

2350

Plant Mixed Asphalt Pavement

Rev 11/29/99 for the 2000 Construction Season

Sections 2331 and 2340 of the Standard Specifications are deleted and replaced with the following;

2350.1 DESCRIPTION

This work consists of the construction of one or more pavement courses of 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.

2350.2 MATERIALS

A Aggregate

A1 General Requirements

The aggregate blend used in the work shall conform to the requirements of Section 3139, as revised following this provision, for the particular material specified, except as hereinafter otherwise or additionally stipulated. Class B carbonate aggregate shall be limited in 2350 mixtures as follows:

**Table 2350-A1
Aggregate Restriction**

Mixture Type	Maximum % - 4.75 mm (-#4)		Maximum % + 4.75 mm (+#4)	
	Wear	Nonwear	Wear	Nonwear
LV, MV	100	100	100	100
HV	80	80	50	100
HV > 10 million ESAL's	50	80	0	100

A2 Aggregate Gradation for Asphalt Mixtures

The combined aggregates, including mineral filler when required, shall conform to the following gradation requirements.

**Table 2350-1
Broad Band Aggregate Gradation for Asphalt Mixtures
(% passing of total washed gradation)**

Sieve Size mm (in)	1	2	3	4	5*
37.5(1 1/2")	100	-	-	-	-
25.0 (1")	90-100	100	-	-	-
19.0 (3/4")	55-90	90-100	100	-	-
12.5 (1/2")	-	45-90	90-100	100	-
9.5 (3/8")	-	-	35-90	90-100	100
4.75 (#4)	15-70	20-75	20-80	25-85	65-95
2.36 (#8)	10-55	15-60	15-65	20-70	45-80
0.075 (#200)	2-7	2-7	2-7	2-7	2-7

* Gradation 5 is intended for thin lift leveling.

B Additives

An additive is any material added to an 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 Department Bituminous Engineer. Anti-foaming agents 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

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 2350.2F. 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 Recycled Asphaltic Pavement Materials (RAP)

The Contractor may use up to 30 percent recycled asphaltic pavement (RAP) in all wearing layers and High Volume (HV) non-wear layers. Medium Volume (MV) mixtures may contain a maximum of 30% RAP in the non-wear layers above 90 mm (3.5") and a maximum of 40% RAP in layers 90 mm (3.5") and greater in depth from the surface. Low Volume (LV) mixtures may contain a maximum of 40% RAP in the non-wear layers. The combined RAP and virgin aggregate shall meet the composite fine aggregate angularity or crushed requirements (both coarse and fine aggregate) for the mixture being produced. The RAP sand will be considered 50 percent crushed if the Angularity Index, according to ASTM C1252 Method A, equals or exceeds 40, and 100 percent crushed if the Angularity Index equals or exceeds 45.

RAP containing any objectionable material, i.e., road tar, metal, glass, wood, plastic, brick, fabric, or any other objectionable material having similar characteristics will not be permitted for use in the asphalt pavement mixture.

Asphalt binder content in the RAP shall be determined according to Mn/DOT Lab Manual Method 1851 or 1852.

C1 Asphalt Binder Selection Criteria for All Mixtures with RAP

The following summarizes the criteria for adjusting the asphalt binder grade when RAP is included in an HMA mixture.

	#20% RAP	>20% RAP
Overlay	No grade adjustment required	No grade adjustment required
New Construction	No grade adjustment required	See Table below

New Construction >20% RAP

Specified Asphalt Binder Grade	New Asphalt Binder Grade used with RAP
PG 64-34	> 20% RAP Not Allowed
PG 58-34	PG 52-34
PG 64-28	PG 64-28
PG 58-28	PG 52-34
PG 52-34	PG 52-34
All other grades	Contact Department Bituminous Engineer

The binder grade can also be selected by using the appropriate blending chart approved by the Bituminous Office if the mix designer chooses to adjust the binder selection to compensate for the stiffness of the reclaimed asphalt binder.

D Crushed Concrete and Salvaged Aggregate

Crushed concrete is allowed as an aggregate source for up to 50 percent of the aggregate in non wear mixtures. Crushed concrete is not allowed in wearing courses.

Salvaged aggregate is allowed as an aggregate source for up to 100 percent of the aggregate in wearing and non-wearing mixtures. All salvaged aggregate shall be stockpiled uniformly to limit variation in mixture properties. Salvaged aggregates shall meet quality and crushing requirements as specified herein.

E Scrap Shingles

Scrap shingles, as an asphalt binder source, may be included in both wear and non-wear courses to a maximum of 5 percent of the total weight of mixture when approved by the Engineer. Only scrap shingles from manufacturing waste are suitable. The percentage of scrap shingles used will be considered part of the maximum allowable RAP percentage. Scrap Shingle Specifications are on file in the Bituminous Office.

F 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.99-13-MRR-05 and AASHTO MP-1. The PG asphalt binder cannot be modified with air blowing procedures unless it is approved by the Bituminous Office. The Contractor shall not use petroleum distillates such as fuel oil, diesel fuel or other fuels in the asphalt tanks.

G Asphalt Mixture Requirements

**Table 2350-2
Mixture Requirements**

Mixture Property	High Volume HV	Medium Volume MV	Low Volume LV
20 year Design ESAL's	> 3 million	1 - 3 million	< 1 million
Marshall Blows	75	50	50
Stability, minimum N (lb f)	6000 (1350)	6000 (1350)	5000 (1125)
Air Voids, %	4.0	3.5	3.0
Fines/Asphalt _{effective} Ratio Wear:	0.6 - 1.30	0.6 - 1.30	0.6 - 1.30
Fines/Asphalt _{effective} Ratio Non-wear:	0.6 - 1.40	0.6 - 1.40	0.6 - 1.40
Tensile Strength Ratio ⁽¹⁾ , min %	70	70	70
Coarse Aggregate One Faced %:	85	55	-
Angularity (CAA) Two Faced %:	60	-	-
Fine Aggregate Angularity (FAA) ⁽²⁾	44.0	40.0	-
Manufactured Crushed fines, % ⁽²⁾	75	25	-
Max. allowable RAP percentage, Wear	30	30	30
Max. allowable RAP percentage, Non-wear	30	30 , 40 ⁽³⁾	40

- (1) Moisture susceptibility (TSR) test specimen shall be 100 mm (4 in)
- (2) Either method may be used, however the choice must be made prior to start of production.
- (3) MV may contain 40 % RAP below 90 mm (3.5 in.) from the surface.

Shoulder mixture placed in a separate paving operation shall be designed for 3.0 percent air voids.

**Table 2350-3
Voids in Mineral Aggregate (VMA) Mixture Requirements**

Gradation	Fine Mixture % pass 4.75 mm (#4)	VMA Minimum	Coarse Mixture % pass 4.75 mm (#4)	VMA Minimum
1	> 35	13.5	≤ 35	13.0
2	> 40	14.0	≤ 40	13.5
3	> 45	15.0	≤ 45	14.5
4	> 50	16.0*	≤ 50	15.5*
5	> 65	16.0*	-----	-----

*For LV 4 & LV 5 mixes lower VMA requirements by 0.5%.

2350.3 MIXTURE DESIGN

A Mixture Design General

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

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 the specification requirements shown in tables 2350-1, 2 & 3.

B Laboratory Mixture Design (Option 1)

Test results and documentation as described in section 2350.3D 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 Department Bituminous Engineer or the District Materials Engineer a 35 kg (80 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 quality of 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 (as defined in 3139) shall be submitted to the Department 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 Department 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 properties as specified in Table 2350-2 and 2350-3. The proposed JMF shall be submitted on forms approved by the Department. In addition, the Contractor shall submit a 15 kg (35 lb) uncompacted sample plus three Marshall briquettes compacted at the optimum asphalt content and Marshall design blows conforming to the JMF for laboratory examination and evaluation.

B3 Tensile Strength Ratio sample

Mixture or Marshall 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 2350.3D. One of the following options may be used to verify that the tensile strength ratio (TSR) meets the requirements in Table 2350-2.

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 Materials Laboratory 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 a minimum of 6 Marshall specimens at the required 6-8% void content and 8200 grams of uncompacted mixture.

C Produced Mixture Design (Option 2)

Test results and documentation as described in section 2350.3D 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 Department Bituminous Engineer or the District Materials Engineer a 35 kg (80 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 quality of 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 Department Bituminous Engineer or District Materials Engineer at least 30 calendar days prior to the start of asphalt production.

C2 Mixture Sample

At least 5 working days prior to supplying mixture to a Department project, the Contractor shall provide the Department 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 2350.5C3a, representing the most recent Quality Management certified production of the mixture for review and approval. The Contractor shall supply sufficient material or Marshall 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 Table 2350-1, Table 2350-2, and Table 2350-3 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 2350-4.

D Documentation

Each proposed JMF submitted under 2350.3B and 2350.3C 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 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.
- (4) The proportion of each material (in percent of total aggregate).
- (5) The composite gradation based on (3) and (4) above. Note: Include virgin composite gradation based on (3) and (4) above for mixtures containing RAP.

- (6) The test results from the composite aggregate blend at the proposed JMF proportions indicating compliance with fine aggregate angularity uncompacted voids as shown in Table 2350-2. Or calculated - 4.75 mm (-#4) crushing from the composite blend of the proposed JMF. Selection of either FAA or - 4.75 mm (#4) crushing shall be made at the time of mix design submittal. This selection will dictate the choice of method used for determination of compliance and acceptance for the duration of time the Department approved Mixture Recommendation is in force.
- (7) 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.
- (8) The composite gradation plotted on a FHWA 0.45 power chart. (Federal form PR-1115)
- (9) For mixtures containing RAP include extracted asphalt content of the RAP with no retention factor included.
- (10) The percentage (in units of 0.1 percent) of asphalt binder material to be added, based upon the total mass of the mixture.
- (11) When using mixture design option 1, include the following:
- (a) A mix design with a minimum of three different asphalt contents (minimum 0.4 percent between each point), with at least one point at, one above and one below the optimum asphalt 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 content.
 - (c) The Marshall 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 bitumen content.
 - (e) The percent Voids in Mineral Aggregate (VMA) at each bitumen content.
 - (f) The fines to Effective Asphalt (F/A) ratio calculated to the nearest 0.1 percent.
- (12) The results of Tensile Strength Ratio (TSR) tests, conducted according to ASTM D4867 as modified by Mn/DOT

E 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 for small quantities of material provided under 2350.4H. 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 District 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 Department Bituminous Engineer. Test tolerances are described in section 2350.5D.

2350.4 CONSTRUCTION REQUIREMENTS

A General

The following construction requirements provide for the construction of all courses. When construction is under traffic, the requirements of the Standard Specifications 2221.3D will apply.

B Restrictions

In general, no work within the roadway will be permitted in the spring until seasonal load restrictions on roads in the vicinity have been removed. However, work within the roadbed may be permitted before that time if, in the opinion of the Engineer, it can be done without damage to the subgrade. HMA shall not be placed when, in the opinion of the Engineer, the weather or road bed conditions are unfavorable.

No asphalt pavement wearing course shall be placed after October 15th in that part of the state north of an east-west line between Browns Valley and Holyoke, nor after November 1st south of that line. The Engineer may waive these restrictions when:

- (1) The asphalt mixture is not being placed on the traveled portion of the roadway, or

- (2) The roadway involved will not be open to traffic during the following winter, or
- (3) The Engineer directs in writing the mixture be placed

The Contractor shall not use petroleum distillates such as kerosene and fuel oil to prevent adhesion of asphalt mixtures in pavement hoppers, truck beds, or on the contact surfaces of the compaction equipment. Anti-adhesive agent must meet the criteria for "Effect on Asphalt" as described on page 2.2 and shall be used in accordance with the information on pages 1.7 and 1.8 of the Asphalt Release Agent Report Feb. 1996, on file in Mn/DOT's Office of Environmental Services and the Bituminous Office.

C Equipment

C1 Asphalt Mixing Plants

C1a Requirement for All Plants

The Contractor shall test and calibrate all scales according to Mn/DOT Standard Specifications section 1901, except as otherwise designated by the contract.

C1a(1) Equipment for the Preparation of the Aggregate

Add mineral filler to the mixture using a storage silo equipped with a device to ensure a constant and uniform feed.

C1a(2) Equipment for the Preparation of Asphalt Material

Tanks for storage of asphalt material at the plant shall be equipped to heat the material and maintain the material at the required temperatures. The discharge end of the circulating line shall be below the surface of the asphalt material. Provide agitation for modified asphalt, when used, if recommended by the supplier.

An outage table or chart and measuring stick shall be provided for each storage or working tank. Tanks shall be equipped with provisions for taking of asphalt binder material samples. After delivery of asphalt binder material to the Project, the Contractor shall not heat the material above 175°C (350 °F). For modified asphalt, the maximum storage temperature shall not exceed the recommendation of the asphalt supplier.

C1a(3) Asphalt Binder Control

When asphalt binder material is proportioned by volume, the plant shall be equipped with either a working tank or a metering system for determining bitumen content of the mixture.

The working tank shall have a capacity between 3800 L (1000 gal) and 7600 L (2000 gal). The working tank shall be calibrated and supplied with a calibrated measuring stick. The tank may be connected to a mixing unit and used only during spot check operations, but it shall be available at all times.

Any feedback shall be returned to the working tank during spot check operations.

The metering system shall consist of at least one approved bitumen flow meter in addition to the bitumen pump. The flow meter shall be connected to the bitumen supply to measure and display only the bitumen being fed to the mixer unit. The meter readout shall be positioned for convenient observation. Means shall be provided for comparing the flow meter readout with the calculated output of the bitumen pump. In addition, the system shall display in liters (gal) or to the nearest 0.001 metric ton (t) (0.0011 ton), the accumulated bitumen quantity being delivered to the mixer unit. The system shall be calibrated and adjusted to maintain an accuracy of \pm one percent error. This calibration shall be required for each plant set-up prior to production of mixture.

C1a(4) Dryer: The aggregate shall be free of unburned fuel.

C1a(5) Thermometric Equipment:

The plant shall be equipped with a sufficient number of thermometric instruments to ensure temperature control of the aggregate and the asphalt binder material.

C1a(6) Pollution Controls

C1a(6)(a) Pollution 1717

C1a(7) Surge and Storage Bins

The plant may include facilities to store hot asphalt mixture for coordinating the rate of production with the paving operations. Storage of the hot mixture will be permitted for a period not to exceed 18 hours, provided the following requirements are met:

- (a) Hot mix storage facilities shall be designed and operated to prevent segregation of the mix, drainage of the asphalt from the mix, and to prevent excessive cooling or overheating of the mixture.
- (b) The temperature of the mixture at time of discharge from the storage facility shall be within a tolerance of 5°C (9 °F) of the temperature when discharged from the silo or mixer.

C2 Placement and Hauling Equipment

All equipment shall be serviced away from the paving site to prevent contamination of the mixture. Units that drip fuel, oil, or grease shall be removed from the paved surface until such leakage is corrected.

C2a Asphalt Pavers

Asphalt pavers shall be self-contained, power-propelled units, with an operational vibratory screed, capable of spreading and finishing courses of asphalt plant mix material in widths applicable to the specified

typical sections and thicknesses, indicated in the Contract.

The screed or strike-off assembly shall produce a finished surface of the required evenness and texture without tearing, shoving, or gouging. For mainline paving, screed extensions and auger extensions are required if the paving width on either side of the paver is greater than the basic screed unless otherwise directed by the Engineer. Strike-off only extension assemblies are not allowed for mainline wearing course paving, unless directed by the Engineer.

Automatic screed control by means of an erected string line, shall only be required when stated in the Contract.

All pavers shall be equipped with an approved automatic screed control. The automatic controls shall include a system of sensor-operated devices which follow reference lines or surfaces on one or both sides of the paver as required. The speed of the paver shall be adjusted to produce the best results.

All mixtures shall be spread without segregation to the cross sections shown in the plans. In general, leveling layers shall be spread by the method producing the best results as approved by the Engineer. The objective is to secure a smooth base of uniform grade and cross section so that subsequent courses will be uniform in thickness. The leveling layer may be spread with a properly equipped paver or with a motor grader equipped with a leveling device, or with other means for controlling the surface elevation of the leveling layer.

All mixtures shall be spread, to the fullest extent practicable, by an asphalt paver. Mixtures may be spread by a motor grader only on areas that are inaccessible to a paver or on driveway entrances and on irregular areas where the quantity of mixture makes it impractical to place with a paver.

On shoulder surfacing and uniform width widening, when the placement width is too narrow for a paver, the mixture in each course shall be spread with an approved mechanical device.

The placement of each course shall be completed over the full width of the section under construction on each day's run unless otherwise directed by the Engineer.

C2b Trucks

Trucks for hauling asphalt mixtures shall have tight, clean, and smooth beds. Mixture shall not be allowed to adhere to the truck beds. Adherence may be prevented by spraying the truck bed with an anti-adhesive agent in accordance with Section 2350.4B. Each truck shall be equipped with a cover of canvas or other suitable material to protect the mixture from weather. The cover shall extend at least 300 mm (1 ft) over the sides and be attached to tie-downs unless the truck is furnished with a mechanical or automated covering system which prevents air flow underneath by stretching the cover tightly on the top of or inside the sideboards. The cover shall be used when directed by the Engineer.

C2c Motor Graders

Motor graders shall be self-propelled and have pneumatic-tires with a tread depth of 13 mm (1/2 in)

or less. They shall be equipped with a blade not less than 3 m (10 ft) in length and shall have a wheel base of not less than 4.5 m (15 ft).

D Treatment of the Surface

D1 Tack Coat

An asphalt tack coat shall be applied to existing asphalt and concrete surfaces, and to the surface of each course or lift constructed, except for the final course or lift, according to Mn/DOT Standard Specification 2357.

The contact surfaces of all fixed structures and the edge of the in-place mixture in all courses at transverse joints and longitudinal joints shall be given a uniform but not excessive coating of liquid asphalt or emulsified asphalt before placing the adjoining mixture.

E Compaction Operations

After being spread, each course shall be compacted to the required density. The rollers shall, as practicable, be operated continuously so all areas are thoroughly compacted to the required density. When not operating, the rollers shall not stand on the uncompacted mixture or newly rolled pavement having a surface temperature exceeding 60 °C (140 °F). Rolling with steel-wheeled rollers shall be discontinued if it produces excessive crushing or pulverizing of the aggregate or displacement of the mixture.

To prevent adhesion of the mixture to the steel roller wheels, the contact surfaces of the wheels shall be kept properly moistened using water or a water solution containing small quantities of a detergent or other approved material.

To secure a true surface, variations such as depressions or high areas, which may develop during rolling operations, and lean, fat or segregated areas shall be corrected by removing and replacing the material in the defective area. All such corrections shall be accomplished as directed by the Engineer at no expense to the Department.

When mixtures are spread by a motor grader, pneumatic-tired rollers shall compact the mixture simultaneously with the spreading operation.

F Construction Joints

Joints shall be thoroughly compacted to produce a neat, tightly bonded joint that meets surface tolerances. Both transverse and longitudinal joints are subject to specified density requirements. Randomly selected core locations may fall on the joint, in these instances, cores shall be taken tangent to the joint.

F1 Transverse Joints

A transverse joint (full paver width at right angles to the centerline) shall be constructed when mixture placement operations are suspended. The forward end of the freshly laid strip shall be thoroughly compacted by rolling before the mixture has cooled. When work is resumed, the end shall be cut vertically for the full depth of the layer unless a formed edge is constructed as approved by the Engineer.

F2 Longitudinal Joints

Longitudinal joints between strips shall be parallel to the centerline. In multiple lift construction, the longitudinal joints between strips in each lift shall be constructed not less than 150 mm (6 in) measured transversely from the longitudinal joints in the previously placed lift. When the wearing course is constructed in an even number of strips, one longitudinal joint shall be on the centerline of the road. When it is constructed in an odd number of strips, the centerline of one strip shall be on the centerline of the road, provided that no joint is located in the wheel path area of a traffic lane.

Longitudinal joints in multiple lift construction over portland cement concrete pavements may be aligned directly over the concrete pavement longitudinal joints at the discretion of the Engineer.

At longitudinal joints formed by placing multiple strips, the adjoining surface being laid shall, after final compacting, be slightly higher (but not to exceed 3 mm (1/8 in)) than the previously placed strip. When constructing a strip adjoining a previously placed strip or a concrete pavement, any fresh mixture that overlaps a previously placed strip or pavement shall be removed (to the longitudinal joint line) before any rolling is done.

After final compaction, all asphalt wearing course surfaces adjacent to concrete pavements shall be flush with the concrete surface, within a tolerance of 3 mm (1/8 in).

After final compaction, all asphalt surfaces adjacent to gutters, manholes, pavement headers, or other fixed structures shall be slightly higher (but not to exceed 6 mm (1/4 in)) than the surface of the structure.

G Asphalt Mixture Production
(FOB Department Trucks)

For asphalt mixture production, the Contractor shall, in addition to the asphalt mixture required on the Project, produce and deliver asphalt mixture to the Department. The mixture shall be the mixture being produced and shall be loaded on Department furnished trucks at the mixing plant at a time agreed on by the Engineer and Contractor. The Engineer will notify the Contractor of the total quantity of mixture desired not less than 2 weeks prior to completion of the wearing course construction. The Engineer will not accept the asphalt mixture if it is inappropriate for the Department's intended use.

H Asphalt Mixtures Measured by the Square Meter per Specified (mm) Thickness

For asphalt mixture measured by the square meter per specified (mm) (square yd per in) thickness, the Contractor shall certify in writing that the asphalt mixture delivered to the Project meets the appropriate requirements. An approved bituminous paving recommendation is not required for total project quantities less than 215,000 m² mm (10,120 yd² inches) or 500 metric tons (550 tons) of HMA, however, the mixture shall meet the requirements of Table 2350-2 and Table 2350-3. The Department will obtain samples, as determined by the Engineer, to verify percent design air voids, compliance with VMA, and gradation requirements of Table 2350-1. These results will also be used for material acceptance.

2350.5 MIXTURE QUALITY MANAGEMENT (CONSTRUCTION)

A Quality Control (QC)

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 hot mix asphalt (HMA) pavement which meets the requirements of the specifications.

A1 Contractor Certified Plant Asphalt Mixtures

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 Asphalt Plant Authorized Agent agrees to calibrate and maintain all plant and laboratory equipment within allowable tolerances set forth in these specifications and the Mn/DOT 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 2350 asphalt mixtures must be sampled and tested in accordance with 2350 requirements. When mixtures are supplied to projects not specifying 2350 requirements for more than 3 working days the supplier shall either:

- (1) Begin testing at least 2 days before producing 2350 Asphalt mixtures for a project with 2350 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 Department 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 Department Bituminous Engineer and Department 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 sampling and testing.
- (2) Observing sampling and tests performed by the QC personnel.
- (3) Monitoring the required QC summary sheets and control charts.
- (4) Taking additional samples at any time and any location during production.
- (5) Verification of calibrations of laboratory testing equipment.
- (6) Communicating Mn/DOT test results to the Contractors's QC personnel in a timely manner.

C Contractor's Quality Control

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 as approved by the Engineer. The laboratory shall be furnished with the necessary equipment and supplies for performing Contractor quality control testing in accordance with section 5-693.400 in the Mn/DOT Bituminous Manual and these specifications and the latest version of the Mn/DOT Bituminous Manual.

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 Mn/DOT 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.

C3 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 Bituminous Office. The Contractor shall obtain a sample of at least 25 kg (55 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

Marshall samples and companion samples for the Department for a period of 7 working 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, as shown in C3a, 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 ton). However, when mix production is less than 100 metric tons (110 ton) per day on successive days, the test will be run when the accumulative tonnage on such days exceeds 100 metric tons (110 ton). At the start of production, double the testing frequency for the first two tests for Marshall Bulk Specific Gravity and Maximum Specific Gravity, conduct four tests.

For informational purposes only:

On the first day of production, at the time the verification sample is obtained, an additional sample will be collected for hot-cold comparison of mixture properties. Hot-cold comparison testing shall be performed at the rate of one per project or one per stationary plant per year unless otherwise directed by the Engineer.

The hot-cold comparison sample will be split into three representative portions. The Engineer will observe the Contractor testing the sample. One part shall be compacted immediately while still hot (additional heating maybe required to raise the temperature of the sample to compaction temperature). The second part will be allowed to cool to ambient air temperature and then be heated to compaction temperature and compacted. The third part will be allowed to cool to ambient air temperature and then be transported to the District Materials Laboratory where it will be heated to compaction temperature and compacted. From this information a calibration factor will be developed to compare the specific gravity of the hot compacted samples to reheated compacted samples. Each test will involve a minimum of three Marshall specimens. This test may be repeated at the discretion of the Contractor or the Department.

Note: Care must be taken when reheating samples for mixture properties analysis tests. Mix samples should be reheated to 70(160EF) to allow splitting of the sample into representative fractions for the various tests. Overheating of the mixture portions to be tested for maximum specific gravity (Rice Test) may result in additional asphalt being absorbed in the aggregate.

C3a Production Tests

When more than one Mn/DOT approved test procedure is available, the Contractor shall select one method at the beginning of the Project (when material is submitted for Mix Design Verification) and use that method for the entire project. The Contractor and Engineer may agree to change test procedures during the construction of the project.

C3a(1) Asphalt Binder Content, percent

- (a) Meter Method (Virgin only) Mn/DOT Bituminous Manual
- (b) Incinerator Oven ⁽¹⁾ Mn/DOT Bituminous Manual Method 1853
- (c) Extraction Mn/DOT Laboratory Manual Method 1851 or 1852
- (d) Spot Check (Virgin only) Mn/DOT Bituminous Manual 5-693.848

(1) 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 and approved by the District Materials Engineer.

C3a(2) Marshall Bulk Specific Gravity, G_{mb} (3 specimens) .. AASHTO T166, Mn/DOT Mod**C3a(3) Maximum Specific Gravity, G_{mm} AASHTO T209, Mn/DOT Modified****C3a(4) Production Air Voids (individual and isolated) (calculation) . . . Asphalt Institute MS 2**

Isolated air voids are calculated using the maximum gravity and the corresponding bulk specific gravity from a single test. Individual air voids are calculated using the moving average maximum specific gravity and the bulk specific gravity from that single test.

C3a(5) Voids Mineral Aggregate (VMA) (calculation) Asphalt Institute MS 2**C3a(6) Gradation - Blended Aggregate AASHTO T-11 & T-27**

(all gradations require a - 0.075 mm(#200) wash)

(a) Virgin Aggregate Mixtures - Drum or Screen less Plants
Belt Samples or extracted production samples.

(b) All Other Mixtures:

1. Field Extraction Mn/DOT Laboratory Manual Method 1854
2. Hot Bins - Drybatch (Optional)
3. Incinerator Oven Mn/DOT Laboratory Manual Method 1853 (Optional) except samples that contain over 50% class B.⁽¹⁾
4. Extraction Mn/DOT Laboratory Manual Method 1851 or 1852 (Optional)

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

Testing to determine the blended aggregate gradation shall be determined every 2000 metric tons (2,200 ton), or portion thereof (minimum of one per day), on samples taken at the same time as the required mixture sample for a given increment.

C3b Coarse and Fine Aggregate Crushing

The percentage of crushing of aggregate blends less than 100 percent crushed shall be tested using the methods shown below 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 crushing requirement.
- (2) If CAA crushing test results exceed 8 percent of the requirement, take one sample per day and perform one test per week.
- (3) If FAA test results exceed 5 percent of the requirement, take one sample per day and perform one test per week.

Crushing counts must be reported on the test summary sheet. Adjustments in target values from the composite blend must be made at the end of each days paving. If the target quantity (percent of - 4 to be crushed) changes due to mixture proportion or composite gradation change, a new target shall be established for the next days paving. Failure to meet requirements shown in Table 2350-2 will result in a reduced payment as shown in Table 2350-5. 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.

- C3b1 Coarse Aggregate Angularity ASTM D5821**
- C3b2 Fine Aggregate Angularity ASTM C1252 Method A**
- C3b3 - 4.75 mm (#4) Manufactured Crushed Fines (Calculation) Mn/DOT Bituminous Manual**
- C3c Field Tensile Strength Ratio (TSR) ASTM D4867 Mn/DOT Modified**

Asphalt mixture samples shall be taken at a rate of 1 per 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 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 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. Specimen size shall be 100 mm (4 in.).

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

1. Any individual aggregate stockpile component gradation that deviates more than 10 percent from the original gradation submitted at design as shown in 2350.3. This deviation may be determined from stockpile or extracted gradations conducted by the Contractor or the Engineer.
2. Decision of the Engineer.

If the TSR result fails to meet the minimum specified value as shown in Table 2350-2, the Contractor shall be notified immediately by the Department. Action by the Contractor 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.

C3d 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) mixture produced. These samples shall be taken at random as directed by the 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 Engineer.

These samples may be tested and if the results deviate beyond the tolerance specified in Table 2350-6, 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.

C3e 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 Bituminous Office. Sampling shall be conducted by Contractor and monitored by the Inspector, on the first day of production of each course and then at the discretion of the Engineer. Sampling and testing is suggested when rain on stockpiles exceed more than 5 mm (0.2 in.) in a 24 hour period. The sample shall be stored in an airtight container. Microwave testing is prohibited.

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. A preventative measure could include covering stockpiles.

C3f Asphalt Binder Samples

The Contractor shall sample the first shipment of each type of asphalt binder, then sample at a rate of one per 1,000,000 liters (250,000 gallons), sample size shall be 1.0 L(1 Quart). All samples shall be taken in accordance with the Mn/DOT 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.

C4 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 to other sites as requested by the Engineer, by 11 AM 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 2350-1.
 2. Coarse and fine aggregate crushing.
 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).
 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 Engineer on a daily basis.
- (3) Provide the Engineer 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, Bituminous Plant Recommendation #, 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.

C5 Documentation (Control Charts)

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

- (1) Blended aggregate gradation, include sieves shown in Table 2350-1 for specified mixture.
- (2) Percent asphalt binder content
- (3) Maximum specific gravity
- (4) Production air voids
- (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.

C6 Control Limits

The production air voids, VMA and JMF gradation control limits are based upon the minimum specified requirements as shown in Tables 2350-2 & 3. Gradations and Asphalt binder content limits are based upon the current Department approved JMF. Gradation control sieves (subject to Table 2350-5) are shown in Table 2350-1. 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 2350-4.

**Table 2350-4
Control Limits (N=4)**

Item	JMF Limits	Warning Limits
VMA, %	- 1.3	- 1.0
Production Air Voids, %	\pm 1.3	\pm 1.0
Asphalt Binder Content, %	- 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

C7 Warning Bands

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

C8 JMF Adjustment

A request for a JMF adjustment may be made to the Department Bituminous Engineer or District 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 design requirements in Section 2350.2G, a revised JMF shall be issued. Each trial mixture design submittal as described in section 2350.3A 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 bands in Section 2350.2A2. 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.

C9 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 section 2350.5C3a production tests 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 calculation of the moving average for the tests listed in 2350.5C3a 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 2350-5.

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 adjustment does not improve the properties and 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 the following Table .

**Table 2350-5
Payment Schedule**

Item	% Payment ⁽¹⁾
Coarse and Fine Aggregate Crushing ⁽²⁾	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.

C10 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.

C10a 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.

C10b 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.

C10c Individual Failure - Production Air Voids, Percent Asphalt Binder, and VMA

If the individual Quality Control tests for individual Air Voids, percent asphalt binder content, and/or voids in the mineral aggregate (VMA) exceed twice the warning limits and the results are verified by QA 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 2350-5 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.

C10d Individual Failure - Gradation

If the individual gradation test exceeds twice the warning limits and is outside the gradation bands listed in Table 2350-1, and is verified by QA tests, the material is considered unsatisfactory or unacceptable. Reduced payment as outlined in table 2350-5 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.

C10e Coarse and Fine Aggregate Crushing Failure

If any test result for Coarse Aggregate Angularity, Fine Aggregate Angularity or - 4.75 mm (- #4) calculated crushing fail to meet minimum requirements in table 2350-2, and the result is verified by Department tests, all material placed is subject to reduced payment as provide in table 2350-5. 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.

D Quality 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. The Engineer may sample materials or final density at any time to determine quality levels. A split from these samples will be provided to the Contractor for testing. Results from these tests must be included in the control charts.

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 Mn/DOT Technical 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 testing Department equipment in accordance with the latest version of the Mn/DOT Bituminous Manual.

**Table 2350-6
Test Result Tolerances ***

Item	Allowable Difference	
Marshall 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) %	Mn/DOT Verification Min = 65	
Asphalt Binder Content		
Meter Method, %	0.2	
Spot Check Method, %	0.2	
Chemical Extraction Methods, %	0.6	
Incinerator Oven, %	Same Oven	Different Oven
	0.2	0.3
Chemical vs. Meter, Spot Check, or Incinerator methods	0.4	
Gradation Sieve % passing		
25.0, 19.0, 12.5 9.5 mm (1", 3/4", 1/2", 3/8 ")	6.0	
4.75 mm (No. 4)	5.0	
2.36 mm (No. 8)	4.0	
0.075 mm (No. 200)	2.0	

* Test tolerances listed are for individual test comparisons.

E Verification Testing

Verification testing shall be performed on one set of production tests 2350.5C3a, C3b on a daily basis. 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 Table 2350-1 through Table 2350-3, and asphalt content as specified by the mixture recommendation and shall meet the tolerances listed in Table 2350-6. These include the mixture properties of G_{mm} (mixture max gravity), G_{mb} (mixture bulk gravity), asphalt binder content, VMA (calculated) Coarse and Fine Aggregate crushing, and gradation. These do not include the aggregate bulk specific gravity G_{sb} , fines to effective asphalt, or the tensile strength

ratio TSR. Asphalt binder content and gradation must be determined by either extraction method 2350.5C3a(1)b or 2350.5C3a(1)c. Asphalt content from the verification test result must be used to determine VMA.

Test results will be made available to the Contractor within two Mn/DOT working days, from the time the sample is obtained by the District Materials Laboratory, for G_{mm} mixture max gravity, G_{mb} mixture bulk gravity, air voids (calculated), asphalt binder content, VMA (calculated). Gradation and crushing results will be provided to the Contractor within three Mn/DOT working days.

A verification sample is a sample which is sampled and tested by Mn/DOT to assure compliance of the Contractor's Quality Control program. 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.

The verification process is intended to identify potential sampling and/or testing discrepancies 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. 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 48 hours of determination that verification is not successful, the Contractor shall cease mixture production and placement until the problem is identified and resolved. The District Materials 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.

E1 Testing Methodology Verification

E1a 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 2350-6, the testing methodology has successfully been verified. Proceed to the Sampling methodology verification procedure.

E1b 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 2350-6, a determination of validity is required {E1b(1)}. (Retests of the first material shall be conducted by Department and Contractor before proceeding to E1b(1)).

E1b(1) Verification validation

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

E1b(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.

E1b(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, which ever comes first. Acceptance for materials supplied to date, since last acceptable verification, will be made based upon the Department 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.

E2 Sampling Methodology Verification

To verify the sampling methodology, the Department test results described in E1a or E1b(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.

E2a Verification and QC moving average meet tolerance.

If the Department verification test results in E1a or verification validation test results in {(E1b(2))}, as compared to the contractors most recent moving average QC test results, are within 1.5 times the tolerances listed in Table 2350-6, the sampling methodology is successfully verified. Acceptance of material will be based on the Contractor's QC data.

E2b Verification and QC moving average do not meet tolerance.

If the Department verification test results in E1a or verification validation test results in {(E1b(2))}, as compared to the Contractor's most recent moving average QC test results, are not within 1.5 times the tolerances listed in Table 2350-6, a determination of validity is required {E2b(1)}.

E2b(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.

E2b(2) Verification Validation (Second verification meets tolerance vs moving average)

If the second verification sample tested meets the 1.5 times tolerance specified, the first verification

sample can be considered an exception. Acceptance of material will be based upon the Contractor's QC data.

E2b(3) Verification Validation (Second verification does not meet tolerance)

If the second verification sample tested fails to meet 1.5 times the 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 Contractor's moving average and the Department verification can be reestablished. If reestablishment of test results is not achieved within 48 hours, the Contractor shall cease mixture production and placement until the problem is resolved. 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 Table 2350-5 and 2350-10

2350.6 PAVEMENT DENSITY

A General.

All pavements will be constructed in accordance with the Maximum Density Method unless otherwise specified. Compaction of variable thickness leveling layers (minimum thickness less than 40 mm (1.5 inches)), layers less than 40 mm (1.5 inches), thin lift leveling, wedging layers, patching layers, driveways, areas which can not be compacted with standard highway construction equipment and non-traffic areas (excluding shoulders without rolled in rumble strips) will be accomplished according to the Ordinary Compaction Procedure, Subsection 2350.6C.

B Maximum Density Method.

All courses or layers of plant mixed asphalt mixtures for which the Maximum Density Method is used shall be compacted to a density not less than the percentage shown in the Table of Required Density, Table 2350-8, for the applicable mixture and course.

B1 Maximum Density Determination.

The Density requirements listed in Table 2350-8 are percent of maximum specific gravity (G_{mm}) based on the individual lot. The Maximum specific gravity value used to calculate the percentage density for the lot shall be the average value obtained from the maximum gravity results from production tests taken during that days paving. If a new job mix formula is established, a new maximum specific gravity reflecting the new job mix formula will be used for maximum density determination.

B2 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 multiplied by 100, (maximum specific gravity basis is the average G_{mm} of QC tests done on the day that the individual lot was paved). Determination of the bulk specific gravity of the cores shall be in accordance with AASHTO T-166, Mn/DOT modified dated 11/24/99. For coarse graded mixtures the Engineer may require determination of bulk specific gravity of the cores be in accordance with ASTM D1188, Mn/DOT modified. The determination of coarse and fine graded mixtures will be based on the percentage of material passing the 4.75 mm(#4) sieve as defined in Table 2350-3.

Compaction operations shall be completed within 8 hours of mixture placement and before core samples are obtained for density determination. Only pneumatic tired or static steel rollers are permitted for any compactive effort performed between 6 and 8 hours after mixture placement.

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 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 specifications.

Divide the days production into equal lots as shown in Table 2350-7 and obtain three cores in each lot. Two cores will be taken from random locations selected by the Engineer. The third core, a companion core, shall be taken 0.3 meters longitudinally from either of the first two cores. The companion cores shall be given to the Department Street Inspector upon completion of coring and sawing. The random locations will be determined by the Engineer using statistically derived stratified random number Tables. These will also be used for partial lots. 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.

If the companion cores from two consecutive days paving meet specified tolerances for bulk specific gravity, as shown in Table 2350-6, 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.

**Table 2350 - 7
Lot Determination**

Daily Production Metric Ton	English(ton)	Lots
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

B3 Core Testing

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. Cores shall be cut using a 100mm(4 in) minimum outer diameter coring device. 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. These companion cores may be tested by the Inspector on Department scales or transported to the Department's Field Laboratory or District Materials Laboratory.

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 2350.7A

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.

The Engineer may allow recoring of a sample only when the core has been damaged through no fault of the Contractor, either during the coring process or in transit to the laboratory.

B4 Required Density

**Table 2350-8
Required Density**

Percent Density		
Location	HV mixtures	MV and LV mixtures
Traffic Lanes ⁽¹⁾	91.5 ⁽²⁾	91.5 ⁽²⁾

- (1) Includes Parking Lanes as determined by the Engineer.
- (2) Minimum reduced by one percent for the first lift constructed on aggregate base, or cold recycled base courses and first lift of an overlay on a roadway with a 6.35 metric ton (7 ton) or less spring load restriction.

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.

B5 Maximum Density 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. If multiple layers are placed in a single day, cores shall be sawn and separated for each layer, tested and reported by the end of the next working day.

The Contractor's cores will be used for acceptance if the determined bulk specific gravity G_{mb} from AASHTO T-166, Mn/DOT modified dated 11/24/99 or ASTM D1188 is within ± 0.030 of the state companion G_{mb} value.

When the density of a lot, of compacted mixture, is less than the specified minimum, payment will be made at an adjusted price as specified in Table 2350-10:

Table 2350-9-Blank

Table 2350-10
Payment Schedule for Maximum Density(1)
(Wear and Nonwear)

% Density HV, MV, & LV Mixtures	Payment Factor (% Contract Price)
93.1 and above	104 (2)
92.6-93.0	102 (2)
91.5-92.5	100
90.5-91.4	98
90.0-90.4	95
89.5-89.9	91
89.0-89.4	85
88.5-88.9	70
Less than 88.4	(3)

- (1) Incentive payment is excluded when the minimum density requirement has been reduced by one percent for the first lift constructed on aggregate base, cold recycled base courses, first lift of an overlay on a roadway with a 6.35 metric ton (7 ton) or less spring load restriction or on the first lift constructed over pcc pavements that have 30% or more faulted joints & cracks and/or contain mid panel cracks.
- (2) The payment in this portion of the specification shall only apply if the individual air voids, as determined from mixture production test (2350.5C3a(4)) that represents the tonnage placed at that specific cores location, are no less than - 0.5 percent from the target value.
- (3) Areas of asphalt 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. These cored samples shall be taken by the Contractor as directed by the Engineer. 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 (50 ft) 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 Tables 2350-10. 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 Tables 2350-10. 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 2350-10.

C Ordinary Compaction Method

This compaction method shall not be used on mainline, ramp, loop paving, or unless otherwise designated. 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 m² (395 yd²) 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 roller's coverages. Densities will be determined by means of a portable nuclear testing device or suitable approved alternate. The 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 or suitable approved alternate after each roller passes. Rolling shall be suspended when testing shows either a decline of more than 2% of the maximum specific gravity 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 asphalt 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 asphalt 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. 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 (5 ft) or more. It shall be so constructed that the gross wheel load force shall be a minimum of 13 kN (3000 lbs) per wheel for LV and MV mixtures and 22 kN (5,000 lbs) per wheel for HV mixtures 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 otherwise specified in the contract. 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

Trench rollers 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 asphalt mixture shall be in accordance with the temperature requirements of Table 2350 - 11.

**Table 2350 -11
Mixture Temperature Control**

Air Temperature		Compacted Mat Thickness, mm ^(A)			
		25 mm (1 in)	40 mm (1-1/2 in)	50 mm (2 in)	75 mm (3 in) or greater
°C	(°F)				
+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 Department Bituminous Engineer) a minimum laydown temperature.

2350.7 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, except that, if automatic grade controls are used, this thickness requirement will not apply to the first course placed. This thickness requirement will not apply to a leveling course whether or not automatic grade controls are required. 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 the elevations and grades established by the Engineer. This requirement shall also apply to the first course placed other than leveling when automatic controls are used.
- (2) The surface of the Non-wear 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.

C Pavement Smoothness:

C1 General

Pavement smoothness will be evaluated on the final mainline pavement surface. The following Table shows pavement surfaces which are excluded from profilograph testing but subject to 2350.7B surface requirements.

**Table 2350-12
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 2350-13A, 2350-13B, or 2350-13C in accordance with the following unless otherwise modified.

Schedule for Identification of Pavement Sections

Construction Type	Table
New construction with minimum of 3 lifts	2350-13 A
Overlay with a minimum of 3 lifts 40 mm (1.5") minimum lift thickness	2350-13 A
Construction with 8' min shoulder separation between C&G and driving lanes min 3 lifts.	2350-13 A

Single lift overlays 40mm (1.5") or more in thickness that have profile milling of the original pavement.	2350-13 B
New construction with minimum 2 lifts.	2350-13B
Construction with curb and gutter adjacent to at least one driving lane	2350-13 B
Single lift mill (mainline and shoulder) and fill overlays	2350-13B
Two- lift overlays (40mm (1.5")) minimum lift thickness on an unmilled surface	2350-13 B
Winter carry-over wearing course	2350-13 B
Reclaim with 2 lifts	2350-13B
Uniform mill with 2 lifts	2350-13 B
BOC with PSR(2.7-3.2) and 2 lifts	2350-13 B

New construction with 1 lift	2350-13C
Single lift overlays on an unmilled surface.	2350-13 C
Construction adjacent to existing pavement	2350-13 C
BOC with 2 lifts and PSR<2.7	2350-13 C

Note: Profile Milling: Profile milling shall consist of (1) Using a grade leveling ski control or traveling string line not less than 30 feet in length attached to the milling machine and operating parallel to its line of travel or (2) Using an erected string line, offset from and parallel to the pavement edge on one or both sides, and set parallel to the established grade for the pavement surface.

Uniform Milling: Uniform milling shall consist of specified depth milling.

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 6 km/hr (4 mph). Motive power may be provided manually or by the use of a propulsion unit approved by the 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 Engineer on the first day the 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, manhole 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 7.62 m (25 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 retested 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 Department 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 equal to or exceeding 10.2 mm in a 7.62 m (0.4 inch in a 25 ft) span shall be identified separately. When the profile trace shows a successive, uninterrupted bump, dip; or dip, bump combination(up to a maximum of 3 alternating trace deviations that relate to one bump or dip on the roadway), identify and evaluate these occurrences as one event.

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 pavement segments having no more than two events or two individual bumps or dips with a vertical deviation of 10.2 to 25 mm (0.4 to 1.0 in) in a 7.62 m(25ft) span. Correction of segments with more than two events or two individual bumps or dips, as defined above, will be allowed only when approved by the Engineer . 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, by replacing the area or by inlaying. 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, inlay or replacement, the surface correction shall begin and end with a transverse saw cut.

If the smoothness evaluation indicates that corrective work is necessary for more than 50% of a segment, surface correction will be limited to mill and inlay(40 mm(1 ½) min).

All corrective work shall be subject to the approval of the Engineer. After all required correction work is completed a final profile index shall be determined. 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.

The Contractor will not receive an incentive payment for ride if more than 25% of all density lots for the project (mainline paving) fail to meet minimum density requirements.

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 in lieu of requiring the Contractor to take corrective action when the profile index for a segment indicates corrective action is necessary.

Penalties, based on the table the profile index is evaluated under, are as follows:

Table 2350-13A: \$560 per 0.1 km (\$900 per 0.1 mile)

Table 2350-13B: \$420 per 0.1 km (\$675 per 0.1 mile)

Table 2350-13C: \$280 per 0.1 km (\$450 per 0.1 mile)

Table 2350-13 A
Initial Profile Index ⁽¹⁾

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- 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 in a project 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 2350-13 B
Initial Profile Index ⁽¹⁾

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 - 15.8	(0.0 - 1.0)	145	225
15.9 - 31.6	(1.1 - 2.0)	100	150
31.7 - 47.3	(2.1 - 3.0)	55	75
47.4 - 110.5	(3.1 - 7.0)	0	0
110.6 - 126.3	(7.1 - 8.0)	(55)	(75)
126.4 - 142.0	(8.1 - 9.0)	(100)	(150)
142.1 - 157.8	(9.1- 10.0)	(145)	(225)
Over 157.8	Over 10.0	Corrective Action	Corrective Action

(1)If all segments in a project 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 2350-13 C
Initial Profile Index (1)

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)	95	150
31.7-47.4	(2.1-3.0)	65	100
47.5-79.0	(3.1-5.0)	35	50
79.1-158.0	(5.1-10.0)	0	0
158.1-189.6	(10.1-12.0)	(35)	(50)
189.7-221.2	(12.1-14.0)	(65)	(100)
221.3-252.8	(14.1-16.0)	(95)	(150)
(252.8)	(16.0)	Corrective Action	Corrective Action

(1) If all segments in a project 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.

2350.8 METHOD OF MEASUREMENT**A Asphalt Mixture**

Asphalt 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 asphalt 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 Asphalt Mixtures Measured by the Square Meter per Specified (mm)(Square Yard Inch)Thickness

Asphalt 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.

2350.9 BASIS OF PAYMENT

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

If the Marshall density at the recommended or established asphalt content is in excess of 2565 kg/m³ (160 lb/ft³), payment for mixture will be calculated at the following percent of the contracted unit price.

$$\% \text{ Payment} = \{ 100 - [\{ 100 \times (\text{Marshall Density} - 2565) \} / 2565] \}$$

$$\% \text{ Payment} = \{ 100 - [\{ 100 \times (\text{Marshall Density} - 160) \} / 160] \}_{\text{ENGLISH}}$$

In the absence of 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 the item of asphalt mixture production at the Contract unit price of mixture produced will be compensation in full for all costs of producing the mixture and loading it on board the Department's trucks at the mixing plant. The provisions of 1903 are modified to the extent that the Department will not make a price adjustment in the event of increased or decreased quantities of asphalt mixture items.

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; this includes the cost of material.

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

Item No.	Item	Unit
2350.604	Type ___ _ ___ Course Mixture, ___ mm thick	square meter
2350.607	Type ___ _ ___ Course Mixture	square yard inch
2350.609	Type ___ _ Bituminous Mixture for Specified Purpose	metric ton (ton)
2350.609	Type ___ _ Bituminous Mixture Production	metric ton (ton)
2350.609	Type ___ _ Wearing Course Mixture	metric ton (ton)
2350.609	Type ___ _ Non Wearing Course Mixture	metric ton (ton)

3139 GRADED AGGREGATE FOR ASPHALT MIXTURES

Section 3139 of the standard specification is deleted and replaced with the following;

3139.1 SCOPE

This specification covers graded aggregate for use in Asphalt mixtures.

3139.2 REQUIREMENTS**A Composition****A1 General**

The aggregate shall consist of sound, durable particles of gravel and sand, crushed stone and sand, or combinations thereof. It shall be free of objectionable matter such as metal, glass, plastic, brick, rubber, and any other material having similar characteristics. Coarse aggregate shall be free from coatings of clay and silt to the satisfaction of the Engineer.

The Contractor shall not compensate for the lack of fines by adding soil materials such as clay, loam, or silt. Overburden shall not be blended into the asphalt aggregate.

A2 Classification

The aggregate shall conform to one of the following classifications. The class of aggregate to be used shall be the Contractor's option unless otherwise specified in the Contract.

A2a Class A

Class A aggregate shall consist of crushed igneous bedrock (specifically; basalt, gabbro, granite, rhyolite, diorite and andosite) and rock from the Sioux Quartzite Formation. Other igneous or metamorphic rock may be used with specific approval of the Engineer. Class A materials may contain no more than 4.0% non-Class A aggregate. This recognizes the fact that some quarries may contain small pockets of non-Class A material within that source. Intentional blending or addition of non-Class A material is strictly prohibited!

A2b Class B

Class B aggregate shall consist of crushed rock from all other bedrock sources such as carbonate and metamorphic rocks. (gneiss or schist)

A2c Class C

Class C aggregate shall consist of natural or partly crushed natural gravel obtained from a natural gravel deposit.

A2d Class D

Class D aggregate shall consist of 100 percent crushed natural gravel. The crushed gravel shall be produced from material retained on a square mesh sieve having an opening at least twice as large as the Specification permits for the maximum size of the aggregate in the composite asphalt mixture. The amount of carryover (material finer than) the selected screen shall not exceed ten percent.

A2e Class E

Class E aggregate shall consist of a mixture of any two or more of the above classes of approved aggregate (A, B, and D). The use of Class E aggregate, as well as the relative proportions of the different constituent aggregates, shall be subject to the approval of the Engineer. The relative proportions of the constituent aggregates shall be accurately controlled either by the use of a blending belt approved by the Engineer prior to production or by separately weighing each aggregate during batching operations.

A2f Steel Slag

Steel slag may not exceed 25 percent of the mass of the total aggregate. Stockpiles will be accepted for use if the total expansion, determined by ASTM D4792, is less than 0.50%.

A3 Mixture Aggregates

Each different material (source, class, kind, or size) shall be fed at a uniform rate from its storage unit. An individual source, class, type, or size of material shall not be stockpile blended with another source, class, type or size of material.

A4 Taconite Tailings (TT)

Taconite tailings shall be obtained from ore that is mined westerly of a north-south line located east of Biwabik, Mn (R15W-R16W); except that taconite tailings from ore mined in southwestern Wisconsin will also be permitted for use.

Approved taconite tailing sources are on file with the Department Bituminous Engineer.

B Manufactured Crushed Fines (-4 material)

All Class A, B, D, and E material that passes the 4.75 mm (#4) screen will be considered as crushed fines.

Manufactured Crushed Fines (-4 material) from Class C Aggregate. Produce manufactured crushed fines (-4 material) from a gravel source by passing the gravel over a selected screen, 9.5 mm (3/8 in.) or larger, prior to mechanical crushing. The material which passes the 9.5 mm (3/8 in.) screen shall not be incorporated into the manufactured crushed fines but may be used as it qualifies for natural sand. The amount of carryover (material finer than) the selected screen shall not exceed ten percent. The material retained on the 9.5 mm (3/8 in.) screen shall be crushed. The material that passes the 4.75 mm (#4) screen, after crushing, will be considered as 100% crushed fines. Material retained on the 4.75 mm (#4) screen after crushing will not be counted as +4 crushing until tested.

C Quality Requirements

C1 Los Angeles Rattler Loss

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.

C2 Magnesium Sulfate Soundness

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 requirements listed above on the coarse aggregate fraction is prohibited from use in the mixture.

C3 Spall Materials and Lumps

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

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.

The following percentages by mass shall not be exceeded:

C3a	Type LV Mixture Aggregates	<u>Percent</u>
	Total Spall in Total Sample	5.0
	Lumps in the Fraction Retained on the 4.75 mm (#4) Sieve	0.5
C3b	Type MV Mixture Aggregates	<u>Percent</u>
	Total Spall in the Fraction Retained on the 4.75 mm (#4) Sieve	2.5
	Shale Content of Fraction Passing the 4.75 mm (#4) Sieve	5.0
	Lumps in the Fraction Retained on the 4.75 mm (#4) Sieve	0.5

C3c	Type HV Mixture Aggregates	<u>Percent</u>
	Total Spall in Total Sample	1.0
	Lumps in the Fraction Retained on 4.75 mm (#4) Sieve	0.5

C4 Insoluble Residue

If Class B carbonate material is used in the mix, the minus 0.075 mm (#200) sieve size portion of the insoluble residue shall not exceed 10 percent.

3139.3 SAMPLING AND TESTING

A Sampling, Sieve Analysis, Lumps, Crushing, Shale and Spall Tests: The Mn/DOT Bituminous Manual

B Los Angeles Rattler Test.....AASHTO T96

C Soundness (Magnesium Sulfate).....AASHTO T104

D Insoluble Residue Test.....Mn/DOT Laboratory Manual