testing tolerances shown in Table 2360-13. Production may be resumed upon determination of acceptable extraction gradation analysis in accordance with 2360.2C, consensus properties in 2360.2D and mixture requirements in accordance with 2360.2F. Acceptable verification will be determined based upon the average of the two sample test results.

If the gradation, design air voids, VMA, and % asphalt binder are within the specified tolerance as shown in the proposed JMF and within specified control limits in Table 2360-11, and the retained tensile strength ratio was successfully tested and accepted as indicated in section 2360.3B3; the initial moisture damage susceptibility verification shall be accepted and production may be resumed. If any of these parameters fail to be verified within tolerances, the mixture

submitted must be tested and evaluated for moisture damage sensitivity criteria acceptance, prior to full scale production.

All mixture placed on Mn/DOT projects shall meet the specified quality indicators and required field density. Failure to do so will result in reduced payment or removal and replacement with acceptable material. This includes initial production 500 metric ton (550 ton) lots used for mixture verification.

Failure to meet the specified verification of mixture properties after three consecutive 500 metric ton (550 ton) lots will require the Contractor to use Option 1 (2360.3B) or Option 2 (2360.3C).

## **E Documentation**

Each proposed JMF submitted under 2360.3B, 2360.3C, and 2360.3D shall include the following documentation and test results.

- (1) The name(s) of the individual(s) responsible for the Quality Control of the mixture during production.
- (2) The low project number on which the mixture will be used.
- (3) The design traffic level and the initial, design, and maximum number of gyrations  $N_{\text{initial}}$ ,  $N_{\text{design}}$ , and  $N_{\text{maximum}}$ .
- (4) The percentage in units of 1 percent (except the 0.075 mm (#200) sieve in units of 0.1 percent) of aggregate passing each of the specified sieves for each aggregate to be incorporated into the mixture. The gradation of aggregate from salvaged asphaltic material shall be derived from the material after the residual asphalt has been extracted.
- (5) The source and description of the materials to be used. The aggregate pit or quarry source number. The proportion of each material (in percent of total aggregate).
- (6) The composite gradation based on (1) and (2) above. Note: Include virgin composite gradation based on (1) and (2) above for mixtures containing RAP.
- (7) The test results from the composite aggregate blend at the proposed JMF proportions indicating compliance with Coarse Aggregate Angularity Table 2360-4 and Fine Aggregate Angularity as shown in Table 2360-5.
- (8) The bulk (dry) and apparent specific gravities and water absorption (by % weight of dry aggregate) of both coarse and fine aggregate, for each product used in the mixture (including RAP). Use AASHTO T-84 and T-85 test methods with modifications on file in the

Bituminous office. The tolerance allowed between the Contractor's and the Department's specific gravities are  $G_{sb}$  (individual) = 0.040 and  $G_{sb}$  (combined) = 0.020.

- (9) The composite gradation plotted on a FHWA 0.45 power chart. (Federal form PR-1115)
- (10) For mixtures containing RAP include extracted asphalt binder content of the RAP with no retention factor included.
- (11) The percentage (in units of 0.1 percent) of asphalt binder material to be added, based upon the total mass of the mixture.
- (12) The temperature ranges the mixture is intended to be discharged from the plant and compacted at the roadway shall be provided by the asphalt binder supplier. Temperatures to be included are, laboratory mixing and compaction temperature ranges and maximum field mixing and compaction temperatures.
- (13) Evidence that the completed mixture will conform to all specified physical requirements as follows: Design air Voids ( $V_a$ ), VMA, VFA, TSR, F/A<sub>e</sub> (Fines to effective asphalt ratio), Densification % $G_{mm}$  at  $N_{initial}$ ,  $N_{design}$ , and  $N_{Maximum}$ .
- (14) When using laboratory mixture design Option 1 (2360.3B) or Option 3 (2360.3D), include the following:
  - (a) A mix design with a minimum of four different asphalt binder contents (minimum 0.4 percent between each point), with at least one point at, one above and one below the optimum asphalt binder percentage.
  - (b) The maximum specific gravity at each bitumen content. The theoretical maximum specific gravity used for percent air voids determination shall be calculated based on the average of the effective specific gravities measured by a minimum of two maximum specific gravity tests at the asphalt contents above and below the expected optimum asphalt binder content.
  - (c) The Gyratory test results for the individual and average bulk specific gravity, density, height, stability, and flow of at least three specimens at each bitumen content.
  - (d) The percent air voids in the mixture at each asphalt binder content.
  - (e) The percent Voids in Mineral Aggregate (VMA) at each asphalt binder content.
  - (f) The fines to Effective Asphalt (F/A) ratio calculated to the nearest 0.1 percent.
  - (g) Graphs showing air voids, voids in the mineral aggregate,  $G_{mb}$ ,  $G_{mm}$  and unit weight vs percent asphalt binder content for each of the four asphalt binder contents submitted with trial

mix.

(h) Labeled gyratory densification tables and curves, generated from the gyratory compactor, for all points used in the mixture Submittal.

## **F HMA Paving Recommendation**

A Department approved Paving Recommendation includes a job mix formula (JMF) from the composite gradation, aggregate component proportions, and asphalt content of the mixture. Design air voids, Voids in Mineral Aggregate, and aggregate bulk specific gravity values are indicated on the paving recommendation also. Warning limits and JMF limits will be shown for gradation control sieves, percent asphalt binder content, Air voids, and VMA.

A Department approved paving recommendation is required for all paving except material provided under 2360.7C. All submitted materials must meet aggregate and mixture design requirements before a paving recommendation is issued. The Department will verify two trial mix designs per mix type designated in the plan, per Contract at no cost to the Contractor. Additional mix designs will be verified at a cost of \$2000 per design, payable to the Commissioner of Transportation.

For city, county, and other agency projects that do not have federal or state-aid funding, the Contractor shall provide to the Materials Laboratory a complete Project proposal including addenda, supplemental agreements, change orders, and any Plan sheets (including typical sections) that affect the mix design. The Department will not start the verification process without this information.

All test procedures and required forms are on file with the Bituminous Engineer. Test tolerances are shown in Table 2360-13.

## **F1 Initial Production Test Strip HMA Paving Recommendation**

When the Contractor elects to use the 500 metric ton (550 ton) initial production, Option 3 (2360.3D), an initial JMF will be issued to provide the working range to begin production. Successful verification and validation of this JMF from the plant produced material will be made as set forth in section 2360.3D. Failure to successfully verify the mixture will result in cancellation of the JMF.

## **2360.4 Mixture Quality Management**

### **A Quality Control :**

The Contractor shall provide and maintain a quality control program. A quality control

program is defined as all activities, including mix design, process control inspection, sampling and testing, and necessary adjustments in the process that are related to the production of a Superpave (HMA) pavement which meets the requirements of the specifications.

## **A1 Contractor Certified Plant HMA**

### **A1a Certification Procedure**

The Contractor shall:

- (1) Complete application form and request for plant inspection.
- (2) Provide a site map of stockpile locations.
- (3) Pass plant and testing facility inspection by having the plant inspector and bituminous plant authorized agent complete and sign the Asphalt Plant Inspection Report (TP 02142-02, TP 02143-02). By signing the Asphalt Plant Inspection Report, the HMA plant authorized agent agrees to calibrate and maintain all plant and laboratory equipment within allowable tolerances set for these specifications and the Department's Bituminous Manual.
- (4) Obtain approved mix design recommendations prior to production.

### **A1b Maintaining Certification**

To maintain certification, the plant must produce, test, and document all certified plant asphalt mixtures in accordance with the above requirements on a continuous basis. Continuous basis means all asphalt mixtures supplied from a certified plant to any Department project with 2360 HMA mixtures must be sampled and tested in accordance with 2360 requirements. When mixtures are supplied to projects not specifying 2360 requirements for more than 3 working days the supplier shall either:

- (1) Begin testing at least 2 days before producing 2360 Asphalt mixtures for a project with 2360 requirements, or
- (2) Use the first-day sampling rate of four samples during the first 2000 metric tons (2200 ton) as stated in this specification.

The Contractor shall assure the plant certification procedure is performed annually after winter suspension and before producing material for a Project with certified plant requirements. The Contractor shall recertify a plant when it is moved to a new location.

### **A1c Revocation of Plant Certification**

The Mn/DOT Construction Engineer may revoke certification of an asphalt plant when requirements are not being met or records are falsified. The Department may revoke the Technician Certification for the individual involved.

The Mn/DOT Bituminous Engineer and Mn/DOT Contract Administrator will maintain a list of companies who have had their asphalt plant certification revoked.

## **B Quality Assurance (QA)**

The Department will perform QA testing as part of the acceptance process. The Engineer is responsible for QA testing, records, and acceptance. The Engineer will accomplish the QA process by:

1. Conducting assurance and verification sampling and testing.
2. Observing sampling and tests performed by the QC personnel.
3. Taking additional samples at any time and any location during production.
4. Monitoring the required QC summary sheets and control charts.
5. Verification of calibrations of laboratory testing equipment.
6. Communicating Mn/DOT test results to the Contractor's QC personnel in a timely manner.

## **C Contractor's Quality Control (QC)**

### **C1 Personnel Requirements**

Along with the proposed mix design data, the Contractor shall submit to the Engineer an organizational chart listing the names and phone numbers of individuals and alternates responsible for mix design, process control administration, and inspection. The Contractor shall also post the organizational chart in the Contractors's test facility.

The Contractor's quality control organization or private testing firm shall have Certified Technicians who have met the requirements on file with the department's technical certification program. Individuals performing process control testing must be certified as a Level I Bituminous Quality management (QM) Tester. Individuals performing mix design calculations or mix design adjustments must be certified as Level II Bituminous QM Mix Designer. The Contractor shall have a Certified Level II Bituminous QM Mix Designer available to make any necessary process adjustments. The Contractor shall have a minimum of one person per paving operation certified as a level II Bituminous Street Inspector.

### **C2 Laboratory Requirements:**

The Contractor shall furnish and maintain a laboratory at the plant site or other site approved by the Engineer. The laboratory shall be furnished with the necessary equipment and supplies for performing Contractor quality control testing in accordance with these specifications and the latest version of the Mn/DOT Bituminous Manual. An approved Superpave Gyratory Compactor (SGC)

shall be used to conduct quality management testing. A protocol for evaluation of SGC's has been developed by the FHWA. Successful completion and acceptance of the required testing outlined in this protocol shall constitute an approved gyratory compactor. Documentation shall be submitted, when requested for approval by the Bituminous Engineer.

The laboratory shall be equipped with a telephone for use by the Contractor or the Engineer. A fax machine and copy machine shall be available for use by the Contractor or the Engineer at the laboratory site. The laboratory equipment shall meet the requirements listed in section 400 of the Bituminous Manual and test methods described herein, including extraction capabilities. The laboratory shall be on site, calibrated, and operational prior to the beginning of production.

The Engineer shall be allowed to inspect measuring and testing devices to confirm both calibration and condition. The Contractor shall calibrate and correlate all testing equipment in accordance with the latest version of the Mn/DOT Bituminous Manual. Superpave gyratory compactors shall be calibrated, as specified by the manufacturer, a minimum of twice per year for units in permanent locations, upon arrival at portable locations and at the start of Superpave projects or when mixture bulk specific gravity values become suspect.

#### **D Sampling and Testing:**

The Contractor shall use random numbers, as indicated in the bituminous manual 5-693.7 Table A or ASTM D3665; select locations based upon the method described in section 5 of ASTM D3665 so that all QC samples are taken at random locations. The tests for mixture properties shall be conducted on representative portions of the mix, quartered from a larger sample of mixture taken from behind the paver, or alternate approved sampling method on file in the department Bituminous office. The Contractor shall obtain a sample of at least 35 kg (75 lb). This sample may be either split in the field or transported to the test facility by a method to retain heat to facilitate sample quartering procedures. The Contractor shall store and retain Gyratory samples and companion samples for the Department for a period of 7 days. The Contractor shall maintain these split samples in containers (labeled with companion numbers) approved by the Engineer. The Contractor shall perform QC sampling and testing according to the following schedule:

Determine the planned tonnage for each mixture to be produced during the production day. Divide the planned production by 1000. Round the number to the next higher whole number. This number will be the number of production tests required for that mixture. Split the planned production into even increments and select sample locations as described above. During production mixture volumetric property tests will not be required on the days when mix production is less than 100 metric tons (110 tons). However, when mix production is less than 100 metric tons (110 tons) per day on successive days, the test will be run when the accumulative tonnage on such days exceeds 100 metric tons (110 tons). At the start of production, double the testing frequency on the first two sets of production tests, for Gyratory Bulk Specific Gravity and Maximum Specific Gravity (conduct four tests).

**E Production Tests:**

When more than one Mn/DOT approved test procedure is available, the Contractor shall select, with the approval of the Engineer, one method at the beginning of the project and use that method for the entire project. The Contractor and Engineer may agree to change test procedures during the construction of the Project.

**E1 Asphalt Binder Content, Percent**

**E1a Incinerator Oven <sup>(1)</sup> ..... Mn/DOT Lab Manual Method 1853**

**E1b Chemical Extraction ..... Mn/DOT Lab Manual Method 1851 or 1852**

**E1c Spot Check (Virgin Only) ..... Mn/DOT Bituminous Manual 5-693.848**

**E1d Meter Method (Virgin Only) ..... Mn/DOT Bituminous Manual**

<sup>(1)</sup>Incinerator Oven may not be used when the percentage of class B material exceeds 50% within the composite blend, unless a correction factor is determined by the Contractor and approved by the District Materials Engineer or designee.

**E2 Gyratory Bulk Specific Gravity, Gmb (2 specimens) .....  
..... ASHTO TP4, T166, Mn/DOT modified**

**E3 Maximum Specific Gravity, Gmm ..... AASHTO T209, Mn/DOT modified**

**E4 Air Voids - Individual and Isolated (Calculation) ... Asphalt Institute MS 2 and SP 2**

During production of the mix, the Contractor shall monitor the volumetric properties of the Superpave mixture with a Superpave gyratory compactor. Gyratory compaction shall be conducted to  $N_{\text{maximum}}$  and calculations for % $G_{\text{mm}}$  at  $N_{\text{initial}}$  and  $N_{\text{design}}$  shall be determined by applying the calculated correction factor as described in the Asphalt Institute SP 2 manual. The isolated air voids are calculated using the maximum mixture specific gravity and the corresponding bulk specific gravity from a single test. The individual air voids are calculated from the moving average determined from the previous four test results for the maximum mixture specific gravity ( $G_{\text{mm}}$ ) and the %  $G_{\text{mm}}$  at  $N_{\text{initial}}$ ,  $N_{\text{design}}$ , and  $N_{\text{maximum}}$  determined by the gyratory compactor. Mixture densification during production shall meet requirements in Table 2360-8 for % $G_{\text{mm}}$  at  $N_{\text{initial}}$ ,  $N_{\text{design}}$ , and  $N_{\text{maximum}}$ .

Production control for % $G_{\text{mm}}$  at  $N_{\text{design}}$  shall conform to the control limits shown in Table 2360 - 11. Production control for %  $G_{\text{mm}}$  at  $N_{\text{initial}}$  and  $N_{\text{maximum}}$  shall not exceed the limit shown in Table 2360-8 by more than 1.0 %. Mixture produced beyond these limits, as measured by the moving average of four tests, shall result in a cancellation of the approved Department JMF. A new mix design and Submittal that satisfies these specification criteria will be required.

**E5 Void Mineral Aggregate (VMA) (calculation) ..... Asphalt Institute MS 2**

**E6 Gradation - Blended Aggregate ..... AASHTO T-11 & T-27**

All gradation require a minus 0.075mm (#200) wash.

**E6a Plant produced Mixture :**

- (1) Field Extraction Mn/DOT Lab Manual Method 1854
- (2) Hot Bins - Drybatch
- (3) Incinerator Oven Mn/DOT Lab Manual Method 1853<sup>(1)</sup>
- (4) Chemical Extraction Mn/DOT Lab Manual Method 1851 or 1852

(1) If the incinerator oven is used when a mixture contains more than 50% Class B, an aggregate correction factor as approved by the District Materials Engineer shall be applied.

Extracted gradations shall be run at a rate of 1 test per 2000 metric tons (2200 ton)s of mixture or a minimum of 1 per day.

**E7 Field Moisture Damage Testing (TSR):**

HMA mixture samples shall be taken at 10,000 metric tons (11,000 ton) increments for all mixture produced on the project. These samples shall be taken at random as directed by the project Engineer. The samples shall be 50 kg (110 lb) minimum and split in half. The Department companion of this split shall be labeled with the date, time, project number and approximate cumulative tonnage to date. The Department companion shall be given to the Department street inspector or plant monitor immediately or delivered to the District Materials Engineer within 48 hours of sampling, as specified by the Project Engineer. Sampling method shall conform to one of the approved methods on file in the Bituminous Office. These samples may be tested at the discretion of the Engineer.

The following conditions will automatically require a sample to be taken and tested:

- 1. Any individual aggregate stockpile component gradation deviates more than 10% from the original gradation submitted at design as shown in 2360.3. This deviation may be determined from stockpile or extracted gradations conducted by the Contractor or the Department.
- 2. At the discretion of the Engineer.

If the TSR result fails to meet the minimum specified value as shown in 2360.2F7, the Contractor shall be notified immediately and action shall be taken to resolve the problem. This action may include addition of antistripping agent, addition of hydrated lime, or changes in aggregate components. Any costs associated with these changes shall be borne by the Contractor.

Field TSR tests shall be conducted on all mixtures according to ASTM D4867, Mn/DOT modified, specimen size shall be 150 mm (6 in).

**E8 Aggregate Specific Gravity (Gsb) . . . . . AASHTO T84 and T85, Mn/DOT modified**

Samples of all aggregate stockpiles shall be collected on each aggregate used in the production mixture, at a rate of one sample per 10,000 metric tons (11,000 ton)s mixture produced. These samples shall be taken at random as directed by the project Engineer. These representative stockpile samples shall be 40 kg (90 lb) of each aggregate component. Each sample shall be split in half. The Department companion shall be labeled with date, time, project number and approximate cumulative tonnage to date. The Department companion shall be given to the Department street inspector or plant monitor immediately or delivered to the District Materials Engineer within 48 hours of sampling, as specified by the Project Engineer.

These samples may be tested and if the results deviate beyond the tolerance specified in Table 2360-13, the results will be used for acceptance of specific gravity. Dispute resolution shall follow the procedure on file with the Bituminous office, however any mixture placed following notification of new specific gravity values will be based upon Department results unless proven incorrect. The Contractor shall be notified when new specific gravity values become available and what impact this will have on the calculated VMA.

**E9 Coarse Aggregate Angularity (CAA) . . . . . ASTM D5821**

CAA test results shall meet the minimum percent fractured faces as shown in Table 2360-4. Coarse Aggregate Angularity shall be determined by ASTM D - 5821 on the composite blend from aggregates used in production of hot mix asphalt. Mixtures that contain virgin aggregates may be tested from composite belt samples. Mixtures that contain RAP must be tested from extracted aggregates taken from standard production samples. The percentage of fractured faces of the composite aggregate blend less than 100% shall be tested at the following rates:

- (1) Perform two tests per day for each mixture blend for a minimum of two days and then one per day if the test samples meet CAA requirement.
- (2) If CAA crushing test results exceed requirement by greater than 8 percent, take one sample per day and perform one test per week.

CAA results must be reported on the test summary sheet. Mixture placed and represented by results below the minimum requirement, as shown in Table 2360-4, will be subject to reduced payment as shown in Table 2360-12.

**E10 Fine Aggregate Angularity (FAA) . . . . . ASTM C1252 Method A**

FAA test results shall meet the minimum criteria shown in Table 2360-5. Fine Aggregate Angularity shall be determined by ASTM C1252 Method A on the composite blend from aggregates used in production of hot mix asphalt. Mixtures that contain virgin aggregates may be tested from composite belt samples. Mixtures that contain RAP must be tested from extracted aggregates taken from standard production samples. The percentage of uncompacted voids from

the composite aggregate blend shall be tested at the following rates.

- (1) Perform two tests per day for each mixture blend for a minimum of two days and then one per day if the test samples meet CAA requirement.
- (1) If FAA test results exceed requirement by greater than 5 percent, take one sample per day and perform one test per week.

FAA results must be reported on the test summary sheet. Mixture placed and represented by results below the minimums, as shown in Table 2360-5, will be subject to reduced payment as shown in Table 2360-12.

**E11 Moisture Content ..... Mn/DOT 5-693.950**

Provide a mixture with a moisture content not greater than 0.3 percent. The moisture content in the mixture shall be measured behind the paver or alternate approved sampling method on file in the department Bituminous office. A sample shall be taken on the first day of production of each course and then at the discretion of the Engineer. The sample shall be stored in an airtight container. Microwave testing is prohibited.

Superpave HMA that exceeds 0.3 % moisture content is unacceptable. The Contractor shall take appropriate action to remove excess water from the mixture. This action may include reducing the production rate, mixing stockpile aggregates prior to placement into the feed bins, and use of covered stockpiles.

**E12 Asphalt Binder Samples:**

The Contractor shall sample the first shipment of each type of asphalt binder, then sample at a rate of one per million liters (250,000 gallons), sample size shall be 0.5 L (1 pint). All samples shall be taken in accordance with the bituminous Manual 5-693.920. Sampling shall be conducted by Contractor and monitored by the Inspector. Promptly submit sample to the Department Materials Laboratory in Maplewood. The Contractor shall record sample information on Asphalt Sample Identification Card.

**F Documentation (Records):**

The Contractor shall maintain control charts on an ongoing basis. Reports, records, and diaries developed during the progress of construction activities for the project, shall be filed as directed by the Engineer and will become the property of the Department. The Contractor shall:

- (1) Number test results in accordance with standard Department procedures and record on forms supplied by the Department.

(2) Facsimile all production test results on test summary sheets to the District Materials Laboratory or other site as requested by the Engineer, by 2 PM of the day following production.

(2a) The following production test results and mixture information shall be included on the Department approved test summary sheet.

1. Percent passing on sieves listed in Table 2360-2.
2. Coarse and fine aggregate Angularity.
3. Maximum specific gravity ( $G_{mm}$ ).
4. Bulk specific gravity ( $G_{mb}$ ).
5. Percent asphalt binder content ( $P_b$ ).
6. Calculated production air voids ( $V_a$ ), %  $G_{mm}$  at  $N_{initial}$ , %  $G_{mm}$  at  $N_{design}$ , %  $G_{mm}$  at  $N_{maximum}$
7. Calculated voids in mineral aggregate (VMA).
8. Composite aggregate specific gravity ( $G_{sb}$ ) reflecting current proportions.
9. Stockpile proportions in use at the time of sampling.
10. Tons where sampled.
11. Cumulative tons.
12. Fines to effective asphalt ratio ( $F/A_e$ ).

(2b) Submit copies of all failing test results to the Project Engineer on a daily basis.

(3) Provide the Department with asphalt delivery invoices on a daily basis.

(4) Provide a daily plant diary to include a description of QC actions taken (adjustment of cold feed percentages, changes in JMFs, etc.) include all changes or adjustments on the test summary sheets.

(5) Provide weekly truck scale spot checks.

(6) Provide a Department approved accounting system for all mixes and provide a daily and final project summary of material quantities and types.

(7) Furnish an automated weigh scale and computer generated weigh ticket. The ticket shall indicate project number, mix designation, pit number, truck identification and tare, net mass, date and time of loading. Any deviations from the minimum information to be provided on the computer generated weigh ticket must be approved by the Engineer in writing.

(8) Charts and records for a mixture produced at one plant site shall be continued from contract to contract.

## **G Documentation (Control Charts):**

The following data shall be recorded on the standardized control charts:

- (1) Blended aggregate gradation, include sieves shown in Table 2360-2 for specified mixture.
- (2) Percent asphalt binder content

- (3) Maximum specific gravity
- (4) Production air voids, %  $G_{mm}$  @  $N_{design}$
- (5) VMA

Individual test results shall be plotted in black for each test point. A solid black line shall connect points. The moving average for each test variable shall be plotted in red starting with the fourth test. A dashed red line shall connect the points. The Department's assurance and verification test results shall be plotted with green asterisks. Specification JMF and Warning limits shall be indicated on the control charts using a green inked dotted line. The Engineer may waive the plotting of control charts.

**H Control Limits**

The production Air Voids and VMA limits are based upon the minimum specified requirements as shown in Tables 2360-8 and 2360-9. Gradations and Asphalt binder content limits are based upon the current Department approved JMF. Gradation control sieves include each sieve shown in Table 2360-2 with control points demarcated, as per mixture specified. The mixture production targets are listed on the approved department paving recommendation. Control limits are the target plus or minus the limits shown in Table 2360-11.

**Table 2360-11  
Control Limits**

Item	JMF Limits	Warning Limits
VMA, %	- 0.3	- 0.0
% $G_{mm}$ @ $N_{design}$ / Production Air Voids	$\pm$ 1.3	$\pm$ 1.0
Asphalt Binder Content, Percent	- 0.4	- 0.3
Sieve - % Passing		
25, 19, 12.5, 9.5, 4.75 mm (1", 3/4", 1/2", 3/8", #4 )	$\pm$ 7.0	$\pm$ 6.0
2.36 mm (No. 8)	$\pm$ 6.0	$\pm$ 5.0
0.075 mm (No. 200)	$\pm$ 2.0	$\pm$ 1.5

**I Warning Bands**

Warning Bands are defined as the area between the JMF limits and the warning limits.

**J JMF Adjustment**

A request for a JMF adjustment may be made to the Materials Engineer by the Contractor. The

requested change will be reviewed for the Department by a Certified Level II Bituminous QM Mix Designer. If the request meets the mixture requirements in Section 2360.2F, a revised JMF shall be issued. Each trial mixture design Submittal as described in section 2360.3A may have three JMF adjustments per mixture per project without charge. Additional JMF adjustments requested must be accompanied with a \$500 fee per each additional JMF adjustment, payable to the Commissioner of Transportation.

If a JMF change is requested for the 0.075 mm (#200) sieve, the Fines to Effective Asphalt Ratio shall be determined on the moving average from the previous four gradation tests conducted during actual production for the 0.075 mm (#200) sieve. Adjustments to conform to actual production shall not exceed the tolerances specified for the JMF limits. Regardless of such tolerances, the adjusted JMF shall be within the mixture specification gradation design broad bands shown in Table 2360-2. Should a redesign of the mixture become necessary, a new JMF shall be submitted according to the requirements of the specification. The JMF asphalt content may only be reduced if the production VMA meets or exceeds the minimum VMA design requirement for the mixture being produced.

## **K Corrective Action**

When the moving average values trend toward the warning limits, the Contractor shall take corrective action. The corrective action, if any, shall be documented. All tests shall be part of the project files and shall be included in the moving average calculations.

The Contractor shall notify the Engineer whenever the moving average values exceed the warning limits. If two consecutive moving average values exceed the warning limits, the Contractor shall stop production and make adjustments. Production shall only be restarted after notifying the Engineer of the adjustments made. The Contractor shall increase the testing rate to one set of production tests (2360.4E) per 450 metric tons (500 ton) whenever the moving average exceeds the warning limits. This includes the start-up period after shut down for consecutive averages exceeding the warning limits. The moving average shall not be calculated until the fourth test after the required stop in production.

Failure to stop production and make adjustments when required shall subject all mixture produced from the tonnage point the mixture exceeded the warning limit to the tonnage point when the moving average is back within the warning limits to be considered unsatisfactory. Reduced payment for unsatisfactory mixtures will be applied in accordance with Table 2360-12.

If the process adjustment improves the property in question such that the moving average after four additional tests is within the warning limits, the Contractor may continue production with no reduction in payment. If the moving average after four additional tests stays in the warning bands, the mixture will be considered unsatisfactory. Reduced payment for unsatisfactory mixtures will be applied starting from the plant tonnage the mixture exceeded the warning limit to the tonnage when the moving average is back within the warning limits in accordance with Table 2360-12.

**Table 2360-12  
Payment Schedule**

<b>Item</b>	<b>Percent mixture bid price, Payment <sup>(1)</sup></b>
Coarse and Fine Aggregate Angularity <sup>(2)</sup>	95
Gradation	90
VMA	85
Asphalt Binder Content	85
Production Air Voids (individual)	70

(1) Lowest Single Payment applies

(2) Corrective action provision does not apply, any results below minimum specified subject to this reduced payment.

**L Failing Materials**

If the moving average values exceed the JMF limits, the Contractor shall stop production and make adjustments. Production shall only be restarted after notifying the Engineer of the adjustments made. The calculation of the moving average shall continue after the stop in production.

When the total production of a mixture type for the entire project requires less than four tests, single data points shall be compared to the square root of n times the warning limit, where n is the number of production tests. If the test results exceed these limits, the corrective action outlined previously will apply or if necessary, reduced payment as outlined below.

When the Contractor's testing data fails to meet specified tolerances, quality assurance and verification data shall be used in-place of the Contractor's data to determine the appropriate payment factor.

**L1 Moving Average Failure - Production Air Voids**

Mixture placed with the individual production air voids moving average of four, exceeding the JMF limits will be considered unacceptable and shall be removed and replaced by the Contractor at the Contractor's expense. Tonnage subjected to replacement or reduced payment shall be calculated as the tons placed from the sample point of all test results beyond the warning limits which contributed to the moving average value that exceeded the JMF limit, through the sampling point when the test result is back within the warning limits. If the Engineer decides to leave the mixture in place because of special circumstances, the mixture will be paid for at 50 percent of the contract bid price.

## **L2 Moving Average Failure - Percent Asphalt Binder Content, VMA, and Gradation**

For properties including asphalt binder content, VMA, and Gradation, where the moving average of four exceeds the JMF limits, payment will be at 75 percent of the contract bid price for mixture provided the mixture is allowed to remain in place by the Engineer. Tonnage subjected to replacement or reduced payment shall be calculated as the tons placed from the sample point of all test results beyond the warning limits which contributed to the moving average value that exceeded the JMF limit, through the sampling point when the test result is back within the warning limits.

## **L3 Individual Failure - Production Air Voids, Percent Asphalt Binder, and VMA**

If the individual Quality Control tests for individual Air Voids<sup>(1)</sup> or percent asphalt binder content exceed twice the warning limits and the results are verified by QA tests, the material is considered unsatisfactory or unacceptable. If individual Quality Control tests for VMA exceed twice the JMF limits and the results are verified by assurance or verification tests, the material is considered unsatisfactory or unacceptable. An investigation will be conducted to determine the extent of the problem and the amount of any price adjustments for unsatisfactory or unacceptable mixtures. Reduced payment as outlined in Table 2360-12 shall apply to all mixture represented by those results. Tonnage subjected to reduced payment shall be calculated as the tons placed from the sample point of the failing test until the sampling point when the test result is back within the warning limits.

(1) The daily verification sample test result shall be compared to the isolated air void determined from the verification sample taken for compliance.

## **L4 Individual Failure - Gradation**

If the individual gradation test exceeds twice the warning limits, is outside the gradation bands listed in Table 2360-2, and is verified by QA tests, the materials are considered unsatisfactory or unacceptable. An investigation will be conducted to determine the extent of the problem and the amount of any price adjustments as defined above for unsatisfactory or unacceptable mixtures. Reduced payment as outlined in Table 2360-12 shall apply to all mixture represented by those results. Tonnage subjected to reduced payment shall be calculated as the tons placed from the sample point of the failing test until the sampling point when the test result is back within the warning limits.

## **L5 Coarse and Fine Aggregate Crushing Failure**

If any test result for Coarse Aggregate Angularity or Fine Aggregate Angularity fail to meet minimum requirements in Tables 2360-4 and 2360-5, and the result is verified by Department tests, all material placed is subject to reduced payment as indicated in Table 2360-12.

## **M Assurance**

The Engineer will periodically witness the sampling and testing being performed by the Contractor. If the Engineer observes that the sampling and quality control tests are not being

performed in accordance with the applicable test procedures, the Engineer may stop production until corrective action is taken. The Engineer will notify the Contractor of observed deficiencies promptly, both verbally and in writing. The Engineer will document all witnessed samples and tests.

All testing and data analysis shall be performed by the Certified Level I Bituminous Quality Management (QM) Technician. Certification shall be in accordance with the Department's Highway Technician Certification Program. The Department shall post a chart giving the names and telephone numbers for the personnel responsible for the assurance program.

The Engineer shall calibrate and correlate all laboratory testing equipment in accordance with the latest version of the Mn/DOT Bituminous Manual.

**Table 2360-13  
Test Result Tolerances**

<b>Item</b>	<b>Allowable Difference</b>
Gyratory Bulk Specific Gravity ( $G_{mb}$ )	0.030
Mixture Maximum Specific Gravity ( $G_{mm}$ )	0.019
Fine Aggregate Angularity, uncompacted voids (U) %	1.0
Coarse Aggregate Angularity, % fractured faces (%P)	15
Aggregate combined blend Specific Gravity ( $G_{sb}$ )	0.020
Tensile Strength Ratio (TSR)	Minimum Design = 80 Mn/DOT Verification = 75
<b>Asphalt Binder Content</b>	
Meter Method, %	0.2
Spot Check Method, %	0.2
Chemical Extraction Methods, %	0.6
Incinerator Oven Extraction, %	0.2
<b>Gradation Sieve % passing</b>	
25.0, 19.0, 12.5 9.5 mm (1", 3/4", 1/2", 3/8 ")	6.0
4.75 mm (#4)	5.0
2.36 mm (#8)	4.0
0.075 mm (#200)	2.0

**N Verification Testing**

Verification testing shall be performed, on one set of production tests 2360.4E, excluding sections E7, E8, E11 and E12 on a daily basis. In addition to Mn/DOT's QA program, a verification sample and verification companion will be obtained on a daily basis.

The verification sample will be used to verify the requirements listed in 2360.4E and shall meet the tolerances listed in Table 2360-13. These include the mixture properties of  $G_{mm}$  mixture max gravity,  $G_{mb}$  mixture bulk gravity, production air voids (calculated isolated), asphalt binder content, VMA (calculated) and gradation. These do not include the aggregate bulk specific gravity  $G_{sb}$  or the tensile strength ratio TSR. Asphalt binder content and gradation must be determined by either extraction method 2360.4E1a or 2360.4E1b. Asphalt binder content from the verification test result must be used to determine VMA.

A verification sample is a sample which is sampled and tested by Mn/DOT to assure compliance of the Contractor's Quality Control program. This verification sample will be taken by the Department street inspector or plant monitor as determined by the Project Engineer. A verification companion is a companion sample, to Mn/DOT's verification sample, provided to the Contractor. The Contractor is required to test this verification companion sample. These results shall be used as part of the QC program.

This verification process is intended to identify potential sampling and/or testing problems between the Contractor and the Department. In the event verification of the aforementioned mixture properties is unsuccessful, an investigation into the source of problems will commence immediately. During the interim, until the source of error is found, the Departments test results will be used for acceptance. If the source of problem(s) is not found within 72 hours of determination that verification is not successful, the Contractor shall cease mixture production and placement until the problem is identified and resolved. The Department Laboratories will not run accelerated testing indefinitely. All efforts must be made to determine the source of the lack of proper verification of mixture properties. This process is available in flow chart format in the Bituminous Office.

## **N1 Testing Methodology Verification**

### **N1A Verification and Companion test results meet tolerance**

If the Department verification test results and the Contractor's verification companion test results meet the specified tolerances shown in Table 2360-13, the testing methodology has successfully been verified. Proceed to the Sampling methodology verification procedure.

### **N1B Verification and Companion test results do not meet tolerance**

If the Department verification test results and the Contractors verification companion test results are not within the specified tolerances listed in Table 2360-13, a determination of validity is required {N1B(1)}.

#### **N1B(1) Verification validation**

When tolerances are not met, the Department will collect the previously saved QA sample and test accordingly.

N1B(2) Verification validation (QA check meets tolerance)

If the test results from the QA sample as compared to the QC split companion (which was already performed by the Contractor) meets the tolerances specified, the verification test is considered an exception and the QA companion result is acceptable for verification of the Contractors QC testing methodology. Proceed to the Sampling methodology verification procedure.

N1B(3) Verification validation (QA check does not meet tolerance)

If the test result from the QA sample does not meet the tolerance specified, the original verification test is validated and the Department will continue to test the remaining QA samples until they meet the tolerance or remaining samples are all tested, whichever comes first. Acceptance for materials supplied to date, since last acceptable verification, will be made based upon the Agencies test results. An investigation shall commence immediately to determine the cause of this difference. Testing equipment, procedures, and personnel will be reviewed to determine the source of the problem.

## **N2 Sampling Methodology Verification**

To verify the sampling methodology, the Department test results described in N1A or N1B(2) must be compared to the Contractors most recent moving average QC test results. Validation of sampling methodology is conducted after successful completion of testing methodology verification.

N2A Verification and QC moving average meet tolerance.

If the Department verification test results in N1A or verification validation test results in {(N1B(2))}, as compared to the Contractors most recent moving average QC test results, are within the tolerances listed in Table 2360-13, the sampling methodology is successfully verified. Acceptance of material will be based on the Contractors QC data.

N2B Verification and QC moving average do not meet tolerance.

If the Department verification test results in N1A or verification validation test results in {(N1B(2))}, as compared to the Contractors most recent moving average QC test results, are not within tolerances listed in Table 2360-13, a determination of validity is required {N2B(1)}.

N2B(1) Verification Validation

When tolerances are not met, the Department will collect another verification sample from subsequent production. A determination will be made whether there has been poor sampling methodology or whether the test result is an exception.

N2B(2) Verification Validation (Second verification meets tolerance vs moving average)

If the second verification sample tested meets the tolerance specified, the first verification sample can be considered an exception. Acceptance of material will be based upon the Contractors QC data.

**N2B(3) Verification Validation (Second verification does not meet tolerance)**

If the second verification sample tested fails to meet tolerance with the Contractor's moving average, then the sampling methodology is suspect. Acceptance of material will be based upon the Department's verification test results. This will remain in effect until acceptable tolerance between the Contractors moving average and the Department verification can be reestablished. Investigation of sampling procedures, equipment, and personnel will commence immediately.

If verification test results that are used for acceptance indicate failure to comply with volumetric or densification properties, the material placed will be subject to penalties or removal and replacement as described in Tables 2360-12 and 2360-16.

**2360.5 Pavement Density**

**A General**

All pavements will be constructed in accordance with the Maximum Density Method unless otherwise specified. Compaction of leveling layers less than 40 mm (1.5 in), tight blade leveling, wedging layers, patching layers, driveways, areas which cannot be compacted with standard highway construction equipment, will be accomplished according to the Ordinary Compaction procedure described in 2360.5C.

**B Maximum Density Method**

All courses of plant mixed bituminous mixtures for which the Maximum Density Method is used shall be compacted to a density not less than the percentage shown in Table 2360-14.

**B1 Pavement Density Determination**

The density of each lot shall be expressed as a percentage of the maximum specific gravity (%  $G_{mm}$ ) obtained by dividing the average bulk specific gravity for the lot by the maximum specific gravity, (maximum specific gravity basis is the average  $G_{mm}$  of QC tests done on the day that the individual lot was paved), times 100. If a new job mix formula is established, a new maximum specific gravity reflecting the new job mix formula shall be used for maximum density determination. Determination of the bulk specific gravity of the cores shall be in accordance with AASHTO T-166, Mn/DOT modified or T-275 when the percentage of water absorbed by volume exceeds 2.0% . Where the percentage of water absorbed by volume equals:

$$\{(B - A) \div (B - C)\} \times 100 \quad A = \text{Mass (in grams) of specimen in air}$$

B = Mass (in grams) of surface-dry specimen in air

C = Mass (in grams) of specimen in water

A new core must be taken when the percentage of water absorbed exceeds 2.0% by volume. Testing the original pavement core alters the core such that a second test on that core cannot be performed. A new core shall be taken 0.3 meters (1 ft.) longitudinally forward of the previously cored specimen and tested according to AASHTO T-275.

Compacted mixtures represented by samples or tests having deficient densities shall not be re-rolled. The Contractor shall not operate below the specified minimum density on a continuing basis. A continual basis shall be defined as all lots in a days production failing to meet minimum density or more than 50% of the lots on multiple days which fail to meet minimum density requirements. Production shall be stopped until the source of the problem is determined and corrective action is taken to bring the work into compliance with specified minimum required density.

## **B2 Required Density**

Density determination for wearing and non-wearing courses is identified and separated by their location from the surface and is shown in Table 2360-14. Density for shoulder courses are identified by mixture placement operations. When shoulders are paved in a separate operation, density determination shall be made for the shoulder pavement separate from the mainline. Lot tonnage will be delineated for the shoulders separate from the mainline for the day paving was conducted. Shoulders paved in the same pass as the mainline will be included in the random selection of core locations within the specified lot derived from daily tonnage. The density required for shoulders, paved in the same pass as the mainline, shall conform to the mainline requirement shown in Table 2360-14. Acceptance will be based upon the entire lot.

**Table 2360-14  
Required Minimum Density**

	<b>Wear<sup>1</sup></b>	<b>Nonwear<sup>2</sup></b>	<b>Shoulders<sup>2</sup></b>
<b>Location from surface</b>	< 100 mm (4")	≥ 100 mm (4")	all
<b>% Gmm</b>	92	93	93

1) Minimum reduced by one percent on the first lift constructed over pcc pavements that have 30% or more: faulted joints & cracks and/or contain mid panel cracks. Where faults and cracks are defined as follows:

fault > 6.35 mm (0.25 in)

mid panel cracks are > 2 mm (1/16 in) width and 0.6 m (2 ft.) or more in length.

2) Minimum reduced by one percent for the first lift constructed on base compacted by the quality compaction method, or cold recycled base courses and first lift of an overlay on a roadway with 6.35 metric ton (7 ton) or less spring load restriction.

The inplace density of each course of asphalt mix construction shall be evaluated by the use of 100 mm (4 in.) or larger diameter roadway cores.

**B3 Lots and Core Locations**

Divide the days production into equal lots as shown in Table 2360-15 and obtain three cores. Two cores will be taken from random locations selected by the Engineer. The third core, a companion core, shall be taken 0.3 meters (1 ft.) longitudinally from either of the first two cores. The companion cores shall be given to the Department Street inspector immediately upon completion of coring and sawing. The random locations will be determined by the use of statistically derived stratified random number tables. These will also be used for partial LOTs. Both transverse and longitudinal joints are subject to maximum density requirements. Randomly selected core locations may fall on the joint, in these instances, cores shall be taken tangent to the joint. Cores will not be taken within 0.3 meter (1 ft.) of any unsupported edge. The Contractor shall be responsible for maintenance of traffic, coring, patching the core holes, and sawing the cores if necessary to the proper thickness prior to density testing.

**Table 2360-15  
Description of Lots**

Daily Production		Lots
Metric Ton	(ton) English	
0 - 545	( 0 - 600)	1
546 - 910	(601 - 1000)	2
911 - 1455	(1001 - 1600)	3
1456 - 3275	(1601 - 3600)	4
3276 - 4545	(3601 - 5000)	5
4546 +	(5001 +)	6

Cores will be taken by the Contractor and observed by the Department. The Contractor will cut pavement samples from the completed work with power equipment, and restore the surface by the end of the next working day with new, well compacted mixture without additional compensation. Failure to restore the surface within 24 hours of coring shall subject the Contractor to a fine of \$100 per working day, per lot, until the core holes are restored. Provide 100 mm (4 in) diameter or larger samples. All samples shall be marked with the lot number, and core number or letter. The cores shall be transported to the laboratory as soon as possible to prevent damage due to improper handling or exposure to heat.

If the companion cores from two consecutive days paving meet specified tolerances for bulk specific gravity, as shown in Table 2360-13, the companion core rate may be reduced to thirty percent of the lots, rounded to the nearest whole number. This reduction shall be subject to approval

by the Engineer. If any companion cores fail to meet tolerance on subsequent days, the core rate shall revert to the original rate of one companion per lot.

Measure each core three times for thickness prior to saw cutting, report the average lift thickness on the core sheet. These average thickness will contribute to thickness compliance as described in section 2360.7C

**B4 Acceptance and Payment Schedule**

Density of compacted mixture shall be accepted by pavement cores on a LOT basis. Core locations will be determined by the Engineer. Cores shall be tested by the Contractor and verified by the Department. Density determination will be made by the end of the next working day after placement and compaction and prior to placement of subsequent layers.

The Contractor’s cores will be used for acceptance if the determined bulk specific gravity  $G_{mb}$  from AASHTO T-166, Mn/DOT modified or T-275 is within  $\pm 0.030$  of the state companion  $G_{mb}$  value. Partial payment will be made for those LOTs that have an average density less than the minimum % of  $G_{mm}$  based on Table 2360-16.

If the Department companion core test result for bulk specific gravity ( $G_{mb}$ ) deviates beyond the allowable tolerance of 0.030, substitute Department companion result for Contractor’s core result and then average the Department result with the non-companion result for the lot density acceptance.

If the  $G_{mb}$  tolerance fails in more than 2 Lots in a day of either consistently high or low differences between the companion cores then an investigation to determine the source of errors shall be conducted. Companion cores samples shall be increased to two per lot and tested until investigation is complete and tolerances are met.

**Table 2360-16  
Payment Schedule For Maximum Density**

<b>Percent of Maximum Specific Gravity <sup>(1)</sup> ( ≤ 100 mm (4") from Surface)</b>	<b>Percent of Maximum Specific Gravity <sup>(1)</sup> ( &gt;100 mm (4 ") from Surface)</b>	<b>Percent Payment</b>
93.6 and above	94.6 and above	104 <sup>(2)</sup>
93.1 - 93.5	94.1 - 94.5	102 <sup>(2)</sup>
92.0 - 93.0	93.0 - 94.0	100
91.0 - 91.9	92.0 - 92.9	98
90.5 - 90.9	91.5 - 91.9	95
90.0 - 90.4	91.0 - 91.4	91
89.5 - 89.9	90.5 - 90.9	85
89.0 - 89.4	90.0 - 90.4	70
Less than 89.0 <sup>(3)</sup>	less than 90	<sup>(3)</sup>

- (1) In calculating the percent of maximum specific gravity, report to the nearest tenth.
- (2) The payment in this portion of the specification shall only apply if the individual production air voids, as determined from mixture production test (2360.4E) that represents the tonnage placed at that specific core location, are within - 0.5 percent of the target value.
- (3) Areas of HMA pavement shall be removed and replaced by the Contractor at their expense with mixture of the specified density and, when acceptably replaced, will be paid for at the contract unit price per ton for the original material; or the Engineer may permit the unacceptable material to remain in place with a 50 percent payment factor. The limits of the area to be removed will be determined by cored samples. The densities shall be determined at 15 m (50 ft) increments both ahead and back of the point of unacceptable density, and at the same offset as the original core site. If these tests indicate unacceptable density, 15 m (50 ft) incremental testing shall continue until a point of acceptable density is found, which is a maximum of 3.0 percent or less below the target minimum density. If the incremental testing extends into a previously accepted lot, removal of the unacceptable material will be required; however, the results of these tests shall not be used to recalculate the previously accepted lot density. If a portion of the lot density is determined to be within the limits of acceptability, that area shall be compensated at the level shown in Table 2360-16. All costs incurred from additional coring and testing, resulting from unacceptable material will be paid by the Contractor. The unacceptable pavement area is computed as the product of the longitudinal limits so determined by the 15 meter (50 ft) cores and the full width of the paver pass, laying in the traffic lane or lanes. Shoulders shall be exempt from this calculation unless density failure occurred in the shoulder area.

Tests indicating greater than 3 percent density below the specified minimum shall be excluded from computation of the remainder of that lot's density. The remaining portion of the lot, determined to have acceptable density, shall be compensated at the specified values shown in Table 2360-16. Test results on the replacement pavement shall not be included in the original lot density computations, unless the quantity replaced represents 20 percent or greater of the lot tonnage. When the percentage of replaced material exceeds 20 percent, the replaced pavement density shall be tested and results averaged with the remaining lot results. When the percentage of replaced material is less than 20 percent of a lot, that replacement material shall have one core with one companion taken within the new pavement and accepted as outlined in Table 2360-16.

## **C Ordinary Compaction**

This compaction method shall not be used on mainline, ramps, or loop paving. A control strip shall be used to establish a rolling pattern. This shall be used by the Contractor for the compaction of the asphalt mixture for the layer on which the control strip is constructed, or until a new control strip is constructed. The control strip requirement may be waived by the Engineer in small localized areas or other areas not conducive to its establishment.

A control strip shall be constructed at the beginning of the work on each lift of each course.

Each control strip shall have an area of at least 330 m<sup>2</sup> (395 yd<sup>2</sup>) and shall be of the same thickness as the lift it represents. The subgrade or pavement course upon which a control strip is to be constructed shall have the prior approval of the Engineer. The control strips shall remain in place and become part of the completed work.

The materials used in the construction of the control strips shall conform to the specified requirements for the course. The materials used in the control strip shall be from the same source and of the same type as the materials used in the remainder of the course that the control strip represents.

The equipment used in the construction of the control strips shall be approved by the Engineer and shall be the same type and mass used on the remainder of the pavement course represented by the control strip. A minimum of two rollers shall be required. A rolling pattern shall be established for each roller. A pneumatic-tired roller shall be available for compaction operations within 24 hours after request by the Engineer. The final rolling shall be performed with a tandem steel-wheeled roller. Areas that are inaccessible to the conventional type rolling equipment shall be compacted to the required density by using trench rollers or mechanical tampers.

Construction of the control strips will be as directed by the Engineer. Compaction shall commence as soon as possible after the mixture has been spread to the desired thickness and shall continue until no appreciable increase in density can be obtained by additional rollers coverages. Densities will be determined by means of a portable nuclear testing device or approved alternate. Contractor shall furnish documentation of the growth curve to the Engineer.

To determine when no appreciable increase in density can be obtained, two test points shall be established in the control strip on a random basis and the density at each point shall be measured by a portable nuclear device after each roller passes. Rolling shall be suspended when testing shows either: a decline of more than 2% of  $G_{mm}$  or when additional roller passes fail to increase the density.

After said testing is accomplished, rolling on the remainder of that course shall be done in accordance with the pattern developed in the test strip for that roller. A separate rolling pattern and time interval shall be established for each roller.

A new control strip shall be ordered by the Engineer when:

- (a) A change in the JMF is made, or
- (b) A change in the source of material is made or a change in the material from the same source is observed.

A new control strip may be ordered by the Engineer or requested by the Contractor when:

- (a) Ten days of production have been accepted without construction of a new control strip, or

- (b) There are other reasons to believe that a control strip density is not representative of the bituminous mixture being placed.

The nuclear testing device or approved alternate shall be furnished and operated by the Contractor. The furnishing of the testing device and the operator will be considered incidental to the furnishing and placement of the bituminous mixture and shall not be compensated for separately. The device shall be calibrated according to procedures described in the Mn/DOT Bituminous Manual.

Each course shall be uniformly compacted until there is no further evidence of consolidation and all roller marks are eliminated. When this method is employed, and the quantity of mixture placed by the paver exceeds 100 metric tons (110 ton) per hour, at least two rollers are required for compacting the mixture placed by each paver.

### **C1           Rollers**

The following requirements for rollers apply only when compaction is obtained by the ordinary compaction method.

### **C2           Steel-Wheeled Rollers**

Steel-wheeled rollers shall be self-propelled and have a minimum total mass of 7.3 metric tons (8 ton), or as otherwise specified in the Contract. When vibratory rollers are used, they shall produce 45 kN per meter (3085 lbf per ft ) of width. The frequency should be at least 2400 vpm and amplitude setting low. The roller shall be capable of reversing without backlash and shall be equipped with spray attachments for moistening all rollers on both sets of wheels.

### **C3           Pneumatic-Tired Rollers**

The pneumatic-tired roller shall have a compacting width of 1.5 m or more. It shall be so constructed that the gross mass is not less than 22 kN (5,000 lbs) per wheel and can be varied as directed by the Engineer. The tire arrangement shall be such that full compaction will be obtained over the full width with each pass of the roller.

The roller may be self propelled or provided with suitable tractive equipment, unless the Contract specifies a certain type. If more than one roller is propelled by a single tractive unit, then that combination will be counted as a single roller unit.

### **C4           Trench Rollers**

The trench roller shall be self propelled and have a mass of not less than 4400 kg per meter (2960 lb per ft) of width.

### **C5           Mixture Temperature Controls**

If compaction is obtained by the ordinary compaction method, the minimum laydown

temperature in all courses (as measured behind the paver or spreading machine) of the bituminous mixture shall be in accordance with the temperature requirements of Table 2360-17.

**Table 2360-17  
Mixture Temperature Control**

Air Temperature	Compacted Mat Thickness, mm (A)			
°C      (°F)	25 mm    (1 in)	40 mm (1-1/2 in)	50 mm    (2 in)	75 mm (3 in) or greater
+0-5 (32-40)	--	129 (B)    (265)	124        (255)	121        (250)
+ 6-10 (41-50)	130 (B)    (270)	127        (260)	121        (250)	118        (245)
+ 11-15 (51-60)	127 (B)    (260)	124        (255)	118        (245)	115        (240)
+ 16-21 (61-70)	121(B)    (250)	118        (245)	115        (240)	113        (235)
+ 22-27 (71-80)	118        (245)	115        (240)	113        (235)	113        (235)
+ 28-32 (81-90)	113        (235)	110        (230)	110        (230)	110        (230)
+ 33     (91+)	110        (230)	110        (230)	110        (230)	107        (225)

(A) Based on approved or specified compacted lift thickness.

(B) A minimum of one pneumatic-tire roller shall be used for intermediate rolling unless otherwise directed by the Engineer. The Engineer may specify or modify in writing (with concurrence from the Bituminous Engineer) a minimum laydown temperature.

### **2360.6 Thickness and Surface Smoothness Requirements**

#### **A                    Thickness**

After compaction the thickness of each course shall be within a tolerance of 6 mm (1/4 in) of the thickness shown in the Plans. This thickness requirement will not apply to a leveling course. Any part of any course that is constructed to less than the minimum required thickness may be removed and replaced at the discretion of the Engineer.

On that portion of any course constructed to more than the maximum permissible thickness, the materials used in the excess mixture above that required to construct that portion of the course to the Plan thickness plus 6 mm (1/4 in) will be excluded from the pay quantities and may require removal and replacement at the discretion of the Engineer.

Cores taken for density determination shall be measured for thickness also. Each core shall be measured 3 times for thickness prior to sawing. Report the average of these three measurements. Each lot's average core thickness shall be documented and submitted to the Engineer. If the average of the two Contractor cores exceed the specified tolerance, an additional two cores may be taken in

the lot in question. The average of all core thickness measurements per course will be used to determine compliance with thickness specifications.

**B Surface Requirements**

After compaction, the finished surface of each course shall be reasonably free of open and torn sections and shall be smooth and true to the grade and cross section shown on the Plans with the following tolerances:

- (1) Where a leveling course is specified, it shall be constructed to within a tolerance of 15 mm (1/2 in) of elevations and grades established by the Engineer. This requirement shall apply to the first course placed other than leveling when automatic control is used.
- (2) The surface of the Nonwear course and wearing course shall show no variation greater than 3 mm (1/8 in) from the edge of a 3 m (10 ft) straightedge laid parallel to or at right angles to the centerline. Shoulder surfacing and surfacing on temporary connections and by-passes shall show no variations greater than 6 mm (1/4 in) from the edge of a 3 m (10 ft) straightedge laid parallel to the centerline.
- (3) The transverse slope of the surface of each course, exclusive of the shoulder wearing course, shall not vary from the slope shown in the Plans by more than 0.4 percent.
- (4) The distance between the edge of each course and the established centerline shall be no less than the Plan distance nor more than 75 mm (3 in) greater than the Plan distance. In addition, the edge alignment of the wearing course on tangent sections and on curve sections of 3 degrees or less shall not deviate from the established alignment by more than 25 mm (1 in) in any 7.5 m (25 ft) section.

Any material placed outside the above described limitations shall be removed after being cut or sawed at no expense to the Department.

**C1 General**

Pavement smoothness will be evaluated on the final mainline pavement surface. Table 2360-18 shows pavement surfaces which are excluded from profilograph testing but subject to 2360.6B surface requirements.

**Table 2360-18  
Profilograph Testing Exclusions**

Pavement Surfaces Excluded From Profilograph Testing
Ramps, Loops, Climbing Lanes

Side Streets, Side Connections
Turn Lanes, Storage Lanes, Crossovers, By-pass Lanes
Shoulders
Acceleration, Deceleration Lanes
Intersections constructed under traffic
Sections less than 15.24m (50 ft) in length
Mainline paving where the posted speed is less than or equal to 70 km/h (45 mph)
Single lift overlays over concrete.

**C1 A Smoothness Requirements**

Pavement smoothness requirements will be evaluated by Table 2360-19A, 2360-19B, or 2360-19C in accordance with the following unless otherwise modified.

**Schedule for Identification of Pavement Sections**

Construction Type	Table
New construction with minimum of 3 lifts . . . . .	2360-19 A
Overlay with a minimum of 3 lifts 40 mm (1.5") minimum lift thickness . . . . .	2360-19 A
Single lift overlays 40mm (1.5") or more in thickness that have profile milling of the original pavement. . . . .	2360-19 A
New construction with minimum 2 lifts. . . . .	2360-19 B
Construction with curb and gutter adjacent to driving lane . . . . .	2360-19 B
Single lift mill (mainline and shoulder) and fill overlays . . . . .	2360-19 B
Two- lift overlays (40mm (1.5") minimum lift thickness on an unmilled surface . . . . .	2360-19 B
Winter carry-over wearing course . . . . .	2360-19 B
New construction with 1 lift . . . . .	2360-19 C
Single lift overlays on an unmilled surface. . . . .	2360-19 C
Construction adjacent to existing pavement . . . . .	2360-19 C

**C2 Measurement**

Smoothness will be measured with a 7.62 m (25 ft) California type profilograph, which produces a profilogram (profile trace of the surface tested). One pass will be made in each lane, 2.74 m (9 ft) from centerline. Each lane will be tested and evaluated separately. The Engineer will determine the length in kilometers (miles) for each mainline traffic lane. The profilograph will be

operated at a speed no greater than a normal walk, no greater than 5 km/hr (3 mph). Motive power may be provided manually or by the use of a propulsion unit approved by the Project Engineer.

### **C3            Profilograph testing**

The Contractor will furnish a properly calibrated and documented, 7.62 m (25 ft) California type profilograph. The profilograph shall be equipped with automatic data reduction capabilities unless otherwise authorized by the Engineer. Calibration documentation shall be provided to the Project Engineer on the first day profilograph is used on the project. User selected profilograph settings are on file in the Bituminous Office. The Contractor will furnish a competent operator, trained in the operation and evaluation of the 7.62 m (25 ft) California profilograph..

All objects and foreign material on the pavement surface will be removed by the Contractor prior to testing.

The pavement surface will be divided into sections which represent continuous placement. A section will terminate 7.62m (25 ft) before a bridge approach panel, bridge surface or similar interruption. A day's work joint will be included in the trace with no special consideration. A section will be separated into segments of 0.1 km (0.1 mi) A segment will be in only one traffic lane.

A profilogram will be made for each segment of 15.24 m (50 ft) or more. The profilogram will include the 4.57 m (15 ft) at the ends of the section only when the Contractor is responsible for the adjoining surface.

End of run areas not included in the profilograph trace and any sections of pavement less than 15.24 m (50 ft) in length shall be checked longitudinally with a 3.028 m (10 ft) straight edge and the surface shall not deviate from a straight line by more than 3 mm in 3.028 m (1/8 inch in 10 ft).

The profile trace and index for each segment of pavement must be furnished to the Engineer within 48 hours after each days run. Identification of all bumps and dips, with signature of the Operator shall be included with the submitted trace.

For each day's run, an evaluation will be submitted to the Engineer within five days after pavement placement. The evaluation submitted shall include identification of segments which may qualify for less than 100 percent payment, segments that qualify for incentive payment and segments to be corrected.

The Contractor will be responsible for all traffic control associated with the smoothness testing.

Any portion of the project may be tested if the Engineer determines that the Contractor's test results are in question. If results are found to be inaccurate, the Contractor will be charged at a rate of \$155.34 per lane km (\$250 per lane mile) that is retested, with a minimum charge of \$500.00. If the results are found to be accurate, the Department will be pay the Contractor at a rate of \$155.34 per lane km (\$250 per lane mile) that is retested, with a minimum charge of \$500.00.

#### **C4 Profile Index**

The profilograph trace will be evaluated by the Contractor for the profile index (PI) in accordance with California Method 526 on file with the Bituminous Engineer. The original trace shall be provided to the Engineer for verification of the Contractor's evaluation.

A profile index shall be calculated for each segment. The index will be determined by summing the vertical deviations outside a 5 mm (0.2 in) blanking band. The units of this index are mm per km (inch per mile). When there is a segment of 76.2 m (250 ft) or less in length, the profilograph measurements for that segment shall be added to and included in the evaluation of the adjacent section to that segment.

Bumps and dips exceeding 10.2 mm in a 7.62 m (0.4 inch in a 25 ft) span shall be identified separately.

#### **C5 Surface Correction**

All areas represented by deviations of 28 mm (1.1 in) or more, as measured by the 7.62 m (25 ft) profilograph, will be corrected by the Contractor.

The Contractor may elect to correct dips or bumps of 10.2 to 25 mm (0.4 to 1.0 in) in a 7.62 m (25 ft) span. The Contractor will be assessed a penalty for dips or bumps of 10.2 to 25 mm (0.4 to 1.0 in) that are not corrected. Bumps and dips not corrected will also be included in the evaluation for the segment smoothness. Corrected dips or bumps will be considered satisfactory when the profilogram shows the dips or bumps are less than 10.2 mm in a 7.62 m (0.4 inch in a 25 ft) span.

Bump, dip, and smoothness correction work shall be for the entire traffic lane width. Pavement cross slope shall be maintained through corrective areas.

All corrective work shall be made by diamond grinding or approved equivalent, overlaying the area, or by replacing the area. The Contractor shall notify the Engineer prior to commencement of the corrective action. If the surface is corrected by grinding, all ground areas shall be treated with an emulsified asphalt fog seal conforming to Specification 2355. If the surface is corrected by overlay or replacement, the surface correction shall begin and end with a transverse saw cut.

The entire length of the correction, including the beginning and end joints, shall be re-evaluated with the profilograph as herein provided. Corrective work and re-evaluation will be at the Contractor's expense.

#### **C6 Payment**

The cost of certified smoothness testing and associated traffic control will be incidental to the cost of the Wear Course Mixture.

The Contractor may receive an incentive payment or be assessed a penalty based on the number of segments and the initial profile index. The total ride incentive shall not exceed 15% of the total mix price. Pay adjustments for incentives will only be based on the initial Profile Index before any corrective work has been performed. Pavement that contains corrective action for profile or bumps is not eligible for incentive pay. These payments or assessments will be based on the following schedules.

For each traffic lane, a \$900 penalty will be assessed for each bump or dip of 10.2 to 25 mm (0.4 to 1.0 in) that is not corrected.

The Engineer may, at his discretion, assess a penalty of \$560/0.1 km (\$900 per 0.1 mile) segment in lieu of requiring the Contractor to take corrective action when the profile index indicates corrective action is necessary.

**Table 2360-19 A**  
**Initial Profile Index <sup>(1)</sup>**

<b>mm per km per 0.1 km segment</b>	<b>(Inches per mile) (per 0.1 mile segment)</b>	<b>Dollars per Segment (Metric)</b>	<b>Dollars per Segment (English)</b>
0- 13.4	(0.0 - 0.8)	190	300
13.5 - 25.3	(0.9 - 1.6)	130	200
25.4 - 38.7	(1.7 - 2.4)	70	100
38.8 - 78.9	(2.5 - 5.0)	0	0
79.0 - 92.3	(5.1 - 5.8)	(70)	(100)
92.4 - 105.7	(5.9 - 6.7)	(130)	(200)
105.8 - 118.3	(6.8 - 7.5)	(190)	(300)
Over 118.3	Over 7.5	Corrective Action	Corrective Action

(1) If all segments of pavement qualify for 100 percent payment with no grinding, the qualifying incentive payment will be increased by \$25 per metric segment and \$40 per English segment.

**Table 2360-19 B**  
**Initial Profile Index <sup>(1)</sup>**

<b>mm per km per 0.1 km segment</b>	<b>(Inches per mile) (per 0.1 mile segment)</b>	<b>Dollars per Segment (Metric)</b>	<b>Dollars per Segment (English)</b>
0 - 15.8	(0.0 - 1.0)	190	300
15.9 - 31.6	(1.1 - 2.0)	130	200

31.7 - 47.3	(2.1 - 3.0)	70	100
47.4 - 110.5	(3.1 - 7.0)	0	0
110.6 - 126.3	(7.1 - 8.0)	(70)	(100)
126.4 - 142.0	(8.1 - 9.0)	(130)	(200)
142.1 - 157.8	(9.1- 10.0)	(190)	(300)
Over 157.8	Over 10.0	Corrective Action	Corrective Action

- (1) If all segments of pavement qualify for 100 percent payment with no grinding, the qualifying incentive payment will be increased by \$25 per metric segment and \$40 per English segment.

**Table 2360-19C**  
**Initial Profile Index <sup>(1)</sup>**

mm per km per 0.1 km segment	(Inches per mile) (per 0.1 mile segment)	Dollars per Segment (Metric)	Dollars per Segment (English)
0 - 31.6	(0.0 - 2.0)	190	300
31.7 - 63.2	(2.1 - 4.0)	130	200
63.3 - 94.8	(4.1 - 6.0)	70	100
94.9 - 189.6	(6.1 - 12.0)	0	0
189.7 - 221.2	(12.1 - 14.0)	(70)	(100)
221.3 - 252.8	(14.1 - 16.0)	(130)	(200)
252.9 - 284.4	(16.1- 18.0)	(190)	(300)
Over 284.4	Over 18.0	Corrective Action	Corrective Action

- (1) If all segments of pavement qualify for 100 percent payment with no grinding, the qualifying incentive payment will be increased by \$25 per metric segment and \$40 per English segment.

## **2360.7 METHOD OF MEASUREMENT**

### **A Bituminous Mixture**

Bituminous mixture of each type will be measured separately by mass, based on the total quantity of material hauled from the mixing plant, with no deductions being made for the bituminous materials.

**B Irregular Width Paving**

Irregular width paving, as classified in the Contract, will be measured by area on the basis of actual surface dimensions placed, without regard to the mixture designation or the number of courses placed on each area.

**C Bituminous Mixtures Measured by the Square Meter per Specified (mm) Thickness**

Bituminous mixture of each type and for each specific course will be measured separately by area and by thickness on the basis of actual final dimensions placed.

**2360.8 COMPENSATION**

**A Basis of Payment:**

Payment for the accepted quantities of HMA mixture used in course at the Contract prices per unit of material will be compensation in full for all costs of constructing the HMA surfacing as specified, including the costs of furnishing and incorporating any aggregate, asphalt binder, mineral filler, hydrated lime, or anti-stripping additives that may be permitted or required.

If the Gyratory density at the recommended or established asphalt content is in excess of 2,565 kg/m<sup>3</sup> (160 lb/ft<sup>3</sup>), payment for mixture will be calculated at the following percent of the contracted unit price.

$$\begin{aligned} \% \text{ Payment} &= \{ 100 - [\{ 100 \times (\text{Gyratory Density} - 2565) \} / 2565] \} \\ \{ \% \text{ Payment} &= 100 - [\{ 100 \times (\text{Gyratory Density} - 160) \} / 160] \}_{\text{ENGLISH}} \end{aligned}$$

In the absence of appropriate Contract items covering shoulder surfacing and other special construction, the accepted quantities of material used for these purposes will be included for payment with the wearing course materials.

Payment for irregular width paving at the Contract unit price of pavement surface area will be compensation in full for the costs of irregular width placement, regardless of mixture designation or the number of courses placed on each area so classified.

Payment for the plant mixed HMA surface will be made on the basis of the following schedule:

<u>Item No.</u>	<u>Item</u>	<u>Unit</u>
2360.604	Type SP __. __ Course Mixture ( __, __ ) __ mm thick . . . . .	square meter

- 2360.607 Type SP \_\_. \_\_ Course Mixture ( \_\_, \_\_ ) thickness . . . . . square yard inch
- 2360.609 Type SP \_\_. \_\_ Bituminous Mixture Production . . . . . metric ton (ton)
- 2360.609 Type SP \_\_. \_\_ Bituminous Mixture for Specified Purpose . . . . . metric ton (ton)
- 2360.609 Type SP \_\_. \_\_ Wearing Course Mixture ( \_\_, \_\_ ) . . . . . metric ton (ton)
- 2360.609 Type SP \_\_. \_\_ Non Wearing Course Mixture ( \_\_, \_\_ ) . . . . . metric ton (ton)