2301 CONCRETE PAVEMENT

2301.1 DESCRIPTION

This work consists of constructing portland cement concrete pavement on a prepared base.

The Department defines paving concrete to include concrete mainline, ramps, loops, integrant curb, shoulders, and curb and gutter placed adjacent to the concrete mainline with the same mixture used in the paving. Integrant curb is a curb constructed monolithically with the pavement.

For the purposes of concrete pavement, the Department defines a concrete plant as the following:

(1) A paving plant using dump or agitator trucks to haul concrete, or
(2) A certified ready-mix plant using truck mixers to haul concrete.

For concrete pavement incentives and disincentives, the Department defines a concrete plant as the following:

(1) A primary concrete plant providing the majority of the concrete to a paving project, and
(2) A secondary concrete plant providing any minor work or fill-ins not provided by the primary concrete plant.

Only one primary concrete plant per project is allowed unless otherwise approved by the Engineer. The Contractor may use a paving plant or a certified ready-mix plant as the primary concrete plant.

2301.2 MATERIALS

A Concrete.....2461

A.1 Slipform Placement..... Mix No. 3A21

A.2 Fixed Form Placement..... Mix No. 3A41

B Coarse and Fine Aggregate Requirements

Test each aggregate fraction proposed for use in accordance with Table 2301-1:

Table 2301-1 Aggregate Testing Requirements	
Aggregate	**Testing Required**
Tested by Department in the last 3 years	No additional testing *
Not tested by the Department in the last 3 years	Preliminary aggregate testing in accordance with 2301.2.B.1, "Required Preliminary Aggregate Testing."
New source	New source concrete aggregate testing in accordance with 3126, "Fine Aggregate for Portland Cement Concrete," and 3137, "Coarse Aggregate for Portland Cement Concrete."
* Perform additional testing as required by the Engineer in conjunction with the Concrete Engineer.	

B.1 Required Preliminary Aggregate Testing

After the Department awards the contract and as soon as coarse and fine aggregates are available for testing, contact the Engineer to coordinate preliminary sampling of aggregate for concrete paving. The Engineer, in conjunction with the Concrete Engineer, will sample and test the aggregate to verify specific gravity, absorption data, and aggregate quality. The Department will perform other tests as determined necessary by the Engineer, in conjunction with the Concrete Engineer.

B.2 Aggregate Alkali Silica Reactivity (ASR) Requirements for Concrete Mixes

The Department will test the designated fine aggregate for alkali silica reactivity (ASR) with Holcim, St. Genevieve, Type I/II portland cement and Lafarge, Davenport, Type I/II portland cement in accordance with ASTM C 1260 Mn/DOT Modified. If the fine aggregate contains an intermediate size aggregate such as "buckshot" or "pea rock" as determined by the Concrete Engineer, the Department will perform testing in accordance with ASTM C 1260.

The Concrete Engineer, in conjunction with the Engineer, will review the 14-day fine aggregate expansion test results to determine the acceptability of the proposed fine aggregate and cement combination in accordance with the 14-day fine aggregate expansion limits in Table 2301-2:

Table 2301-2 Fine Aggregate ASR Mitigation Requirements	
14-day Fine Aggregate Expansion Limits	**Mitigation Requirement**
≤ 0.150	The Department will accept the fine aggregate with or without a mitigator
> 0.150 – 0.250	Mitigate the fine aggregate with 35 percent slag or at least 20 percent fly ash
> 0.250 – 0.300	Mitigate the fine aggregate with 35 percent slag or 30 percent fly ash in accordance with 3115, "Fly Ash for Use in Portland Cement Concrete," modified with at least 66.0 percent SiO_2 + Fe_2O_3 + Al_2O_3 on a dry weight basis and at least 38.0 percent SiO_2
> 0.300	The Department will reject the fine aggregate

For fine aggregate and cement combinations previously tested by the Department, the Concrete Engineer will use the previous test results to determine necessary mitigation. The Contractor may contact the Department to access the list of previously tested fine aggregate sources.

If the fine aggregate and cement combination were not previously tested, the Concrete Engineer will use the higher expansion result of the two fine aggregate and cement combinations to determine necessary mitigation.

Add "buckshot" or "pea rock" as a separate aggregate in accordance with the quality requirements of 3137, "Coarse Aggregate for Portland Cement Concrete," except the Department will determine the shale content in accordance with AASHTO T 113 Mn/DOT Modified, "Lightweight Pieces in Aggregate," fine aggregate procedure. If this aggregate is from the same source as the ¾ in+ [19 mm+] or ¾ in– [19 mm–] aggregate, the Concrete Engineer will waive the requirements specified in 3137.2.D.3(b), "Carbonate in Class C Aggregate by Weight. If this aggregate is from sources other than the ¾ in+ [19 mm+] or ¾ in– [19 mm–] aggregate, approval is at the discretion of the Concrete Engineer.

The Concrete Engineer may reject the fine aggregate if mortar bar specimens exhibit an indication of external or internal distress not represented by the expansion results. The Concrete Engineer will make the final acceptance of the aggregate.

C Cementitious Materials

Design the concrete paving mixes in accordance with the following requirements for cementitious material:

(1) Total alkalis no greater than 0.60 percent in the portland cement (Na2O + 0.658 K2O)

(2) Total alkalis no greater than 5.0 lb per cu. yd [3.0 kg per cu.m] in the combined cementitious material
(3) At least 530 lb per cu. yd [315 kg per cu. m] minimum cementitious,
(4) At least 400 lb per cu. yd [237 kg per cu. m] of portland cement when using fly ash or at least 385 lb per cu. yd [228 kg per cu. m] when using slag as a portland cement replacement,
(5) Provide additional cementitious material to meet requirements in accordance with this section at no additional cost to the Department,
(6) Total cementitious material no greater than 600 lb per cu. yd [356 kg per cu. m] except for high-early strength mixes.

The Department defines high-early strength concrete as concrete with a cementitious content of greater than 600 lb per cu. yd [356 kg per cu. m].

The Contractor may use 100 percent portland cement for the cementitious material for high-early mixes, except if using quartzite or gneiss coarse aggregate provide high-early mixes in accordance with 2301.2.C.1, "Special Cementitious Requirements for Quartzite and Gneiss."

C.1 Special Cementitious Requirements for Quartzite and Gneiss

If providing coarse aggregate from sources identified by the Department as quartzite or gneiss and if the coarse aggregate does not meet the 0.04 percent expansion limit when tested in accordance with ASTM C 1293, replace the portland cement with the following:

(1) 30 % of a fly ash from the Approved/Qualified Products List in accordance with 3115, "Fly Ash for Use in Portland Cement Concrete," except provide fly ash in the concrete mixture with at least 66 percent $Si0_2 + Fe_2O_3 + Al_2O_3$ on a dry weight basis for at least 12 consecutive months and at least 38 percent $Si0_2$ content, or
(2) 35 % of a ground granulated blast furnace slag from the Approved/Qualified Products List.

D Concrete Mix Design Requirements

Design the concrete mix based on an absolute volume of 27 cu. ft ± 0.10 cu. ft [1.000 cu. m ± 0.003 cu. m] in accordance with the following:

(1) Fine aggregates complying with the requirements of 3126, "Fine Aggregate for Portland Cement Concrete," for aggregate quality,
(2) Coarse aggregates complying with the requirements of 3137, Coarse Aggregate for Portland Cement Concrete," for aggregate quality,
(3) Air content of 7.0 percent ±1.5 percent at the point of placement, and

(4) High-early concrete placed at a water-cementitious ratio not greater than 0.38.

Submit the concrete mixes using the Mn/DOT Contractor Mix Design Submittal Worksheet available on the Department's website at least 21 calendar days before the initial placement of concrete using the concrete mix design. For mix design calculations, the Engineer, in conjunction with the Concrete Engineer, will provide specific gravity and absorption data.

The Concrete Engineer, in conjunction with the Engineer, will review the mix design submittal and approve the materials and mix design for compliance with the contract.

The Contractor assumes full responsibility for the mix design and performance of the concrete.

The Engineer determines final acceptance of concrete for payment based on satisfactory field placement and performance.

D.1 Concrete Pavement < 3,500 cu. yd [2,900 cu. m]

If the estimated quantity of concrete pavement in the contract is less than 3,500 cu. yd [2,900 cu. m], calculated by multiplying the planned pavement area by the planned pavement thickness, provide a mix design meeting the following requirements:

(1) Grade A paving concrete placed at a water/cement ratio no greater than 0.45;
(2) Fine aggregates with a gradation in accordance with Table 3126-3, "Fine Aggregate Gradation Requirements;"
(3) CA-15, CA-35, or CA-50 coarse aggregates with a gradation in accordance with Table 3137-4, "Coarse Aggregate Designation for Concrete;"
(4) Instead of item (2) and (3) of this list, provide a Job Mix Formula in accordance with 2301.2.D.3, "Job Mix Formula;" and
(5) The incentive/disincentives for aggregate quality, well-graded aggregate, and water/cement ratio as specified in 2301.2.D.4, "Concrete Pavement Incentives and Disincentives," shall not apply.

D.2 Concrete Pavement ≥ 3,500 cu. yd [2,900 cu. m]

If the estimated quantity of concrete pavement in the contract is equal to or greater than 3,500 cu. yd [2,900 cu. m], calculated by multiplying the planned pavement area by the planned pavement thickness, provide a mix design meeting the following requirements:

(1) Grade A paving concrete placed at a water/cement ratio no greater than 0.40;

(2) Submit a Job Mix Formula in accordance with 2301.2.D.3, "Job Mix Formula;"
(3) For concrete produced at a secondary concrete plant or as otherwise allowed by the Engineer, the Contractor has the option to design a mix in accordance with 2301.2.D.1, "Concrete Pavement < 3,500 cu. yd [2,900 cu. m];" and
(4) The incentive/disincentives for aggregate quality, well-graded aggregate, and water/cement ratio as specified in 2301.2.D.4, "Concrete Pavement Incentives and Disincentives," shall apply,

D.3 Job Mix Formula

Use at least two fractions of coarse aggregate that include the ¾ in+ [19 mm+] and ¾ in− [19 mm−] fractions.

A Job Mix Formula (JMF) contains proportions of materials and individual gradations of each material plus a composite gradation. The Engineer will base the JMF on the combination of coarse and fine aggregate in accordance with Table 2301-3. The Department will waive the gradation requirements of 3126, "Fine Aggregate for Portland Cement Concrete," and 3137, "Coarse Aggregate for Portland Cement Concrete."

Table 2301-3
Job Mix Formula Working Range

Sieve Sizes	Working Range, %*
2 in [50 mm]	±5
1½ in [37.5 mm]	±5
1 in [25 mm]	±5
¾ in [19 mm]	±5
½ in [12.5 mm]	±5
⅜ in [9.5 mm]	±5
No.4 [4.75 mm]	±5
No.8 [2.36 mm]	±4
No.16 [1.18 mm]	±4
No.30 [600 µm]	±4
No.50 [300 µm]	±3
No.100 [150 µm]	±2
No.200 [75 µm]	≤ 1.6

* Working range limits of the composite gradation based on a moving average of 4 tests (N=4).

Add fill-in sieves as needed during the testing process to prevent overloading. Provide combined aggregates with 100 percent passing the 2 in [50 mm] sieve and no greater than 1.6 percent passing the No. 200 [75 µm] sieve. In addition, each coarse

aggregate fraction must comply with the Material Passing the No. 200 [75 µm] sieve requirement in row (i) of Table 3137-1.

Include working ranges based on the composite gradation of the sieves specified in Table 2301-3 with the JMF submittal.

Sample, test, and record the individual results. The Engineer will determine the sampling location by using a random number chart and multiplying the random number by the sampling rate as defined in the Schedule of Materials Control.

The Engineer will randomly verify Contractor combined aggregate gradation results as defined in the Schedule of Materials Control.

If the quantities of concrete produced results in no gradation testing for any given day, include the untested quantity of concrete into the next day's production and include that quantity of concrete in the sampling rate. If the untested quantity is on the last day of production, add that quantity to the previous day's production.

D.3.a JMF Adjustments

If, during production, the moving average of QC aggregate gradation tests falls outside the allowable JMF working range, make adjustments within the limits specified in Table 2301-4 without submitting a new mix design as approved by the Engineer.

Table 2301-4
Allowable JMF Adjustments

Sieve Size	Allowable Adjustment, %
≥ No. 4 [4.75 mm]	±5
No. 8 [2.36 mm] – No.30 [600 µm]	±4
No. 50 [300 µm]	±3
No. 100 [150 µm]	±2

The Contractor may continue paving after submitting a new JMF with working range and aggregate volume adjustments to the Engineer. Submit all JMF adjustments on the Mn/DOT JMF Adjustments Worksheet available from the Department's website.

If the moving average of four tests falls outside of the adjusted allowable working range, stop production and provide a new mix design including JMF as directed by the Engineer, in conjunction with the Concrete Engineer.

D.4 Concrete Pavement Incentives and Disincentives

The Department will apply concrete mix incentives or disincentives for contracts using at least 3,500 cu. yd [2,900 cu. m] of concrete, calculated by multiplying the planned pavement area by the planned pavement thickness, of paving concrete.

The Department will only apply coarse aggregate quality incentives or disincentives for materials provided or produced by the Contractor's primary concrete plant.

The Department will not provide water/cement ratio incentive payments for high-early mixes. The Department will only apply water/cement incentives or disincentives for concrete hauled in dump trucks, agitator trucks, or both.

If the Contractor adds water to the pavement surface without approval by the Engineer, the Department will not pay water/cement or ride incentives on sections where the water is added and the Engineer may reject the pavement in accordance with 1503, "Conformity with Contract Documents," and 1512, "Unacceptable and Unauthorized Work."

D.4.a Coarse Aggregate Quality Incentive/Disincentive

The Engineer will accept the coarse aggregate for paving concrete by statistical methods and in accordance with all other aggregate quality requirements of 2301, "Concrete Pavement," 2461, "Structural Concrete," and 3137, "Coarse Aggregate for Portland Cement Concrete."

The Coarse Aggregate Quality Incentive/Disincentive for CLASS B and CLASS C Aggregates will comply with the following:

The Engineer will take samples at the belt leading to the weigh hopper or other locations close to the incorporation of the work. The Engineer will take samples in accordance with Table 2301-5:

Table 2301-5
Coarse Aggregate Quality Incentive/Disincentive Sampling Rates

Plan Concrete, cu. yd [cu. m]	Samples per Fraction (n)
3,500 – 7,500 [2,900 – 6,250]	3
7,501 – 10,000 [6,251 – 8,500]	5
10,001 – 25,000 [8,501 – 21,000]	10
25,001 – 50,000 [21,001 – 42,000]	15
> 50,000 [42,000]	20

The Engineer will consider the entire project as a single lot for each of the two fractions containing the highest percentage by weight. If the project is planned for construction over multiple years and before placing any concrete pavement, request

that the Engineer calculate the incentive/disincentive payment on a yearly basis. The Engineer, in conjunction with the Concrete Engineer, will modify the sampling and testing rates as necessary.

The Engineer will establish a new statistical family for each change in aggregate source, fraction, or both.

The Engineer will randomly choose the acceptance samples.

The Engineer will divide a lot representing the plan cubic yards [cubic meters] of concrete by the number of samples to form sublots. The Engineer will multiply the number of cubic yards [cubic meters] in a sublot by a random number to obtain the position in the sublot for the sample. The Engineer will split the samples and leave half of the sample for the Contractor. The Engineer's laboratory will test the samples and report the individual results. The Engineer will calculate a Quality Index (QI) for each fraction in accordance with the following:

$$QI = X + k(s)$$

Where:

$$\text{X} = \text{mean} = \sum \frac{X_i}{n}$$

X_i = individual test results

$$\text{s} = \text{standard deviation} = \sqrt{\sum \frac{(x_i - x)^2}{(n-1)}}$$

k = Adjustment Factor based on the number of tests as shown in Table 2301-6:

Table 2301-6
Adjustment Factor "k"

k	No. of Tests
1.09	3
1.20	4
1.23	5
1.26	10
1.27	≥ 15

If Class A, Class B, and Class C aggregates meet the requirements as determined by the Engineer, the Department will provide payment based on a per fraction incentive in accordance with Table 2301-7.

Table 2301-7 Coarse Aggregate Quality Incentive/Disincentive		
Aggregate Class	**QI for Fraction, %**	**Structural Concrete per cu. yd [cu. m] Payment Change per Fraction**
Class A (including quartzite and gneiss)	—	$1.00 [$1.30]
Class B (based on % absorption)	≤1.00	$1.00 [$1.30]
	1.01 – 1.45	$0.50 [$0.65]
	1.46 – 1.76	$0.00
	1.77 – 1.85	−$1.00 [$1.30]
	≥ 1.86	As recommended by the Concrete Engineer, with coordination of the Engineer
Class C (based on % carbonate)	≤ 15.0	$1.00 [$1.30]
	15.1 – 24.0	$0.50 [$0.65]
	24.1 – 31.0	$0.00
	31.1 – 35.0	−$1.00 [$1.30]
	≥ 35.1	As recommended by the Concrete Engineer, with coordination of the Engineer

The Department will not pay incentives or disincentives for Class R aggregates.

If the concrete mixture contains at least three fractions of coarse aggregate, the Engineer will consider only the two containing the highest percentage by weight as eligible for incentive. The Contractor may combine at least two sub-fractions to form the ¾ in – [19 mm –] fraction for either the coarse or fine fraction of the coarse aggregate. Blend the sub-fractions by weight. The Engineer will base the maximum incentive for aggregate quality on the two largest fractions by weight.

The Department will pay for Coarse Aggregate Quality Incentive/ Disincentive for all paving concrete, including water/cement ratio concrete, and high-early concrete provided by the Contractor's primary paving plant.

D.4.b Water/Cement (w/c) Ratio

Provide and place concrete with a water/cement ratio not to exceed 0.40. Make any adjustments immediately when the water/cement ratio exceeds 0.40.

The Department will not make incentive payments for water/cement ratio on high-early mixes.

Do not add water to the surface of the concrete to aid in finishing without the approval of the Engineer. Supply sufficient trucks to ensure a steady forward progress of the paver.

The Department will determine the water/cement ratio for concrete hauled in dump or agitator trucks (concrete hauled in truck mixers are not eligible for w/c ratio incentives) in accordance with the following:

D.4.b(1) Water Content Determination

For a concrete paving batch plant, use an electronic meter approved by the Engineer to record the water, including temper water, added to the mix that is capable of printing the amount of total water on each batch ticket.

For a ready-mix plant, record the total water added to the mix, including temper water, on the computerized Certificate of Compliance.

The Engineer will determine the water content for calculating the water/cement ratio using the average water calculated from 10 batch tickets or Certificates of Compliances surrounding the randomly selected batch ticket sample (four previous tickets, ticket representing the random sample, and the five following tickets).

D.4.b(2) Water Content Verification

The Engineer will use plastic concrete taken at the plant site to verify the water content in the mix as determined in accordance with 2301.2.D.4.b(1), "Water Content Determination." Sample the plastic concrete as directed by the Engineer.

The Engineer will verify the water content in the plastic concrete mixture using the test procedure specified in AASHTO T 318-02, "Standard Test Method for Water Content of Freshly Mixed Concrete Using Microwave Oven Drying." The Engineer will begin the test within 45 min after the water has contacted the cement. Provide the microwave oven and the ancillary equipment as required by the Engineer to perform this test.

D.4.b(3) Cementitious Content Determination

The Engineer will determine the cementitious content for calculating the water/cement ratio using the average total cementitious calculated from 10 batch tickets or Certificates of Compliance surrounding the randomly selected batch ticket sample (four previous tickets, the ticket representing the random sample, and the five following tickets).

D.4.b(4) W/C Ratio Incentive/Disincentive

The Engineer will base the statistical analysis of acceptance for water/cement ratio in accordance with 2301.2.D.4.b(1), "Water Content Determination," and

2301.3.D.4.b(3), "Cementitious Content Determination," at a rate defined in the Schedule of Materials Control.

The Engineer will randomly choose acceptance samples. The Engineer will determine the sampling location by using a random number chart and multiplying the random number by the sampling rate as defined in the Schedule of Materials Control.

The Engineer will sample, test, and record the individual results.

If the quantities of concrete produced results in no Department moisture testing for any given day, include the untested quantity of concrete into the next day's production and include that quantity of concrete in the sampling rate. If the untested quantity is on the last day of production, add that quantity to the previous day's production.

Do not place concrete mix not meeting the 0.40 water/cement ratio requirement in the work. The Engineer may accept material not meeting the contract requirements and the Department will pay for the work in accordance with Table 2301-8.

Table 2301-8
W/C Ratio Incentive/Disincentive

W/C Ratio Test Result	Payment incentive/disincentive per cu. yd [cu. m]
≤ 0.37	+$3.00 [$3.90]
0.38	+$1.75 [$2.25]
0.39	+$0.50 [$0.65]
0.40	$0.00
0.41	−$0.50 [$0.65]
0.42	−$1.75 [$2.25]
0.43	−$3.00 [$3.90]
≥ 0.44	Determined by the Concrete Engineer

The Contractor may remove and replace concrete represented by water/cement ratios greater than 0.40. For concrete left in place with water/cement ratios greater than 0.40, if the level of payment is not defined in the table, the Engineer, in conjunction with the Concrete Engineer, will evaluate the material based on the adequacy of the material for the use intended. Remove and replace unsatisfactory concrete as determined by the Engineer at no additional cost to the Department.

D.4.c Well-Graded Aggregate Optional Incentive

The Engineer will use the Contractor's combined aggregate gradation test results, as verified by Department testing, to determine eligibility for the incentive.

The Contractor has two well-graded aggregate optional incentives available as follows:

(1) Percent Retained Gradation Band in accordance with Table 2301-9.

Table 2301-9
8-18 or 7-18 Percent Retained Gradation Band

Sieve Size	8-18 % Retained	7-18 % Retained
2 in [50 mm]	0%	0%
1½ in [37.5 mm]	≤9%	≤9%
1 in [25 mm]	8–18%	7–18%
¾ in [19 mm]	8–18%	7–18%
½ in [12.5 mm]	8–18%	7–18%
⅜ in [9.5 mm]	8–18%	7–18%
No. 4 [4.75 mm]	8–18%	7–18%
No. 8 [2.36 mm]	8–18%	7–18%
No. 16 [1.18 mm]	8–18%	7–18%
No. 30 [600 µm]	8–18%	7–18%
No. 50 [300 µm]	≤13%	≤13%
No. 100 [150 µm]	≤8%	≤7%
No. 200 [75 µm]	≤8%	≤7%

(2) Gradation Zone II-A of the Coarseness Factor Chart in accordance with Table 2301-10.

Table 2301-10
Coarseness Factor Boundaries – Zone II-A

Coarseness Factor (CF) *	Workability Factor (WF) ‖
52	34–38
68	32–36

* Coarseness Factor (CF) is defined as follows:

$$CF = \frac{\text{Combined \% retained above 3/8 in [9.5 mm] sieve}}{\text{Combined \% retained above No.8 [2.36 mm] sieve}} \times 100$$

‖ Workability Factor (WF) is defined as follows:

WF = Combined % passing No. 8 [2.36 mm] sieve

The Engineer will use statistical analysis of the Contractor's combined aggregate gradation samples for well-graded aggregate on a lot basis representing one day's paving. The lot will represent the cumulative average of the sublot values on each sieve for the gradation band or the cumulative average of the sublot values of the coarseness factor and workability factor for the coarseness factor chart.

An optional incentive is available to the Contractor provided a concrete mixture is designed and produced with a well-graded aggregate gradation that meets one of the following in accordance with Table 2301-11. The Contractor may achieve only one of the optional incentives for any single lot.

Table 2301-11
Well-Graded Aggregate Optional Incentive

Gradation Options	Payment incentive/disincentive per cu. yard [cu. m]
8-18 Retained	$2.00 per cu. yd [$2.60 per cu. m]
7-18 Retained	$0.50 per cu. yd [$0.65 per cu. m]
Gradation Zone II-A	$2.00 per cu. yd [$2.60 per cu. m]

2301.3 CONSTRUCTION REQUIREMENTS

Use "slipform" as the standard construction method for concrete paving, unless otherwise specified in the contract or allowed by the Engineer.

A.1 High-Early Strength Sections

For early use of the pavement as required by the Engineer, construct a section of pavement of high-early strength concrete in accordance with 2301.2.D, "Concrete Mix Design Requirements," at important road crossings, intersections, driveway entrances, or other locations as shown on the plans or directed by the Engineer. Take precautions to satisfactorily finish, cure, and protect high-early strength concrete pavements.

A.2 Operation and Supervision

Notify the Engineer at least 24 h before placing concrete to allow for inspection. Do not place concrete until the Engineer approves preparations for concrete placement. If the Contractor fails to notify the Engineer at least 24 h before concrete placement, the Engineer may not allow concrete placement in accordance with 1503, "Conformity with Contract Documents," and 1512, "Unacceptable and Unauthorized Work."

Provide paving operations supervision in accordance with 1506, "Supervision by Contractor." Provide an organizational chart listing names and phone numbers of individuals and alternates responsible for mix design, quality control administration, and inspection to the Engineer. Post the organizational chart in the Contractor's on-site facility.

Provide a manufacturer's manual explaining the operation and adjustments of the major pieces of power operated equipment used.

A.3 Plant Certification

Before beginning concrete production and in conjunction with the Engineer, perform a thorough on-site inspection of the concrete plant and complete Mn/DOT Form 2164, "Concrete Paving Plant Contact Report." Sign the report to certify compliance with the paving requirements and to certify review of the continual maintenance of the plant.

Calibrate and correlate the testing equipment in accordance with 2461.3.D, "Batching Requirements."

A.3.a Combination Plant Lab – Office Requirements

The Concrete Paving Contractor QC technicians and the Department QA technicians will equally share a combination plant lab – office during concrete paving.

For concrete paving projects in accordance with 2301.2.D.2, "Concrete Pavement ≥ 3,500 cu. yd [2,900 cu. m]," provide a separate combination plant lab – office in accordance with 1604, "Plant Inspection – Commercial Facility," 2031.3.A, "Basic Requirements," and 2031.3.C.4, "Type D Service," except as modified by the following characteristics and requirements:

(1) Located at the plant site within 100 yd [91 m] from the batch plant or other location, as approved by the Engineer,
(2) Plant lab and plant office areas separated and isolated by a wall,
(3) Total plant lab-office floor area, based on exterior dimensions, of at least 224 sq. ft [21 sq. m],
(4) Plant lab floor area, based on exterior dimensions, of at least 144 sq. ft [13.5 sq. m],
(5) Plant office floor area, based on exterior dimensions, of at least 80 sq. ft [7.5 sq. m],
(6) Plant lab furnished in accordance with 2031.3.B.2, "Field Laboratory Furnishings," except as modified by the following:

    (6.1) One sturdily-built workbench or countertop at least 30 in × 144 in [0.75 m × 3.65 m],
    (6.2) Shelf space above workbench or countertop or at other convenient locations, totaling at least 8 linear ft [2.5 m] × 8 in [0.2 m],
    (6.3) Electronic scales of sufficient size to weigh the samples for all required materials testing, and
    (6.4) At least eight (8) burners to perform required aggregate testing per the Schedule of Materials Control.

(7) Plant office furnished in accordance with 2031.3.B.1, "Field Office Furnishings," except as modified by the following:

(7.1) Two desks, one for the Department and one for the Contractor, with total exterior dimensions of at least 30 in × 60 in [¾ m × 1.50 m],
(7.2) At least six desk chairs,
(7.3) File cabinets with at least two file drawers, one for the Department and one for the Contractor,
(7.4) A telephone capable of providing email, and
(7.5) A printer with scanning and copying capabilities.

Do not begin concrete paving operations until the Engineer approves the combination plant lab–office.

A.4 Sampling and Testing

Provide a Mn/DOT Certified Concrete Plant Level 2 Technician to oversee testing and plant operations and to remain on-site during concrete production or have cellular phone availability.

Provide technicians with certifications at least meeting Mn/DOT Concrete Plant Level 1 to perform all of the duties in accordance with the Concrete Manual. The Engineer will provide technicians with certifications at least meeting Mn/DOT Concrete Plant Level 1 to perform all of the duties in accordance with the Concrete Manual.

Perform testing in the accordance with the Concrete Manual and determine testing rates in accordance with the requirements of the Schedule of Materials Control. The Engineer performs testing in accordance with the Concrete Manual and determines testing rates meeting the requirements of the Schedule of Materials Control.

Take samples randomly using ASTM D 3665, Section 5.

A.5 Contractor Charting

Maintain and keep control charts current. Provide and display easily readable sized charts (letter-sized paper) on the testing facility wall or store in a 3-ring binder. Plot the following information on control charts using a method approved by the Engineer:

(1) Composite gradation,
(2) Air content (QC and QA),
(3) Moisture content of aggregates, and
(4) Water/cement ratio.

Also include the following information on the charts:

(1) Date,
(2) Time,
(3) Lot and sublot,
(4) Admixture dosage adjustments, and
(5) Other data necessary to facilitate control of the process.

Provide all reports, records, and diaries developed during the progress of construction activities to the Engineer. Provide all batch tickets and test results to the Engineer on a daily basis. The Engineer may suspend plant operations if the Contractor fails to provide daily test results.

B Subgrade and Aggregate Base Preparations

Prepare the subgrade and aggregate base in accordance with 2112, "Subgrade Preparation," and 2211, "Aggregate Base," and the following:

Fine grade the subgrade to the shape and grade shown on the plans, allowing construction of the pavement to the thickness and cross section shown on the plans. Use an approved fine grading machine mounted on crawler tracks.

Shape and maintain the shoulders to allow surface water to drain away from the pavement and off the shoulders.

C Setting Forms

Provide forms meeting the following requirements and characteristics:

(1) Steel, straight edge sides,
(2) Depth equal to the pavement thickness shown on the plans,
(3) Smooth and free of localized indentations and deformities,
(4) Top face with deviations no greater than ⅛ in [3 mm] in any 10 ft [3 m] section,
(5) Faces of straight forms with deviations no greater than ¼ in [13 mm] in any 10 ft [3 m] section,
(6) Side forms containing no bends or damaged sides,
(7) Forms containing no damaged joint locks or pin pockets, and
(8) Form lengths at least 10 ft [3 m] long with horizontal joint and base width equal to the depth of the forms.

For pavements with radii no greater than 100 ft [30 m], use flexible or curved forms approved by the Engineer. Provide devices to securely set forms and withstand operation of the paving equipment without springing, settlement, or lateral displacement. Provide forms with joint locks to tightly join the ends of abutting form

sections. Connect individual form sections using methods that create a continuous form.

Set the forms to the alignment and grade shown on the plans for a distance equal to at least 3 h ahead of concrete placement.

Compact the foundation before placing the forms in accordance with 2301.3.B, "Subgrade and Aggregate Base Preparations." Ensure the forms have a firm and uniform bearing over the entire base area, are tightly joined and securely staked, and are clean and free of accumulations of hardened concrete. Coat the contact faces of the forms with a form coating material in accordance with 3902, "Form Coating Material," before placing the concrete.

During a rain event, remove and reset the forms as necessary to allow drainage.

D Concrete Equipment and Paving Operations

Provide self-propelled spreading and finishing machines capable of consolidating and finishing the concrete, and producing a finished surface meeting the requirements specified in 2301, "Concrete Pavement."

D.1 Slipform Construction

Place concrete using a slipform paver or combination of pavers designed to spread, consolidate, screed, and float-finish the freshly placed concrete with minimum hand finishing. Provide a slipform paver with a non-oscillating extrusion plate with an adjustable angle of entry.

Place the concrete pavement before placing curb and gutter.

If the sequence of operations includes placing the curb and gutter before the concrete pavement, submit a jointing plan to the Engineer for approval before placing the curb and gutter.

Consolidate the full width and depth of concrete pavement placed by a single pass of a series of internal vibrators. Operate full-width vibrators from 3,600 VPM to 7,000 VPM [60 Hz to 117 Hz] in concrete, and from 4,150 VPM to 8,000 VPM [70 Hz to 133 Hz] when checked in air. Deliver the vibrator impulses directly to the concrete and operate at an intensity to consolidate the concrete uniformly throughout the entire depth and width of the concrete. The Contractor may increase the vibrator frequency as approved by the Engineer. Perform additional testing as directed by the Engineer at no additional cost to the Department. If the vibrator fails, suspend operations and remove unconsolidated concrete.

Regulate the rate of progress of the vibratory equipment and the duration of the application to fully, but not excessively, vibrate the concrete. If the forward progress of the paver stops, suspend the operation of vibrators.

Attach vibrators to spreading or finishing equipment. Do not allow vibrators to come in contact with preset dowel basket assemblies, the grade, pavement reinforcement, or side forms. Do not allow the operation of vibrators to cause separation or segregation of the mix ingredients, including the downward displacement of large aggregate or the accumulation of laitance on the concrete surface. The Contractor may reduce the vibration frequency within the specified range if reducing the forward motion of the paver to avoid segregation of the concrete mix. Connect the power to all vibrators so that they cease when the machine motion is stopped. Stop paving operations if a vibrator fails to operate within the range specified above.

Provide an electronic monitoring device meeting the following characteristics and requirements to display the operating frequency of each individual internal vibrator for concrete pavement placed by the slipform method:

(1) Contains a readout display near the operator's controls; visible to the paver operator and to the Engineer,
(2) Operates continuously as the paving machine operates,
(3) Displays all the vibrator frequencies with manual and automatic sequencing for each of the individual vibrators, and
(4) Records the following at least every 25 ft [7.62 m] of paving or at least every 5 min of time:

    (4.1) Clock time,
    (4.2) Station location,
    (4.3) Paver track speed, and
    (4.4) Operating frequency of individual vibrators.

Provide an electronic copy containing the record of data after the completion of the concrete paving operation. Provide vibration data daily as directed by the Engineer.

Operate the slipform paver with a continuous forward movement, and coordinate all operations of mixing, delivering, and spreading concrete to provide uniform progress with minimal stopping and starting of the paver.

Equip the paver with automatic grade control capable of maintaining the elevation shown on the plans at both sides of the paver by controlling the elevation of one side and controlling the crown, or by controlling the elevation of each side independently. Use an erected string line to achieve the grade reference.

Tightly stretch a wire or string line set parallel to the established grade for the pavement surface to achieve the grade reference. Set the control reference and support the line at intervals to maintain the established grade and alignment.

D.2 Fixed Form Construction

Place concrete using one or more machines to spread, screed, and consolidate between previously-set side forms. Accomplish vibration of these areas using hand-held or machine-mounted internal vibrators.

If not using an electronic monitoring device, use a tachometer or similar device to demonstrate to the Engineer that the paving equipment vibration meets the requirements in this section.

Use hand-held vibrators to consolidate concrete adjacent to side forms and fixed structures. Operate the hand-held vibrators at a speed of at least 3,600 VPM [60 Hz]. Do not allow the vibrator head to contact the joints, load transfer devices, reinforcement, grade, or side forms. If the vibrator fails, suspend operations and remove unconsolidated concrete.

Continue vibration to achieve adequate consolidation, without segregation, for the full depth and width of the area placed.

Provide an adequate number and capacity of machines to perform the work at a rate equal to the concrete delivery rate.

Strike-off concrete with a clary screed, unless otherwise approved by the Engineer. Finish small or irregular areas that are inaccessible to finishing equipment using other methods as approved by the Engineer.

Discontinue any operation that causes displacement of the side forms from the line or grade or causes undue delay, as determined by the Engineer, due to mechanical difficulties.

E Batching and Mixing

Batch and mix the concrete in accordance with 2461, "Structural Concrete," and the following:

E.1 Batching Requirements

Perform the initial spot check of the measuring equipment in accordance with the Concrete Manual for accuracy and sensitivity before starting production operations. Provide a copy of the inspection certificate to the Engineer.

Provide to the Engineer a computerized batch ticket that includes the following:

(1) Date,
(2) State project number (SP) or (SAP),
(3) Time concrete was batched,
(4) Quantity of concrete in this load,
(5) Running total of each type of concrete, each day for each project,
(6) Mix number,
(7) Labels identifying each material that correlates with the contractor mix design, including cementitious and admixture abbreviations or Mn/DOT 5 digit pit numbers),
(8) Target weight of materials,
(9) Actual batched weights of materials,
(10) Temper water, and
(11) Total water weight.

If satisfactory finishing and curing of the pavement does not occur, as determined by the Engineer, suspend batching and mixing operations.

E.2 Cement Cutoff and Yield

Submit the cement records to the Engineer. Make positive cement cutoffs, except if providing cement proportioned in a certified ready-mix plant and delivering the batch to the construction site in truck mixers, in accordance with the following:

(1) Perform individual cement cutoffs at the following intervals:

(1.1) After using 500,000 lb [250 ton] of cement,
(1.2) Before using 2,000,000 lb [1,000 ton] of cement,
(1.3) Using at least every 3,000,000 lb [1,500 ton] or once a week, whichever provides the longer time interval between cutoffs.

(2) If delivering bulk cement directly to the concrete batching plant in railroad cars or sealed transport trucks, submit copies of the freight bills to the Engineer on the same day received from the transporting company.
(3) Advise the Engineer of the method and schedule of cement unloading. Do not unload cement until the Engineer approves the operation.

The Engineer will verify the following:

(1) Individual cutoffs do not show an underrun in cement usage greater than 1.5 percent of the quantity specified,
(2) The final cutoff does not show an overall underrun greater than 1.0 percent, and

(3) If either one or both of these limitations are exceeded, the Engineer will not pay for the concrete represented at the contract unit price.

The Engineer may reject defective concrete in accordance with 1503, "Conformity with Contract Documents," and 1512, "Unacceptable and Unauthorized Work," or the Department may pay for the defective concrete at an adjusted unit price at the same ratio to the contract unit price as the quantity of cement used to the quantity of cement required less the allowable underrun. If the cement exceeds the limitations for individual cutoff and final cutoff, the Department may apply the price adjustment to the cutoff value that produces the greatest monetary deduction.

F Placing Concrete

Dump or discharge concrete without causing grade displacement or damage to the existing asphalt or bond breaker layer. Repair damage to the grade, existing asphalt or bond breaker layer as approved by the Engineer. Provide protection for turning concrete trucks.

Maintain the grade in a moist condition until placement of concrete.

Construct mainline pavement in a single layer of concrete. Place the concrete pavement in one complete pass of the paving machine to minimize the need for hand finishing.

Coordinate paving operations for mixing, delivering, spreading, and extruding the concrete to provide uniform progress of the paver. Use sufficient trucks to ensure a steady forward progress of the paver. If the forward movement of the paver stops for a period long enough to create a cold joint or honeycombing, construct a header joint in accordance with 2301.3.H.3, "Constructing Headers."

Do not add water to the surface of the concrete to aid in finishing without the approval of the Engineer.

When placing concrete on asphalt or asphalt bond beakers, comply with the following:

(1) Do not place concrete on an asphalt surface with an asphalt surface temperature greater than 120 °F [50 °C].
(2) Maintain the asphalt surface in a moist condition as necessary and at a surface temperature not greater than 120 °F [50 °C] before placing the concrete. The Engineer will allow the Contractor to apply water, whitewash of hydrated lime and water, or both to cool the asphalt surface, or other methods allowed by the Engineer.

(3) Before placing concrete on a milled asphalt surface, clean the milled surface by sweeping and patch as shown on the plans in accordance with 2231, "Bituminous Surface Reconditioning," or as directed by the Engineer.

When placing concrete adjacent to in-place concrete pavement, protect the following:

(1) All ends of transverse joints $^{3}/_{16}$ in [5 mm] or wider to the satisfaction of the Engineer. The Engineer will allow sawing through the existing joint when sawing the newly placed concrete, and
(2) The in-place pavement to prevent damage.

Do not allow the edges of the pavement, including longitudinal joints, to deviate from the line shown on the plans by greater than ½ in [13 mm] at any point.

Set manhole and catch basin frames or rings to the elevation shown on the plans during the paving operations.

F.1 Consistency

For slipform concrete pavement placement, place the concrete with a slump value that optimizes placement, except ensure the concrete does not slough or slump and is adequately consolidated and meets all other requirements of 2301, "Concrete Pavement." Maintain the concrete at a uniform consistency. The Engineer will not allow an edge slump greater than ⅛ in [3 mm] or irregular edge alignment.

For fixed form placement, place the concrete with a slump no greater than the maximum allowable slump in accordance with 2461.3.G.6, "Consistency."

F.2 Air Content

Maintain the air content of Type 3 paving concrete at the specified target of 7.0 percent ±1.5 percent of the measured volume of the plastic concrete in accordance 1503, "Conformity with Contract Documents."

Make any adjustments immediately to maintain the desired air content.

Measure the air content after placement on the grade but before consolidation.

If using the slipform paving method, establish an air-loss correction factor (ACF) to determine the air content after consolidation once per half day of paving. Apply the ACF to tests taken before consolidation to estimate the air content after consolidation. Place concrete with an air content of at least 5.0 percent after consolidation.

Take the following actions for the following air content test results with the ACF applied or a test taken after consolidation:

(1) A single test (QC or QA) from 5.0 percent to 5.5 percent, adjust the mix design to obtain an air content greater than 5.5 percent without stopping production.
(2) Two consecutive tests (QC or QA) from 5.0 percent to 5.5 percent, make immediate adjustments to obtain an air content greater than 5.5 percent or stop production. Test every truck until the air content test results meet the requirements. Test at least three additional trucks after obtaining the correct air content.
(3) Any test (QC or QA) less than 5.0 percent, make immediate adjustments to obtain an air content greater than 5.5 percent or stop production. Test every truck until the air content meets the requirements. Test at least three additional trucks to ensure the concrete remains within compliance. Perform additional testing on the hardened concrete as required by the Engineer in conjunction with the Concrete Engineer.

F.2.a Non-Conforming Material

Only place Type 3 concrete meeting the air content requirements in the work. If the Contractor places Type 3 concrete not meeting the air content requirements into the work, the Engineer will not accept nonconforming concrete at the contract unit price. For concrete not meeting the required air content, the Engineer will make determinations regarding the disposition, payment, or removal. The Department will adjust the contract unit price for the contract pay item of the concrete in accordance with Table 2301-12. When there is not a separate structural concrete contract unit price for a contract item, the Department will reduce payment based on a concrete price of $60.00 per cu. yd [$78.00 per cu. m] or the Contractor-provided invoice amount for the concrete in question, whichever is less.

Table 2301-12 Paving Concrete	
Air Content Before Consolidation, %	**Adjusted Contract Unit Price**
>10.5	The Department will pay 75 percent of the contract unit price for the concrete represented and placed as approved by the Engineer.
>8.5 – ≤10.5	The Department will pay 95 percent of the contract unit price for the concrete represented and placed as approved by the Engineer
5.5 – 8.5	The Department will pay 100 percent of the contract unit price for the concrete represented and placed as approved by the Engineer
>4.5 – <5.5	The Department will pay 75 percent of the contract unit price for the concrete represented and placed as approved by the Engineer
>4.0 – ≤4.5	The Department will pay 25 percent of the contract unit price for the concrete represented and placed as approved by the Engineer. If the Engineer, in conjunction with the Concrete Engineer, determines the surface is exposed to freeze-thaw cycling, coat the concrete with an epoxy penetrant sealer from the Approved/Qualified Products List.
≤ 4.0	Remove and replace concrete in accordance with 1503, "Conformity with Contract Documents" and 1512, "Unacceptable and Unauthorized Work" as directed by the Engineer. If the Engineer, in conjunction with the Concrete Engineer, determines the concrete can remain place, the Engineer will not pay for the concrete and if the Engineer determines the surface is exposed to salt-brine freeze-thaw cycling, coat with an epoxy penetrant sealer from the Approved/Qualified Products List.

G Placing Reinforcement

Provide and place reinforcement meeting the following requirements and characteristics:

(1) Provide epoxy coated reinforcement in accordance with 2472, "Metal Reinforcement."

(2) Provide and place reinforcement bars including keyway bars, tie bars, taper steel, and stopper bars.
(3) Place keyways as shown on the plans.
(4) Provide and place supplemental pavement reinforcement as shown on the plans.
(5) Provide and place reinforcement bars on chairs, in stakes, utilizing tie bar basket assemblies or by appropriate equipment for depressing the bars to the specified location.
(6) For slipform paving, stake the tie bar steel to the roadbed, or use a mechanical device attached to the spreader or paver to place tie bar steel required for L1T joints as shown on the plans. Space and depress the tie bar steel to the depth and location shown on the plans. Do not place tie bars over a dowel bar assembly.

H Joint Construction

Unless otherwise shown on the plans, construct all joints perpendicular to the grade. Place dowel bars parallel to the grade and parallel to the centerline of the pavement.

H.1 Dowel Bar Placement

Provide dowel bar assemblies manufactured in single units for the lane widths shown on the plans, unless otherwise approved by the Engineer. Do not use more than two assembled sections in any one joint for ramps, loops, and tapered sections.

Secure the dowel bar assemblies to prevent movement during concrete placement in accordance with Standard Plate 1103 and the following:

(1) If placing dowel bar assemblies on asphalt or asphalt bond breaker layers, secure the assemblies with at least seven anchorage points. Place four of the anchorage points on the assembly side facing the front of the paver. Fasten the assemblies in accordance with the following:

(1.1) Place pins or fasteners of sufficient length and shank diameter of at least 0.177 in [0.45 cm] to penetrate through the asphalt bond breaker layer and into the concrete at least 1 in [25 mm] or at least 2 in [50 mm] into the in-place asphalt layer.
(1.2) Before paving, demonstrate the fastening method to the Engineer for approval.

Within 1 h before covering with concrete, coat the dowel bars with a thin uniform coating of a form coating material in accordance with 3902, "Form Coating Material."

Before placing the concrete, mark the location on both sides of each transverse joint as approved by the Engineer. Transfer the markings to the fresh concrete immediately after completing the final finishing operations.

The Contractor may use a mechanical dowel bar inserter to place dowel bars in the pavement as approved by the Engineer, in conjunction with the Concrete Engineer. Immediately before inserting the dowels, coat the dowels with a thin uniform coating of a form coating material in accordance with 3902, "Form Coating Material." If using a dowel bar inserter, initially and on each production day, demonstrate to the Engineer that the inserted dowel bars in the completed concrete pavement are parallel to the surface and centerline slab and are located at mid-depth of the slab thickness.

H.2 Joint Establishment

Space contraction joints at the intervals shown on the plans, except shorten the spacing at the following to provide panel lengths at least 5 ft [1.5 m]:

(1) Adjacent to header joints,
(2) Reinforced panels,
(3) Railroad grade crossings, and
(4) Free ends of pavement.

Provide either wet-cut saws referred to as "conventional concrete saws" or lighter weight dry-cut saws referred to as "early-entry concrete saws" capable of establishing joints sooner than the conventional saws.

Provide initial joint sawing as shown on the plans. Perform the initial sawing as soon as the concrete will support the joint sawing operation without raveling and before random cracking occurs.

Immediately after completing the joint sawing, use water under nozzle pressure to remove the sawing residue from each joint and the pavement surface.

If widening is necessary, do not widen the joints to full width until the concrete is at least 24 h old, or longer if the sawing causes raveling of the concrete.

Stake preformed joint filler material for expansion joints in place to maintain the position shown on the plans during concrete placement.

Extend transverse joints constructed in the pavement through the integrant curb.

H.3 Constructing Headers

Construct construction headers, temporary headers, and permanent headers as shown on the plans.

The Engineer will not allow incorporating any concrete accumulated in the grout box of the paver into the pavement. Construct all headers such that the concrete contained in the grout box is removed from the project. Use any approved construction header method as shown in the Standard Details.

Use internal vibration to consolidate the concrete along header joints before final finishing.

I Surface Finishing

Use a ⅜ in [10 mm] radius edging tool to finish edges of the pavement.

After consolidating, screeding, and floating the concrete, give the pavement surface a final finish texture in accordance with 2301.3.I.1, "Pavement Texture," unless the contract requires tining in accordance with 2301.3.I.2, "Pavement Tining."

I.1 Pavement Texture

Test the adequacy of the pavement skid resistance meeting the requirements of ASTM E 965-87, "Test Method for Measuring Surface Macrotexture Depth Using a Sand Volumetric Technique." Provide a texture depth of at least $^{1}/_{25}$ in [1.00 mm].

The Department defines a lot as pavement of a single lane. Establish a separate lot for each lane on the project.

The Department defines a sublot as the rate at which an individual measurement is taken over a given length. The Department considers a sublot as one lane wide, measured in accordance with the following:

(1) From the pavement edge to the adjacent longitudinal joint,
(2) From one longitudinal joint to the next, or
(3) In the absence of a longitudinal joint, between pavement edges.
(4) Each ramp and loop 18 ft [5.5 m] wide or less is considered a single lane.

The Engineer will break lots into sublots representing 1,000 linear ft [300 m] of pavement. Test the pavement surface at a point located transversely in the outside wheel path as determined by the Engineer. Test adjoining driving lanes at the same location. The Engineer will determine the locations using a random number multiplied by length of the sublot. If the project or individual lane results in less than three sublots, the Engineer will divide the project or individual lane lot into three sublots of equal length.

Complete surface texture testing no later than 24 h after pavement placement unless otherwise approved by the Engineer. Refer to Table 2301-13 for the acceptance criteria of texture depths below the specification limits.

Table 2301-13 Pavement Texture Depth	
Texture Depth Test Results for Individual Tests	**Acceptance Criteria**
$<{}^{1}/_{25}$ in to $\geq{}^{1}/_{32}$ in [<1.00 mm to ≥0.80 mm]	The Engineer will accept the work if the Contractor amends the operation to achieve the required depth of at least $^{1}/_{25}$ in [1.00 mm] as approved by the Engineer. If the Contractor fails to correct the operation, the Engineer will suspend the paving operation until corrections produce the required results.
$< {}^{1}/_{32}$ in [< 0.80 mm]	Perform concrete grinding of the pavement represented by this test to attain the necessary texture of $^{1}/_{25}$ in [1.00 mm] as required by the Engineer.

Run additional tests at 100 ft [30 m] intervals before and after the failing test location to determine the limits of any individual failing test.

I.2 Pavement Tining

Pull a carpet drag longitudinally along the pavement before the concrete attains its initial set to obtain the final finish. Mount the drag on a bridge. Provide a drag with the following dimensions:

(1) As wide as the concrete placed, and
(2) Longitudinal length with sufficient surface contact to produce a texture approved by the Engineer.

Provide an artificial grass type carpeting for the carpet drag meeting the following characteristics and requirements:

(1) Molded polyethylene pile face,
(2) Blade length from ⅝ in to 1 in [15 mm to 25 mm], and
(3) Total weight of at least 70 oz per sq. yd [2.35 kg per sq. m].

Provide a backing made of a strong, durable material not subject to rot with the backing adequately bonded to the facing to withstand the specified use.

Immediately after carpet dragging the pavement surface, use a mechanized device providing a randomized tine spacing from ⅝ in to 1 in [16 mm to 26 mm] to apply a transverse metal-tine texture to the pavement meeting the following dimensions:

(1) Width from ½ in to ⅛ in [2 mm to 3 mm], and

(2) Depth from ⅛ in to $^{5}/_{16}$ in [3 mm to 8 mm].

Do not dislodge coarse aggregate particles. The Contractor may use manual methods to achieve similar results on ramps and other locations as approved by the Engineer. The Contractor may use other texturing equipment to obtain an equivalent texture as approved by the Engineer.

The Engineer will not require metal-tine texturing on subsidiary paving areas such as cross-overs and parking lanes exempted by the Engineer, or on areas with speed limits no greater than 35 mph [55 km/h] as specifically exempted by the contract or the Engineer.

J Concrete Curing and Protection

After completing final finishing operations, cure all exposed concrete surfaces for at least 72 h. Extend the minimum curing period to 96 h when using fly ash or cementitious substitutions as defined in 2461.2.A.6, "Cementitious Substitutions." Use on of the following curing methods:

(1) Place the membrane curing compound conforming to 3754, "Poly-Alpha Methylstyrene (AMS) Membrane Curing Compound," or 3755, "Linseed Oil Membrane Curing Compound," within 30 minutes of concrete placement or once the bleed water has dissipated, unless the Engineer directs otherwise in accordance with 2301.3.J.1.a, "Membrane Curing Method." Place the membrane curing compound on the edges within 30 minutes after permanent removal of the forms or curing blankets, unless the contract requires otherwise.
(2) Place plastic curing blankets or completely saturated burlap curing blankets in accordance with 2301.3.J.1.b, "Curing Blanket Method," as soon as practical without marring the surface.

Whenever weather conditions are such as to cause unusual or adverse placing and finishing conditions or equipment failures occur, expedite the application of a curing method or temporarily suspend the mixing and placing operations, as the conditions require.

If necessary to remove the coverings to saw joints or perform other required work, and if the Engineer approves, remove the covering for the minimum time required to complete that work.

Failure to comply with the above provisions will result in the Engineer, in conjunction with the Concrete Engineer, applying a monetary deduction in accordance with 1503, "Conformity with Contract Documents." When there is not a separate contract unit price for Structural Concrete, the Department will apply a monetary

deduction of $30.00 per cu. yd [$39.00 per cu. m] or 50 percent of the Contractor-provided invoice amount for the concrete in question, whichever is less.

J.1 Curing Methods

J.1.a Membrane Curing Method

Before application, agitate the curing compound as received in the shipping container to obtain a homogenous mixture. Protect membrane curing compounds from freezing before application. Handle and apply the membrane curing compound in accordance with the manufacturer's recommendations.

Apply the curing compound in accordance with the following:

(1) At a rate of 1 gal per 150 sq. ft (1 L per 4 m^2) of surface curing area.
(2) Apply curing compound homogeneously to provide a uniform, solid, white opaque coverage on all exposed concrete surfaces (equal to a white sheet of typing paper). If using a Department approved curing compound with a non white base color, apply the compound to provide a uniform, solid, opaque consistency meeting the intent of the requirement in this section.
(3) If the curing compound is damaged during the curing period, immediately repair the damaged area by re-spraying.
(4) If the Engineer determines that the initial or corrective spraying result in unsatisfactory curing, the Engineer may require the Contractor to use the blanket curing method, at no additional cost to the Department.

Use the fully-automatic, self-propelled mechanical power sprayer approved by the Engineer to apply the curing compound in accordance with the following:

(1) Operate the equipment to direct the curing compound to the surface from two different lateral directions,
(2) Do not allow the sprayer to ride on the pavement surface,
(3) Ensure the sprayer covers the entire lane width and atomizes the curing compound, and
(4) If puddling, dripping, or non-uniform application occurs, suspend the operation to perform corrections as approved by the Engineer.

Use a fully automatic, self propelled mechanical power sprayer equipped with the following to apply curing compound as approved by the Engineer:

(1) A re-circulating bypass system that provides for continuous agitation of the reservoir material,
(2) Separate filters for the hose and nozzle,
(3) Check valve nozzles,
(4) Multiple or adjustable nozzle system that provides for variable spray patterns,

(5) A shield to control loss of material by wind action, and
(6) A spray-bar drive system that operates independently of the wheels or track drive system.

For applying the curing compound on pavements that are 10 ft [3 m] wide or less and irregular shaped surfaces, the Engineer will allow an airless spraying machine that complies with the following:

(1) A re-circulating bypass system that provides for continuous agitation of the reservoir material,
(2) Separate filters for the hose and nozzle, and
(3) Multiple or adjustable nozzle system that provides for variable spray patterns.

J.1.b Curing Blanket Method

After completion of the finishing operations and without marring the concrete, cover the concrete with curing blankets. Install in a manner that envelops the exposed concrete and prevents loss of water vapor. After the concrete has cured, apply membrane curing compound to the concrete surfaces that will remain exposed in the completed work.

J.2 Protection Against Rain

Protect the concrete from damage due to rain. Have available, near the site of the work, materials for protection of the edges and surface of the concrete. Should any damage result, the Engineer will suspend operations until corrective action is taken and may subject the rain-damaged concrete to 1503, "Conformity with Contract Documents," and 1512, "Unacceptable and Unauthorized Work."

J.3 Protection Against Cold Weather

If the national weather service forecast for the construction area predicts air temperatures of 34 °F [1 °C] or less within the next 24 h and the Contractor wishes to place concrete, the Contractor shall submit a cold weather protection plan.

Protect the concrete from damage, including freezing due to cold weather. Should any damage result, the Engineer will suspend operations until corrective action is taken and may subject the damaged concrete to 1503, "Conformity with Contract Documents," and 1512, "Unacceptable and Unauthorized Work."

J.3.a Cold Weather Protection Plan

Submit a proposed time schedule and plans for cold weather protection of concrete in writing to the Engineer for acceptance that provides provisions for adequately protecting the concrete during placement and curing. Do not place concrete until the Engineer accepts the cold weather protection plans.

J.4 Vibratory and Backfilling Protection

Protect newly placed concrete from damage by adjacent vibratory or backfilling operations for a minimum of 24 h. Resume vibratory and backfilling operations after the concrete has reached a minimum compressive strength of 2,000 psi [13.7 MPa] or a flexural strength of 250 psi [1.7 MPa]. Cast concrete control specimens in accordance with 2461.3.G.5, "Test Methods and Specimens." The Engineer will test the control specimens. If the Engineer discovers evidence of damaged concrete, the Engineer will suspend work until the Contractor corrects the work. The Engineer may reject damaged concrete in accordance with 1503, "Conformity with Contract Documents," and 1512, "Unacceptable and Unauthorized Work."

The Contractor may use hand-operated concrete consolidation equipment, walk-behind vibratory-plate compactors, rollers in "static" mode, and fine grading machines 24 h after placing the concrete, and other equipment as approved by the Engineer, in conjunction with the Concrete Engineer.

K Removal of Forms

Do not remove side forms of pavement and back forms on integrant curb earlier than 12 h after placing the concrete, unless otherwise approved by the Engineer. Remove forms without exerting shock or strain, including temperature variations, on the pavement or curb. Cure concrete in accordance with 2301.3.J, "Concrete Curing and Protection."

L Joint Sealing

Provide a joint sealant in accordance with 3725, "Hot-Poured, Extra-Low Modulus, Elastic-Type Joint and Crack Sealer," unless the type of sealant for contraction joints is otherwise specified in the contract.

If the concrete mixture contains Class B coarse aggregate as defined in 3137, "Coarse Aggregate for Portland Cement Concrete," do not seal joints with silicone.

Perform joint sealing as shown on the plans and in accordance with the following:

(1) Seal joints after the Engineer inspects and approves the joints;
(2) Perform joint sealing on surface dry concrete after cleaning the joints of debris, dirt, dust, and other foreign matter, including accumulations of concrete;
(3) Lightly sandblast the joint walls before final compressed air cleaning;
(4) Immediately before sealing the joints, clean the joints with a jet of compressed air under pressure of at least 85 psi [580 kPa];
(5) Seal transverse integrant curb joints with the same joint sealer used to seal the pavement joints;

(6) Seal joints in accordance with the tolerances shown on the plans;
(7) Provide backer rod material compatible with the sealer as shown on the plans; and
(8) Remove and replace sealer at joints filled above the permissible level shown on the plans at no additional cost to the Department.

Handle and place joint sealer material as recommended by the manufacturer and in accordance with the following requirements:

L.1 Hot-Poured Sealers

Heat hot-poured sealers in a double-boiler type kettle or melter. Fill the space between inner and outer shells with oil or other material as allowed by the manufacturer. Provide heating equipment with automatic temperature control, mechanical agitation, and recirculating pump. Use heating equipment as recommended by the manufacturer of the sealer material. Do not melt quantities of sealer material greater than the quantity used within the same day. After heating the sealer material to the application temperature, maintain the material temperature until placement. Place the sealer material within 4 h after the initial heating to the application temperature.

Apply sealant to the pavement at ambient pavement temperatures greater than 39 °F [4 °C].

L.2 Silicone Sealers

Install silicone sealers as recommended by the manufacturer.

L.3 Preformed Sealers

Provide preformed seals in one continuous length for each joint, except the Contractor may use butt splices in transverse joints at longitudinal joints.

Do not stretch the preformed sealer material in the installation process by greater than 5 percent of the joint length.

M Workmanship and Quality

M.1 Defective Pavement

The Department will pay for concrete pavement meeting the requirements and tolerances in accordance with this section at the contract unit price. Pavement that fails to meet the minimum requirements when tested in the prescribed manner is considered defective. The Department may reject or adjust the payment for defective concrete pavement in accordance with 1503, "Conformity with Contract Documents," and 1512, "Unacceptable and Unauthorized Work."

The Engineer will determine the limits of each individual defective pavement area. If adjusting the price for defective payment, the Engineer will measure the area to the nearest whole square yard [square meter], except the Engineer will consider areas less than 1 sq. yd [1 sq. m] as 1 sq. yd [1 sq. m]. The Engineer will determine the condition of each individual defective area of pavement based on the calculation of greatest deficiency within the area.

M.2 Random or Uncontrolled Cracking

Repair or replace pavement with random or uncontrolled cracks as directed by the Engineer. If repairing the pavement as directed by the Engineer, use a dowel bar load transfer technique in accordance with the Mn/DOT Concrete Pavement Rehabilitation Details. Submit the intended repair technique to the Engineer for approval. Perform pavement repairs at no additional cost to the Department. If the repair fails, replace the pavement at no additional cost to the Department. The Engineer will accept repairs in accordance with 1516, "Acceptance."

M.3 Pavement Smoothness – IRI (International Roughness Index)

Provide concrete pavement smoothness in accordance with 2399, "Pavement Surface Smoothness."

N Thickness Requirements

Provide pavement with a finished pavement thickness as shown on the plans or as modified, in writing, by the Engineer.

N.1 Procedure

Construct pavement to the thickness shown on the plans. On each project and on each roadbed of a divided highway, evaluate pavement thickness in accordance with the following:

(1) Contractor Quality Control Probing (QCP),
(2) Probe Verification Core (PVC), and
(3) Quality Acceptance Core (QAC).

The Department defines plan thickness lot (PTL) as concrete pavement of the same thickness added together lineally. Establish a separate PTL for each concrete plan thickness on the project.

The Department defines a sublot as the rate at which an individual measurement is taken over a given length. The Department considers a sublot as one lane wide, measured in accordance with the following:

(1) From the pavement edge to the adjacent longitudinal joint;
(2) From one longitudinal joint to the next;

(3) In the absence of a longitudinal joint, between pavement edges; or
(4) The Department considers a single lane to be each ramp and loop 18 ft [5.5 m] wide or less.

The Engineer will divide the PTL into sublots of 4,000 lineal lane ft [3,300 lineal lane m] to determine the QCP, PVC, and QAC locations. The Engineer will add partial sublots less than 2,000 ft [1,650 m] to the previous lot. The Engineer will consider partial sublots equal to or greater than 2,000 lineal lane ft [1,650 lineal lane m] as individual sublots. If the PTL for the entire project is less than 4,000 lineal lane ft [3,300 lineal lane m] the Engineer will consider the PTL as an individual sublot.

The Engineer will identify the QCP, PVC, and QAC thickness measurement locations in accordance with the following:

(1) Determine the longitudinal locations using random numbers multiplied by length of the sublot;
(2) Determine the transverse offset locations using a random number multiplied by the width of the traffic lane, ramp, or loop at the determined longitudinal location; and
(3) Adjust the location to ensure the Contractor takes no measurements within 1 ft [0.3 m] of the pavement edge and takes no measurements within 2 ft [0.60 m] of any transverse or longitudinal joint or other obstructions.

N.2 Contractor Quality Control Probing (QCP)

Measure the pavement thickness of freshly finished concrete pavement at a rate of at least four QCP measurements per sublot. Notify the Engineer before performing probing thickness measurements in the plastic concrete so they may inspect or observe the Contractor's QCP tests during the paving operations.

Provide daily summary reports listing the results of the day's QCP thickness measurements and additional probing results to the Engineer.

N.3 Contractor QCP Probing Equipment and Probing Method

Provide the following equipment as approved by the Engineer to perform QCP probing:

(1) Probing rod meeting the following characteristics and requirements:

(1.1) Non-flexing,
(1.2) Length capable of completely penetrating the pavement for measuring,
(1.3) Utilizes a circular or square top plate,
(1.4) Contains a centrally located hole in the top plate with a diameter allowing for easy maneuvering along the length of the probing rod, and

(1.5) Fitted with a locking device fixing the angle between the top plate and the probing rod at 90 degrees when locked.

(2) Base plate meeting the following characteristics and requirements:

(2.1) 10.5 in [267 mm] square 26 gage galvanized steel plates or 11.8 in [295 mm] diameter 28 gage high-strength steel circular plates, and
(2.2) Rigid when in place, allowing the probing rod to be pushed against it without flexing.

(3) Work bridge meeting the following characteristics and requirements:

(3.1) Spans the full width of the freshly laid concrete,
(3.2) Supports a person, and
(3.3) Height above the concrete allows for the use of the probing device.

(4) Tape measure accurate to nearest ⅛ in [even mm] and with a length capable of measuring the depth of penetration of the probing device into the plastic concrete pavement.

Perform probing in accordance with the following:

(1) Place the base plates at the randomly selected locations and anchor the plates to prevent movement during concrete placement. Mark the locations of the base plates to ensure ease of locating the plates after the paver has passed.
(2) Position the bridge at the selected locations to reach and locate each point.
(3) Assemble the probing device. Keeping the probing rod perpendicular to the pavement surface, insert the rod into the plastic concrete until the rod strikes the base plate.
(4) Slide the top plate down the probing rod until it contacts the pavement surface then lock to the probing rod.
(5) Withdraw the probing device.
(6) Measure the length of the probing rod inserted into the plastic concrete from the underside of the top plate to the end of the probing rod. Record this measurement to the nearest ⅛ in [even mm].

N.4 Quality Acceptance Testing – Coring

The Engineer will measure the pavement thickness of concrete for each sublot in accordance with the following:

(1) Probe Verification Core (PVC), and
(2) Quality Acceptance Core (QAC).

The Engineer will mark one of every four QCP measurement locations per sublot for a PVC. The Engineer will mark one QAC per sublot.

The Contractor will core the designated PVC and QAC locations.

N.5 PVC and QAC Coring Method

(1) Begin coring on concrete older than 7 days, when the control beams attain a flexural strength in accordance with Table 2301-1, or when the control cylinders attain a compressive strength of 3,000 psi [20.6 MPa]. Use 3U18 concrete or another concrete mix approved by the Engineer to fill the core holes within 72 h of coring at no additional cost to the Department. Provide traffic control for coring;
(2) Cut 4 in [100 mm] nominal diameter cores at marked locations. Lay the cores next to the holes in a curing condition. Protect the cores. Do not submit cores out of round, not perpendicular, or containing ridges;
(3) The Engineer will field measure the core thickness to the nearest ⅛ in [even mm], verify (Field ID Number) the cores, and record the field measurement on Mn/DOT Form 24327, "Field Core Report," or a computerized spreadsheet available on the Mn/DOT Concrete Engineering website;
(4) Pick up the cores, accompanied by the Engineer. Store the cores in a water tank heated from 60 °F to 80 °F [15 °C to 25 °C] at the Department field office. The Engineer will not require the storage of cores in a curing condition for concrete older than 28 days;
(5) The Engineer will transport the cores in a curing condition, unless older than 28 days, to the Mn/DOT Office of Materials and Road Research; and
(6) The Mn/DOT Office of Materials and Road Research will determine the pavement thickness by measuring the length of the PVC and QAC cores in accordance with the procedure on file at the Mn/DOT Office of Materials and Road Research. Following this procedure, the Mn/DOT Office of Materials and Road Research will use nine probes interconnected in a hydraulic linkage to obtain the average length of the core in one operation. The Mn/DOT Office of Materials and Road Research will record the core length to the nearest 0.05 in [1 mm].

N.6 Non-conforming thickness

The Department will base acceptance of the pavement thickness and price adjustment for deficient thickness on the combination of both lab measured PVC and QAC coring.

The Department defines the tolerance limit for pavement thickness as the plan thickness lot (PTL) minus ½ in [13 mm]. If the QCP measurement shows a thickness deficiency greater than PTL minus ½ in [13 mm], take a core at the location of the deficient QCP. If any core thickness measurement (PVC or QAC) shows a thickness

deficiency greater than PTL minus ½ in [13 mm], consider the pavement defective and take exploratory cores as directed by the Engineer.

The Department defines the defective pavement area as the entire area surrounding the deficient core within a traffic lane and between acceptable cores. The Department considers the pavement acceptable in the remaining areas as the increment where the cores show a thickness deficiency no greater than PTL minus ½ in [13 mm].

Take the first exploratory cores at any location within 10 ft [5 m] on each side of the deficient thickness location and at the same distance from the pavement centerline. Take an additional exploratory core in the adjacent traffic lane if the concrete was placed in the same operation. If the length of each of the first exploratory cores is at least equal to the PTL minus ½ in [13 mm], the Engineer will not require additional cores from this location. If any cores do not fall within the PTL minus ½ in [13 mm], take additional exploratory cores at 25 ft [10 m] intervals and at the same distance from the pavement centerline in the same lane as the original thickness measurement, as directed by the Engineer. Perform coring in the direction of the deficiency until obtaining a core with a length at least equal to the PTL minus ½ in [13 mm]. The Engineer will use exploratory cores to determine the extent of deficient pavement thickness for adjusting the contract unit price or requiring pavement removal and replacement.

For cores showing a pavement thickness greater than the PTL minus ½ in to 1 in [13 mm to 25 mm], the Contractor may choose one of the following:

(1) Remove and replace the defective pavement area at no additional cost to the Department, or
(2) Leave the pavement in place with a monetary deduction of $20 per sq. yd [$25 per sq. m] for the defective pavement area, as approved by the Engineer.

For cores showing a pavement thickness greater than PTL minus 1 in [25 mm], the Engineer, in conjunction with the Concrete Engineer, will determine whether the Contractor will remove and replace concrete pavement or leave the pavement in place at no cost to the Department and apply a monetary deduction of $20 per sq. yd [$25 per sq. m] for the defective pavement area in accordance with 1503, "Conformity with Contract Documents."

The Engineer will use the PVC and QAC cores to determine the final average plan thickness lot (PTL), except for the following:

(1) If exploratory cores are taken to identify the defective pavement area, substitute the two outside exploratory cores that are within PTL minus ½ in [13 mm] for the deficient PVC or QAC.

(2) If the length of a PVC or QAC exceeds the PTL plus 0.30 in [8 mm], the Engineer will limit the core length to the PTL plus 0.30 in [8 mm].

The Engineer will consider the pavement thickness as conforming provided the deficiency of the final average PTL does not exceed PTL minus 0.10 in [3 mm].

If the final average PTL is deficient by more than the PTL minus 0.10 in [3 mm], the Department will pay for the pavement in the PTL at the contract unit price less the monetary deductions in Table 2301-14, excluding areas of defective pavement:

Table 2301-14
Deductions for Thickness Deficiencies

Thickness Deficiency Exceeding Permissible Deviations, *in [mm]*	**Adjusted contract unit price per sq. yd [sq. m] of Payment**
0.00 – ≤ 0.10 [≤ 3]	None (tolerance)
0.10 – ≤ 0.20 [3 – ≤ 5]	$0.20 [$0.25]
0.20 – ≤ 0.30 [5 – ≤ 8]	$0.40 [$0.50]
0.30 – ≤ 0.40 [8 – ≤ 10]	$0.70 [$0.90]
0.40 – ≤ 0.50 [10 – ≤ 13]	$1.00 [$1.25]
0.50 – ≤ 1.00 [13 – ≤ 25]*	$20.00 [$25.00]

* Perform exploratory coring as required by the Engineer.

After Department thickness verification, the Department will test all of the cores for compressive strength at 60 days of age. The Department will test three of the cores from the entire project for rapid chloride permeability (RCP) in lieu of compressive strength testing for information only.

O Opening Pavement to Traffic

Do not open a new pavement slab to general public traffic or operate paving or other heavy equipment on it until the concrete has attained an age of 7 days, or it has reached a minimum flexural strength meeting the requirements of Table 2301-15, or minimum compressive strength of 3,000 psi [20.6 MPa], whichever is less as approved by the Engineer.

If the pavement joints are widened, seal the joints before operating paving or other heavy equipment and general public traffic on the pavement.

Cast the control specimens in accordance with 2461.3.G.5, "Test Methods and Specimens." Cure the control specimens in the same manner and under the same conditions as the pavement represented. The Engineer will test the control specimens in accordance with 2461.3.G.5, "Test Methods and Specimens."

Table 2301-15 Minimum Strength Requirements for Opening Pavements to Construction and to General Public Traffic	
Slab Thickness, *in [mm]*	**Flexural Strength, *psi [MPa]***
≤7.0 [175]	500 [3.4]
7.5 [190]	480 [3.3]
8.0 [200]	460 [3.2]
8.5 [215]	440 [3.0]
9.0 [225]	390 [2.7]
≥ 9.5 [240]	350 [2.4]

Perform operations on new pavement as approved by the Engineer and in accordance with the following:

(1) When moving on and off the pavement, construct a ramp to prevent damage to the pavement slab.
(2) Operate the paving equipment on protective mats to prevent damage to the pavement surface and joints. Before placing the protective mats, sweep the pavement surface free of debris.
(3) Operate equipment on a slab without causing damage. If damage results, suspend operations and take corrective action as approved by the Engineer. Do not operate the equipment wheels or tracks within 4 in [100 mm] of the slab edge.

2301.4 METHOD OF MEASUREMENT

A Concrete Pavement

If the contract includes the contract item *Concrete Pavement* or *Concrete Pavement High Early*, the Engineer will measure in accordance with the following:

(1) Measure the concrete pavement placed to a uniform cross-section thickness by the surface area of the pavement as constructed, including integrant curb;
(2) Verify the pavement thickness based on the final measurement of cores;
(3) Include measurements for concrete pavement without regard to grade, strength, or type of concrete, width, or thickness of the pavement in a single measurement, except if the plans include a contract item for high-early strength concrete; and
(4) Apply incentive or disincentive for *Concrete Pavement* based on the theoretical volume of concrete used by multiplying the measured square yard [square meter] of concrete by the thickness shown on the plans.

B Place Concrete Pavement

If the contract includes the contract item *Place Concrete Pavement*, the Engineer will measure in accordance with the following:

(1) Measure concrete pavement placed to a variable cross-section thickness by area based on specified dimensions, including integrant curb. This measurement will represent the surface area of the pavement as constructed.
(2) Verify the pavement thickness based on the lab measured cores.

B.1 Structural Concrete

If the contract includes the contract item *Structural Concrete* or *Structural Concrete High Early*, the Engineer will measure in accordance with the following:

(1) Measure structural concrete placed to a variable cross-section thickness by volume.
(2) Verify the volume measurements from the computerized batch ticket printouts from the plant, as verified by cement cutoffs and the consideration of any waste.
(3) Include the volume of all specified concrete pavements into a single item without regard to grade, strength, width, or thickness of the concrete pavement, except if the plans include a contract item for high-early strength concrete.
(4) Apply incentives or disincentives for *Structural Concrete* based on the cubic yard [cubic meter].

C Supplemental Pavement Reinforcement

The Engineer will measure supplemental pavement reinforcement over culverts, storm sewers, and water mains, by weight.

D Expansion Joints

The Engineer will separately measure dowelled expansion joints of each design designation as shown on the plans by length along the joint line.

E Reinforcement Bars

The Engineer will not separately measure keyway bars, tie bars, taper steel, stopper bars, and other reinforcement bars.

F Integrant Curb

The Engineer will separately measure integrant curb of each design by length.

G Dowel Bars

The Engineer will measure dowel bars by the actual number of individual dowels placed. The Engineer will not measure dowels included in the contract linear foot [meter] price for *Dowelled Expansion Joints, Design ___*.

H Concrete Coring

The Engineer will not separately measure the number of cores taken, identified, and delivered as required by the contract or directed by the Engineer.

2301.5 BASIS OF PAYMENT

A Concrete Pavement

Unless the plans include a separate contract item for work incidental to *Concrete Pavement*, the contract square yard [square meter] price for C*oncrete Pavement* includes the cost of constructing the pavement, including the cost of batch materials and mixing operations; plant-lab office; producing the concrete; fine grading; forming, including all headers; providing and installing keyway and keyway bars, tie bars, taper steel, stopper bars, and other reinforcement bars; delivering; depositing; placing; spreading; screeding; vibration monitoring; finishing; curing; and protecting the concrete.

If the plans include a separate contract item for *Concrete Pavement High-Early* or if the Contractor requests high-early and the Engineer approves, the Department will not provide extra compensation for the production of high-early strength concrete. The contract square yard [square meter] price for *Concrete Pavement High-Early* includes the cost of constructing the pavement, including the cost of batch materials and mixing operations; plant-lab office; producing the concrete; fine grading; forming, including all headers; providing and installing keyway bars, tie bars, taper steel, stopper bars, and other reinforcement bars; delivering; depositing; placing; spreading; screeding; vibration monitoring; finishing; curing; and protecting the concrete.

If the plans do not include a separate contract item for *Concrete Pavement High-Early* and the Engineer orders high-early concrete, the Department will pay for the additional cement at a rate of the invoice cost plus 15 percent.

B Place Concrete Pavement

Unless the plans include a separate contract item for work incidental to *Place Concrete Pavement*, the contract square yard [square meter] price for *Place Concrete Pavement* includes the cost of constructing the pavement, including fine grading; forming, including all headers; providing and installing keyway and keyway bars, tie

bars, taper steel, stopper bars, and other reinforcement bars; placing; spreading; screeding; vibration monitoring; finishing; curing; and protecting the concrete.

B.1 Structural Concrete

The Engineer will field calculate the volume of *Structural Concrete* and *Structural Concrete High Early* placed. Due to variations in the asphalt or asphalt bond breaker layer, the Contractor may request additional volume up to 102 percent of the Engineer's field calculated volume of *Structural Concrete*, *Structural Concrete High Early*¸ or both. The Engineer will verify additional volume of concrete from the computerized batch ticket printouts from the plant, with consideration of any waste. If the Engineer finds the Contractor's request for the additional volume valid, the Engineer will pay for the additional volume up to 102 percent of the calculated quantity. The contract cubic yard [cubic meter] price for *Structural Concrete* and *Structural Concrete High-Early* includes the cost of producing, delivering, and depositing the concrete, including the cost of the batch materials, mixing operations, and the plant-lab office. If the plans include a separate contract item for *Structural Concrete High-Early* or if the Contractor requests high-early and the Engineer approves, the Department will not provide extra compensation for the production of high-early strength concrete.

If the plans do not include a separate contract item for *Structural Concrete High-Early* and the Engineer orders high-early concrete, the Department will pay for additional cement at a rate of the invoice cost plus 15 percent.

C Other Concrete Items

The contract pound [kilogram] price for *Supplemental Pavement Reinforcement* includes the cost of providing and placing the metal reinforcement, including tie wires, supporting devices, and splicing.

The contract linear foot [meter] price for *Dowelled Expansion Joints, Design* ___ includes the cost of constructing the joints complete in place as shown on the plans, including the costs of providing and placing dowel bar assemblies, filler, and sealer materials.

The contract linear foot [meter] price for *Integrant Curb, Design* ___ includes the cost of forming and finishing the curb and protecting and curing the concrete.

The relevant contract unit price for *Concrete Pavement* or *Place Concrete Pavement* includes the cost of coring, including the cost of material, labor, equipment, delivery, core hole filling, and traffic control.

The Department will pay for concrete pavement on the basis of the following schedule:

Item No.:	Item:	Unit:
2301.504	Concrete Pavement ___ in [___ mm]	square yard [square meter]
2301.504	Concrete Pavement ___ in [___ mm] High-Early	square yard [square meter]
2301.504	Place Concrete Pavement ___ in [___ mm]	square yard [square meter]
2301.511	Structural Concrete	cubic yard [cubic meter]
2301.513	Structural Concrete High-Early	cubic yard [cubic meter]
2301.508	Supplemental Pavement Reinforcement	pound [kilogram]
2301.503	Dowelled Expansion Joints, Design ___	linear foot [meter]
2301.538	Dowel Bar	each
2301.541	Integrant Curb, Design ___	linear foot [meter]

2354 SEAL COAT — MICRO-SURFACING

2354.1 DESCRIPTION

This work consists of constructing micro-surfacing on a prepared pavement.

2354.2 MATERIALS

Micro-surfacing is a mixture of polymer modified asphalt emulsion, well-graded crushed mineral aggregate, mineral filler, water, and other additives.

A Asphalt Emulsion

Provide a polymer modified CSS-1h bituminous material in accordance with 3151, "Bituminous Material," and Table 2354-1:

Table 2354-1
Asphalt Emulsion Requirements

Quality	Test	Requirement
Residue after distillation*	AASHTO T59	≥62%
Softening point	AASHTO T53	≥ 135 °F [57 °C]
Penetration at 77 °F [25 °C]	AASHTO T49	40 – 90
Absolute viscosity at 140 °F [60 °C]	ASTM D 2171	≥800 Pa•s

* Distill at 350 °F ±9 °F [177 °C ±5 °C] for 20 min. Complete the entire distillation procedure within 60 min from the first application of heat. The Department will waive the cement mixing test.

Only use natural latex polymers or manmade latex polymers proven equal. For new synthetic latex polymer, require that the supplier build on a State highway 1 mile [1.6 km] of micro surfacing in accordance with this section to prove equality with natural latex. The State will review this test section with the supplier for 1 year to

determine if the manmade latex performs satisfactorily. The measures for satisfactory performance are less than 5 percent de-bonding, less than 5 percent flushing, and no re-rutting or shoving greater than $^{3}/_{16}$ in [0.48 cm] measured with a 6 ft [1.8 m] straightedge.

Use at least 3 percent polymer solids.

B Aggregate

Provide a Class A aggregate or Taconite Tailings in accordance with 3139, "Graded Aggregate for Bituminous Mixtures." The Contractor may use Class B aggregate blended with Class A aggregate or Taconite Tailings if using the following methods:

If blending aggregate types, ensure that material passing the ⅜ in [9.5 mm] sieve and retained on No. 16 [1.18 mm] sieve is at least 90 percent Class A, Taconite Tailings, or both by weight and meets the requirements of Table 2354-2 and Table 2354-3:

Table 2354-2
Aggregate Durability Requirements

Tests on Aggregate	Test	Requirement, %
Sand equivalent	AASHTO T 176	≥ 60
Abrasion resistance*	AASHTO T 96	≤ 30
Soundness (using $MgSO_4$) ‖	AASHTO T 104	≤ 25

* Use Grading C for Type 3 material. Use Grading D for Type 2 material.
‖ Perform the soundness test on the Class B aggregate of the blend, if applicable.

Table 2354-3 Percent Passing (AASHTO T 11, AASHTO T 27)				
Sieve Size	**Mn/DOT Type 1**	**Mn/DOT Type 2 ISSA* Type II**	**Mn/DOT Type 3 ISSA* Type III**	**QC TOLERANCES Percent in JMF for each sieve size**
⅜ in [9.5 mm]	100	100	100	—
No. 4 [4.75 mm]	100	90–100	70–90	±5.0
No. 8 [2.38 mm]	85–100	65–90	45–70	±5.0
No. 16 [1.18 mm]	72–92	45–70	28–50	±5.0
No. 30 [600 µm]	50–75	30–50	19–34	±5.0
No. 50 [300 µm]	35–55	18–30	12–25	±4.0
No. 100 [150 µm]	15–35	10–21	7–18	±3.0
No. 200 [75 µm]	5–15	5–15	5–15	±2.0
* International Slurry Surfacing Association				

C Mineral Filler

Provide portland cement or hydrated lime, based on the mix design results and in accordance with the following:

(1) Portland cement, Type I in accordance with 3101, "Portland Cement," and
(2) Hydrated lime in accordance with 3106, "Hydrated Lime."

D Water

Provide potable water in accordance with 3906, "Water for Concrete and Mortar."

E Mixture Requirements

E.1 Mix Design

Submit a complete mix design prepared by a qualified laboratory experienced in micro-surfacing technology, 10 business days before beginning production. List the source of materials used for the mix design. Show that the individual proportions of each of the materials, when combined, meet the mix design requirements of Table 2354-4:

Table 2354-4 Mix Design Test Requirements		
Test	**Description**	**Specification**
ISSA TB-114	Wet stripping	≥ 90
ISSA TB-100	Wet track abrasion loss, 1 h soak	≤ 1.8 oz/sq. ft [538 g/sq. m]
ISSA TB-100	Wet track abrasion loss, 6 day soak	≤ 2.6 oz/sq. ft [807 g/sq. m]
ISSA TB-144	Saturated abrasion compatibility	≤ 3 g loss
ISSA TB-113	Mix time at 77 °F [25 °C]	Controllable to ≥120 s
ISSA TB-113	Mix time at 100 °F [37.4 °C]	Controllable to ≥35 s

Provide a Job Mix Formula (JMF) containing from 5.5 percent to 10.5 percent of residual asphalt by dry weight of aggregate and 0.25 percent to 3.0 percent mineral filler by dry weight of aggregate.

If changing aggregate, aggregate blend, or asphalt emulsion sources, submit a new mix design to the Engineer.

E.2 Mix Design Format

Submit the final mix design with information in the following format:

(1) Source of each individual material.
(2) Aggregate:

  (2.1) Gradation,
  (2.2) Sand equivalent,
  (2.3) Abrasion resistance, and
  (2.4) Soundness.

(3) Field simulation tests:

  (3.1) Wet stripping test,
  (3.2) Wet track abrasion loss,
  (3.3) Saturated abrasion compatibility, and
  (3.4) Trial mix time at 77 °F [25 °C] and 100 °F [37.4 °C].

(4) Interpretation of results and the determination of a JMF:

  (4.1) Minimum and maximum percentage of mineral filler,
  (4.2) Minimum and maximum percentage of water, including aggregate moisture,
  (4.3) Percentage of mix set additive (if necessary),
  (4.4) Percentage of modified emulsion,
  (4.5) Residual asphalt content of modified emulsion, and
  (4.6) Percentage of residual asphalt.

(5) Signature and date.

2354.3 CONSTRUCTION REQUIREMENTS

A. Equipment

A.1 Mixing Machine

Provide a continuous micro-surfacing lay down machine. Provide a positive connection conveyer belt aggregate delivery system and an inter-connected positive displacement, water-jacketed gear pump to accurately proportion aggregate and asphalt emulsion. Locate the mineral filler feed to ensure that the proper amount of mineral filler drops on the aggregate before discharging into the pugmill. Provide a pugmill meeting the following characteristics:

(1) Capable of providing a continuous flow,
(2) Twin shaft,
(3) Multi-blade,
(4) At least 4 ft [1.2 m] long, and
(5) Blade size and side clearance meeting the equipment manufacturer's recommendations.

Introduce the asphalt emulsion within the first third of the mixer length to ensure proper mixing of materials before exiting from the pugmill.

Use a self propelled front feed and continuous loading machine with duel driving stations. Provide a remote forward speed control at the back mixing platform for the back operator to control forward speed and the level of mixture in the spreader box. Use sufficient transport units to assure a continuous operation during mix production and application.

Provide individual volume or weight controls for proportioning each material. Position the controls for access at any time. Use the controls to calibrate the operation before production and to determine the amount of each material used at any time.

Provide a water pressure system and nozzle type spray bar to spray water ahead of and outside the spreader box, if necessary. Dampen the surface. Do not create free flowing water ahead of the spreader box.

A.2 Spreader Box

Spread the mix uniformly, using a mechanical type spreader box, attached to the mixer and equipped with spiral augers mounted on adjustable shafts. Continually agitate and distribute the mixture to prevent stagnation, excessive material build-up, or lumps. Equip the spreader box with front and rear flexible seals to achieve direct

contact with the surface of the road. Use a secondary strike off attached to the spreader box to provide a smooth finished surface texture. Do not use burlap drags.

A.3 Rut Filling Box

Provide a rut filling box meeting the following characteristics:

(1) Steel V-configuration screed rut box,
(2) Commercially designed and manufactured to fill ruts,
(3) Capable of spreading the mixture at a width from 5 ft to 6 ft [1.5 m to 1.8 m], and
(4) Strike off to control crown.

A.4 Weighting Equipment

Use portable scales to weigh material certified in accordance with 1901.8, "Mass," and as modified as follows:

(1) Re-certify the scale after any change in location, and
(2) Randomly spot check the scale once a week or once per project, whichever is greater.

B Operations

B.1 Micro-surfacing Types

B.1a Rut Fill..... Mn/DOT Type 3

Rut fill pavement segments longer than 1,000 ft [305 m], if the average rut depth is greater than ½ in [12.7 mm]. Provide a rut box for each designated wheel track. Provide a clean overlap and straight edges between wheel tracks. Construct each rutted wheel track with a crown ¼ in [0.6 cm] per inch [centimeter] of rut depth to allow for proper consolidation by traffic.

B.1.b Scratch Course.....Mn/DOT Type 2 or Type 3, as selected by designer

Apply full lane width in one course. Use a metal strike off bar on the spreader box. Do not allow excess buildup or uncovered areas.

B.1.3 Surface Course..... Mn/DOT Type 2

Apply full lane width in one course. Do not allow excess buildup or uncovered areas.

B.2 Pre-Paving Meeting

Hold a pre-paving meeting with the Engineer on-site before beginning work to discuss the following:

(1) JMF,
(2) Equipment condition,
(3) Equipment calibration,
(4) Test strips,
(5) Detailed work schedule, and
(6) Traffic control plan.

B.3 Calibration

Calibrate each mixing machine before use. Maintain documentation showing individual calibrations of each material at various settings relating to the machine's metering devices. Supply materials and equipment, including scales and containers for calibration (ISSA MA 1). Recalibrate machines on the job after a change in aggregate or asphalt emulsion source.

B.4 Test Strip

Construct a test strip in a location approved by the Engineer.

For each machine used, construct a one-lane wide test strip 1,000 ft [305 mm] long. Begin construction after dark, at least 1 hr after sunset and at least 1 hr before sunrise. Compare the machines for variances in surface texture and appearance.

Do not allow the emulsion to reach temperatures greater than 122 °F [50 °C]. Do not construct the test strip until the emulsion temperature falls below 122 °F [50 °C].

If any of the follow elements of the system used with a job mix change or field evidence shows that the system is out of control, construct a new test strip:

(1) Type of emulsion,
(2) Type and size of aggregate,
(3) Type of mineral filler, and
(4) The lay down machine.

Allow traffic on the test strip within 1 hr after application, without any damage occurring. The Engineer will inspect the completed test strip after 12 hr of traffic to determine if the mix design is acceptable. The Contractor may begin full production after the Engineer accepts a test strip.

Instead of constructing a test strip, the Contractor may submit evidence of the successful construction of a test strip on another State project constructed during the same construction season, using the same mix design. Verify that the system used for the test strip on the other project must be identical to the proposed system.

B.5 Surface Preparation

Clean the surface immediately before placing the micro-surfacing.

B.6 Fog Seal

Apply fog seal to surfaces before the first course of micro surfacing. Provide a CSS-1 or CSS-1h emulsion in accordance with 3151, "Bituminous Material." Apply the material in accordance with 2357, "Bituminous Tack Coat," and the following:

(1) Use one part emulsion to one part water diluted at place of manufacture,
(2) Apply the diluted emulsion at a rate of 0.05 gal per sq. yd to 0.10 gal per sq. yd [0.23 L per sq. m to 0.45 L per sq. yd].

Do not apply the fog seal when the road surface or weather conditions are unsuitable, as determined by the Engineer. Limit the daily application of fog seal to the pavement area receiving micro surfacing that day. Do not open fog sealed areas to traffic until after applying and curing the first course of micro surfacing. Cure the fog seal before applying micro surfacing.

Protect drainage structures, monument boxes, and water shut-offs during the application of the fog seal and during micro-surfacing.

B.7 Surface Quality

Except for areas within 12 in [300 m] of the edge line, lane line, or center line, ensure the transverse cross section of the restored pavement surface is no greater than ⅜ in [9.5 mm] if measured using a 10 ft [3 m] straight edge or $^{3}/_{16}$ in [4.8 mm] if measured with a 6 ft [1.8 m] straight edge.

Construct the surface course without excessive scratch marks, tears, rippling, and other surface irregularities. Repair tear marks wider than ½ in [12.7 mm] and longer than 4 in [100 mm]. Repair tear marks wider than 1 in [25 mm] and longer than 1 in [25 mm]. Repair transverse ripples or streaks deeper than ¼ in [6.35 mm] if measured by a 10 ft [3 m] straight edge.

Construct longitudinal joints with no greater than ¼ in [6.35 mm] overlap thickness if measured with a 10 ft [3 m] straight edge, and less than 3 in [76 mm] overlap on adjacent passes. Locate longitudinal construction joints and lane edges to coincide with the proposed painted lane lines shown on the plans. Place overlapping passes on the uphill side to prevent water from ponding.

Construct transverse joints with no greater than ⅛ in [3 mm] difference in elevation across the joint if measured with a 10-foot [3-meter] straight edge.

Construct edge lines along curbs and shoulders, with no greater than 2 in [50 mm] of horizontal variance in any 100 ft [30.5 m] length. Do not allow runoff in these areas.

Stop micro-surfacing work if the system is out of control and cannot meet the requirements of this section. Correct the micro-surfacing system, as approved by the Engineer, before re-starting the work.

Protect drainage structures, monument boxes, and water shut-offs.

Make repairs to micro-surfacing defects to the full width of paving pass with spreader box. Do not perform hand repairs after micro surfacing mix has set.

B.8 Open to Traffic

Do not open the micro-surface to traffic until the micro-surface cures sufficiently to prevent pickup by vehicle tires. The Department considers properly constructed micro-surface as micro-surface capable of carrying normal traffic within 1 h of application without damage. Protect the new surface from potential damage at intersections and driveways. Repair damage to the surface caused by traffic at no additional cost to the Department.

Confirm that the micro-surface cured within 1 h on the first day of production, after the construction of the test strip. The Engineer will conduct three 1-hour spot checks. If a spot check fails, stop work and construct a new test strip. The Department will consider any spot check or test strip failure as unacceptable work in accordance with 1512, "Unacceptable and Unauthorized Work," and the Engineer will make a deduction in accordance with 2354.5, "Basis of Payment."

After successful completion of three, one hour spot checks on the first day of production, the Engineer will perform spot checks once a day as determined by the Engineer. If a 1-hour spot check fails, the Department will make a deduction in accordance with 2354.5, "Basis of Payment," and require the construction of a new test strip. After a test strip, the Engineer will perform the first day of production procedure.

B.9 Weather Limitations

Begin construction when the air and pavement surface temperatures are at least 50 °F [10 °C] and rising. Do not place micro-surfacing during rain or if the forecast indicates a temperature below 32 °F [0 °C] within 48 h of the planned micro-surfacing. Do not start work after September 15.

C Contractor Quality Control (QC) Testing

Perform Quality Control (QC) sampling and testing.

C.1 Emulsion

Provide material certification and QC test results for each batch of emulsion used. Include the supplier name, plant location, emulsion grade, and batch number on reports.

C.2 Aggregate

Determine the gradation, sand equivalence, and moisture content of the aggregate. Sample from the micro-surfacing machine at a rate of one per 500 ton [453.6 tonne] or at least one per day of mixture production.

C.2.a Gradation and JMF Tolerance

Run gradation tests meeting the requirements of AASHTO T11 and AASHTO T27 at the stockpile site. Report results to the Engineer on the same day as sampling. Provide companion samples as directed by the Engineer. The QC tolerances for the JMF are listed in Table 2354-1. The tolerance range does not extend the specification limits set in Table 2354-1.

C.2.b Sand Equivalent Test

Determine the sand equivalent meeting the requirements of AASHTO T 176 for each aggregate gradation test. Quality control tolerance is ±7 percent of the value established in the mix design (60 percent minimum). Run the sand equivalent test at the stockpile site. Report results to the Engineer on the same day as sampling.

C.2.c Moisture Content

Determine the moisture content of the aggregate. Perform additional testing upon a visible change in moisture. Use the average daily moisture to calculate the oven dry weight of the aggregate.

C.3 Asphalt Content

Randomly calculate and record the percent asphalt content of the mixture from the equipment counter readings, at least three times a day.

C.4 Design Application Rate

The design application rate shall be the total amount of micro-surfacing material placed to meet the requirements for cross section and surfacing. This amount will be the combination of all courses placed.

C.5 Documentation

Provide a daily report containing the following information to the Engineer within one working day:

(1) Date and air temperature at work start up;
(2) Beginning and ending locations for the day's work;
(3) Length, width, total area (square yard [square meter]) covered for the day;
(4) Application rate (pounds per square yd [kilograms per square meter], pounds [kilogram]) of aggregate;
(5) Daily asphalt spot check reports, gallons [liters] of emulsion, weight of emulsion (pounds per gallon [kilogram per liter]);
(6) Asphalt emulsion bill of lading;
(7) Beginning, ending, and total counter readings;
(8) Control settings, calibration values, percent residue in emulsion;
(9) Percent of each material, percent of asphalt cement;
(10) Calibration forms;
(11) Aggregate certification or shipment of tested stock report; and
(12) Contractor's authorized signature.

Sample and test the material in the stockpile to ensure the correct passing material is provided prior to starting micro-surfacing production. Perform tests according to referenced standards and maintain QC documentation. Provide QC documentation as directed by the Engineer and upon completion of the work.

D Department Quality Assurance (QA) Testing

The Department will perform QA sampling and testing.

D.1 Asphalt Emulsion

Sample the first shipment. Provide one sample for every 50,000 gal [200 cu. m] or 200 ton [181.4 tonne].

D.2 Aggregate

Determine the aggregate gradation. Sample at a rate of one per 1,500 ton [1,360 tonne] of aggregate used or at a rate of at least one sample per project, whichever is greater.

Determine the moisture content of the aggregate. Sample at a rate of at least once per day.

2354.4 METHOD OF MEASUREMENT

The Engineer will measure the *Bituminous Material for Micro-Surfacing* and undiluted *Bituminous Material for Fog Seal* by volume at 60 °F [15 °C].

The Engineer will measure the Micro-Surfacing Rut Fill, Micro-Surfacing Scratch Course, and Micro-Surfacing Surface Course by weight [mass] of oven dry weight of aggregate.

2354.5 BASIS OF PAYMENT

The contract gallon [liter] price for the accepted quantity of *Bituminous Material for Micro-surfacing* includes the costs of additives as indicated above and constructing the micro-surfacing as shown in the plans.

The Department will deduct $5,000 from the contract amount for each spot check failure and anytime there is evidence of the system being out of control. The Engineer's decision will be final. If the test strip fails, the Department will deduct $5,000 from the contract amount.

The contract gallon [liter] price for fog seal includes the cost of asphalt emulsion and placement.

The Department will calculate price reductions for failing gradations based on 2 percent of the unit price per ton [metric ton] for each 1 percent passing result outside of a QC tolerance requirement as specified in Table 2354-1 or outside of a gradation range for all sieves. The Department will apply this price reduction schedule for micro surfacing construction to non-warranty work.

The Department will pay for seal coat — micro-surfacing on the basis of the following table:

Item No.:	Item:	Unit:
2354.503	Bituminous Material for Micro-Surfacing	gallon [liter]
2354.504	Micro-Surfacing Rut Fill	ton [metric ton]
2354.504	Micro-Surfacing Scratch Course	ton [metric ton]
2354.504	Micro-Surfacing Surface Course	ton [metric ton]

2355 BITUMINOUS FOG SEAL

2355.1 DESCRIPTION

This work consists of constructing a fog seal on a prepared surface as shown on the plans, except over new chip seals.

2355.2 MATERIALS

A Bituminous Material

Provide bituminous material supplied from a source listed on the Approved/Qualified Products List and meeting the following requirement:

(1) CSS-1h diluted to a ratio of one part water to one part emulsion, or
(2) CRS-2Pd as shown on the plans.

Dilute during manufacture. Do not dilute in the field.

B Emulsified Asphalt

Provide CSS-1h bituminous material for fog seal in accordance with 3151.D, "Cationic Emulsified Asphalt." Dilute asphalt emulsion during manufacture. Do not dilute in the field.

Provide emulsified asphalt meeting the requirements of AASHTO M-316-99 CRS-2Pd and the following modifications:

(1) Distill the Polymer-Modified Cationic Emulsified Asphalt (CRS-2P) at 400 °F [205 °C] for 20 min.
(2) Provide CRS-2P, produced using polymer modified base asphalt only. Do not use a modified latex or an emulsified asphalt not meeting this requirement.
(3) Dilute the CRS-2P to a ratio of three parts emulsion to one part water during manufacture. Do not dilute in the field.

C Fog Seal

Provide the type of asphalt emulsion for fog sealing as shown on the plans.

2355.3 CONSTRUCTION REQUIREMENTS

A Weather Limitations

Perform fog seal operations only during daylight hours and not during foggy weather. Begin fog seal operations when the pavement and air temperatures are 60° F [15.5° C] and rising. The Contractor may perform fog sealing on a damp road surface, but not on a road surface with standing water.

B Road Surface Preparation

Clean pavements, including depressions, before fog sealing.

Cover metal surfaces to prevent adherence of the bituminous material. Remove the protective coverings before opening the road to traffic.

C Application of Bituminous Material

Begin using the rate of application for the bituminous material as shown on the plans. Construct a test strip 100 ft [30 m] long to determine if the bituminous material application rate is adequate given the field conditions. Demonstrate a uniform application of asphalt emulsion producing 100 percent coverage of the surface after curing, as approved by the Engineer. Stop operations if the application demonstration

does not meet the coverage requirements. Minimize the amount of overspray during the fog seal operation.

Apply the bituminous material in accordance with Table 2355-1:

Table 2355-1
Fog Seal Application Temperatures

Bituminous Material	Minimum Temperature	Ideal Temperature
CRS-2Pd	140 °F [60 °C]	170 °F – 180 °F [76.6 °C – 82.2 °C]
CSS-1h	100 °F [37.7 °C]	100 °F –140 °F [37.7 °C – 60 °C]

D Protection of the Surface

Do not allow traffic on the fog sealed surface until after the bituminous material has set and will not pick up on vehicle tires.

E EQUIPMENT

E.1 Distributor

Use a distributor in accordance with 2360.3.B.2.d, "Distributor."

E.2 Brooms

Provide motorized brooms with a positive means of controlling vertical pressure and with the capability to clean the road surface prior to spraying bituminous material.

2355.4 METHOD OF MEASUREMENT

The Engineer will measure the diluted bituminous material for fog seal by volume, at 60° F [15° C].

2355.5 BASIS OF PAYMENT

The Department will pay for fog seal on the basis of the following schedule:

Item No.:	Item:	Unit:
2355.502	Bituminous Material for Fog Seal	gallon [liter]

2356 BITUMINOUS SEAL COAT

2356.1 DESCRIPTION

This work consists of applying bituminous material, a single layer of aggregates, and a fog seal on a prepared surface to construct a seal coat.

2356.2 MATERIALS

A. Bituminous Material

Use bituminous material for seal coats and fog sealing. Provide Cationic Rapid Set Polymer Modified (CRS-2P) for seal coats and CSS-1h diluted one part emulsion to one part water for fog sealing meeting the following requirements for the type and grade required by the contract. Only use bituminous material supplied from a certified source, included on the Approved/Qualified Products List.

B Emulsified Asphalt

Provide emulsified asphalt meeting the requirements of AASHTO M-316-99 CRS-2P and the following modifications:

(1) Distill the CRS-2P at 400 °F [204.4 °C] for 20 min, and
(2) Provide Polymer-Modified Cationic Emulsified Asphalt, CRS-2P produced by using polymer modified base asphalt only. Do not use latex modification.

Provide a CSS-1h, bituminous material for fog seal, in accordance with 3251.2.D.1, "Diluted CSS-1h." Dilute asphalt emulsion shall at place of manufacture. Do not dilute asphalt emulsion in the field.

C Seal Coat

Provide a Class A, Class B, or Class C aggregate in accordance with 3137.2.B, "Classification." Use aggregates, uniform in quality and free from wood, bark, roots, and other deleterious materials. Provide Class C aggregates with 80 percent crushed one face, by mechanical or natural means, of the plus No. 4 [4.75 mm] fraction in accordance with the Laboratory Manual, Method 1214. Provide aggregates meeting the gradation and quality requirements specified in Table 2356-1. Use the aggregate size as shown on the plans.

Table 2356-1
Fine aggregate for Seal Coat

Sieve Size	FA-1, %	FA-2, %	FA-2½, %	FA-3, %	FA-3½, %	QC Range, %
½ in [12.5 mm]	100	100	100	100	100	—
⅜ in [9.5 mm]	100	100	100	100	90–100	±5
¼ in [6.3 mm]	100	100	0–80	0–70	0–70	±7
No 4 [4.75 mm]	0–100	0–100	0–50	0–25	0–25	±7
No. 8 [2.36 mm]	—	0–40	0–12	0–5	0–5	±4
No. 16 [1.18 mm]	0–30	0–10	0–5	—	—	±4
No. 50 [300 µm]	0–15	0–5	—	—	—	±4
No. 100 [150 µm]	0–5	—	—	—	—	±4
No. 200 [75 µm]	0.0–1.0	0.0–1.0	0.0–1.0	0.0–1.0	0.0–1.0	—
Material Tests:						
% shale, max, Mn/DOT 1209	5	5	5	3	2	—
Flakiness index, max, % FHL T 508*	—	25	25	25	25	—
Los Angeles Rattler, max, % loss, AASHTO T 96 (Mn/DOT Modified)	—	—	—	35	35	—

NOTES Values are the percent passing the sieve by weight.
* Test aggregate retained on each sieve, which comprises at least 4 percent of the total sample in accordance with Federal Highways and Lands Test Method 508.

D Water

Use potable water compatible with the seal coat.

E Seal Coat Design

Design the seal coat using the Minnesota Seal Coat Handbook. Base the design on the traffic volume and pavement conditions. Determine the starting application rate for the bituminous material and seal coat aggregate. At least 2 weeks before beginning construction, provide the following design information to the Engineer:

(1) Test results as specified in Table 2356-1,
(2) Seal coat aggregate design application rate,
(3) Bituminous material design application rate,

(4) Loose weight [unit mass] of the aggregate,
(5) Bulk specific gravity of the aggregate, and
(6) 150 lb [70 kg] sample of aggregate from each proposed aggregate source.

Submit 150 lb [70 kg] of material for each source to the Department at least 14 days before beginning construction. The Engineer will review the design. The Department may postpone the start of work until receipt of the design and approval by the Engineer in accordance with the requirements of this section. The Department will charge the Contractor one working day for each weekday that the project is delayed.

After establishing the seal coat design, provide aggregate to the project meeting the requirements of the QC tolerances specified in Table 2356-1.

The Department considers the seal coat's design aggregate application rate as the target amount (minimum or maximum) of material based on the design program.

F Schedule of Price Reduction for Seal Coat Construction

The Department will deduct $1,000 for each failing flakiness test.

If gradations fall outside of the quality control range but within specifications, stop construction and submit a new design.

2356.3 CONSTRUCTION REQUIREMENTS

A Weather Limitations

Construct seal coat operations (including traffic restrictions on the freshly constructed seal coat) and fog sealing in accordance with the following:

(1) From May 15 to August 10 if located in the North and North-Central Road Spring Restriction Zone,
(2) From May 15 to August 31 if located south of the North and North-Central Spring Road Restriction Zone.
(3) Work only during daylight hours,
(4) Begin work when the pavement and air temperatures are 60 ºF [15.5 ºC] and rising.
(5) The road surface may be damp, but ensure that the road is free of standing water, and
(6) Do not perform work during foggy weather.

B Equipment

B.1 Distributor

Use a distributor in accordance with 2360.3.B.2.d, "Distributor."

B.2 Aggregate Spreader

Use a self-propelled mechanical type aggregate spreader, mounted on pneumatic-tired wheels, capable of distributing the aggregate uniformly to the width required by the contract and at the designed application rate.

B.3 Pneumatic-Tired Rollers

Provide at least three self-propelled pneumatic-tired rollers in accordance with 2360.3.B.2.e(2), "Pneumatic Tired Rollers."

B.4 Brooms

Provide motorized brooms with the following characteristics:

(1) Positive means of controlling vertical pressure
(2) Capable of cleaning the road surface before spraying bituminous material, and
(3) Capable of removing loose aggregate after seal coating.

C Road Surface Preparation

Clean pavements, including depressions, before seal coating.

Cover iron fixtures in or near the pavement to prevent adherence of the bituminous material. Remove the protective coverings before opening the road to traffic.

D Application of Bituminous Material

Begin the rate of application for the bituminous material as determined by the seal coat design. Construct a test strip 100 ft [30 m] long to ensure the bituminous material application rate is adequate given the field conditions. After applying the bituminous material to this test strip, place the seal coat aggregate at the design application rate. Inspect the aggregate in the wheel paths for proper embedment. Make adjustments to the rate of application, if necessary. Construct one full lane width at a time. Make additional adjustments to the rate of application, if necessary.

Apply the bituminous material in accordance with Table 2356-2:

Table 2356-2
Recommended Application Temperatures

Bituminous Material	Minimum Temperature	Ideal Temperature
CRS-2P	140 °F [60 °C]*	170 °F–180 °F [76.6 °C–82.2 °C]
CSS-1h	100 °F [37.7 °C]	—

* Intended for uniform lay down of emulsion

E Application of Seal Coat

Before construction, calibrate the aggregate spreader meeting the requirements of ASTM D 5624, in the presence of the Engineer. The Department will not allow a deviation in the rate of aggregate application from the seal coat aggregate design rate greater than ±1 lb per square yard [±0.5 kg/m²].

Provide uniformly moistened aggregates, damp at the time of placement. Place aggregate within 1 min after applying the bituminous material. Do not use previously applied aggregates collected by sweeping.

F Rolling Operations

Complete the initial rolling within 2 min after applying the aggregate at a speed no greater than 5 mph [8 km/h] to prevent turning over aggregate. Make at least three complete passes over the aggregate. Roll the aggregate so the entire width of the treatment area is covered in one pass of all the rollers.

G Sweeping

Sweep off the surplus aggregate on the same day as the seal coat construction. Re-sweep areas the day after the initial sweeping. Dispose of the surplus seal coat aggregate as approved by the Engineer.

H Protection of the Surface

Do not allow traffic on the seal coated road surface until after completing the specified rolling and the bituminous material has set to ensure that it will not pick up on vehicle tires.

I Protection of Motor Vehicles

The Contractor is responsible for claims of damage to vehicles until the roadways and shoulders have been swept free of loose aggregate and permanent pavement markings have been applied. If the Department will apply the permanent pavement markings, the Contractor's responsibility end's after completion of the fog seal and placement of temporary pavement markings.

J Application of Bituminous Material for Fog Sealing

Fog seal completed seal coated areas, after sweeping and before placement of permanent pavement markings. Construct the fog seal in accordance with 2355, "Bituminous Fog Seal," and as modified as follows:

(1) Construct a 100 ft [30 m] test strip,

(2) Review the application of diluted bituminous material and adjust the application rate as necessary to yield a uniform and full coverage of the underlying seal coat,
(3) Apply from 0.07gal to 0.18 gal per sq. yd [0.3 L to 0.8 L per sq. m] diluted,
(4) Apply the fog seal to minimize the amount of overspray, and
(5) Do not allow traffic on the fog seal until it has cured.

K Progress of Work

Allow the seal coat to cure for at least one day before fogging. Place interim pavement markings after the fog seal cures and before removal of traffic control. Do not place permanent pavement markings using latex paint before three days after placing the fog seal. Place all other types of permanent pavement markings at least 14 days after placement of the fog seal.

2356.4 METHOD OF MEASUREMENT

The Engineer will measure the bituminous material for fog seal by volume, at 60 °F [15 °C], undiluted. Dilute the material at a ratio of 1:1 before application at place of manufacture.

The Engineer will measure the bituminous material for seal coat by volume at 60 °F [15 °C].

The Engineer will measure the seal coat by area of pavement surfaced.

2356.5 BASIS OF PAYMENT

The Department will pay for bituminous material for fog seal in accordance with 2355.5, "Basis of Payment."

The contract gallon [liter] price for accepted quantities of *Bituminous Material for Seal Coat,* including necessary additives, includes the costs of providing and applying the material as required by the contract.

The contract square yard unit price for *Bituminous Seal Coat* includes the cost of providing and applying the material as required by the contract. The contract square yard [square meter] price for *Bituminous Seal Coat* includes the cost of additional required bituminous or aggregate material to meet the program requirements.

If test results on seal coat construction show failing gradations, the Department will reduce the contract unit price for seal coat by 1 percent for each 1 percent passing outside of the requirements for any sieve as specified in Table 2356-1, except for the No. 200 [75 µm] sieve. The Department will reduce the contract unit price for seal

coat by 2 percent for each 0.2 percent passing outside the requirements for the No. 200 [75 µm] sieve as specified in Table 2356-1.

The Department will add the deductions for all failing test results together. The Department will determine the contract unit price for seal coating by combining the contract unit prices for *Traffic Control*, *Mobilization*, *Bituminous Materials for Seal Coating*, and *Bituminous Seal Coat* by square yard [square meter].

The Department will pay for bituminous seal coat on the basis of the following schedule:

Item No.:	Item:	Unit:
2356.505	Bituminous Material for Seal Coat	gallon [liter]
2356.506	Bituminous Seal Coat	square yard [square meter]

2357 BITUMINOUS TACK COAT

2357.1 DESCRIPTION

This work consists of treating an existing pavement surface with bituminous material before placing a new bituminous surface to aid bonding of layers.

2357.2 MATERIALS

A Certified Source

Provide bituminous material listed on the Approved/Qualified Products list.

B Emulsified Asphalt

Use SS-1, SS-1h, CSS-1, or CSS-1h emulsified asphalt diluted or undiluted in accordance with 3151.2.C, "Emulsified Asphalt," or 3151.2.D, "Cationic Emulsified Asphalt."

C Cutback Asphalt

The Contractor may use MC 250 cutback asphalt in accordance with 3151.2.B, "Medium Curing Liquid Asphalt," as approved by the Engineer and when the anticipated air temperature may drop below 32 °F [0 °C].

2357.3 CONSTRUCTION REQUIREMENTS

A Restrictions.

Only apply bituminous tack coat to a surface area that will be covered with new pavement in the same day.

Apply bituminous tack coat so traffic can move in at least one direction at all times without pickup or tracking of the bituminous material.

Ensure the asphalt emulsion supplier dilutes the emulsion at a rate of 1 part emulsion to 1 part water. Do not field dilute the emulsion.

B Equipment

Provide a distributor in accordance with 2360.3.B.2.d, "Distributor."

C Application

Apply the bituminous tack coat at a continuous uniform spread rate as specified in Table 2357-1 with 100 percent coverage of the surface. The Engineer may waive the tack coat requirements if multiple lifts are paved on the same day.

Table 2357-1
Tack Coat Application Rates

Pavement type or condition	Application Rate, gal per sq. yd [L per sq. m]		
	Undiluted emulsion SS-1, SS-1H, CSS-1, CSS-1H	Diluted emulsion (1 part emulsion to 1 part water)* SS-1, SS-1H, CSS-1, CSS-1H	MC Cutback‖ MC-250
New HMA	0.03 – 0.05 [0.14 – 0.23]	0.06 – 0.10 [0.28 – 0.46]	0.03 – 0.05 [0.14 – 0.23]
Aged HMA† or un-milled PCC	0.05 – 0.08 [0.23 – 0.37]	0.10 – 0.15 [0.46 – 0.69]	0.05 – 0.08 [0.23 – 0.37]
Milled HMA or milled PCC	0.07 – 0.10 [0.32 – 0.46]	0.14 – 0.20 [0.64 – 0.92]	0.07 – 0.10 [0.32 – 0.46]

* As provided by the asphalt emulsion supplier
‖ When approved by the Engineer
† Older than one year

D Bituminous Temperature

Apply emulsified asphalt at temperatures from 70 °F to 160 °F [21 °C to 71 °C].

Apply cutback asphalt at temperatures from 165 °F to 220 °F [74 °C to 104 °C].

E Bituminous Material Sample

Sample in accordance with the Schedule of Materials Control.

F Pedestrian Crossing

Spread sand on newly tacked surfaces at pedestrian crossings so tack is not tracked on surfaces.

2357.4 METHOD OF MEASUREMENT

The Engineer will measure bituminous material for tack coat by volume at 60 °F [15 °C]

2357.5 BASIS OF PAYMENT

The Department will include the cost of providing and applying sand at pedestrian crossings with other relevant contract items.

The Department will pay for tack coat on the basis of the following schedule:

Item No.:	Item:	Unit:
2357.502	Bituminous Material for Tack Coat	gallon [liter]

If the contract does not contain *Bituminous Material for Tack Coat*, the Department will include the cost of providing and applying bituminous tack coat material with other relevant pay items.

2358 BITUMINOUS PRIME COAT

2358.1 DESCRIPTION

This work consists of treating a prepared base with bituminous material prior to placing a bituminous pavement.

2358.2 MATERIALS

A Medium Curing Liquid Asphalt

Provide Medium Curing Liquid Asphalt in accordance with 3151.2.B, "Medium Curing Liquid Asphalt," for MC-30 or MC-70.

2358.3 CONSTRUCTION REQUIREMENTS

A Restrictions

A.1 Base Moisture Content

Place bituminous prime coat on a prepared base when the base moisture content of the upper 3 in [80 mm] is less than 65 percent of optimum moisture content.

A.2 Traffic

If road is open to traffic, maintain traffic in at least one direction and only close a portion of the traveled way for construction, not to exceed 50 percent.

B Equipment

Use a distributor in accordance with 2360.3.B.2.d, "Distributor."

C Application

Apply the bituminous prime coat at a continuous uniform spread rate of 0.1 gal per cu. yd to 0.3 gal per cu. yd [0.45 L per cu. m to 1.35 L per cu. m].

D Bituminous Temperature

Apply MC-30 bituminous prime coat at temperatures from 85 °F to 145 °F [29 °C to 63 °C]. Apply MC-70 bituminous prime coat at temperatures from 120 °F to 180 °F [49 °C to 82 °C].

2358.4 METHOD OF MEASUREMENT

The Engineer will measure bituminous material for prime coat by volume at 60 °F [15 °C].

2358.5 BASIS OF PAYMENT

The contract gallon [liter] price for *Bituminous Material for Prime Coat* includes the costs of providing and applying the material as required by the contract.

The Department will pay for bituminous prime coat on the basis of the following schedule.

Item No.:	Item:	Unit:
2358.501	Bituminous Material for Prime Coat	gallon [liter]

2360 PLANT MIXED ASPHALT PAVEMENT

2360.1 DESCRIPTION

This work consists of constructing plant mixed asphalt pavement on a prepared subgrade.

Plant mixed asphalt pavement designed according to a gyratory mix design method for use as a pavement surface.

A Mixture Designations

The Department will designate the mixture for asphalt mixtures in accordance with the following:

(1) The first two letters indicate the mixture design type:

(1.1) SP = Gyratory Mixture Design.

(2) The third and fourth letters indicate the course:

(2.1) WE = Wearing and shoulder wearing course, and
(2.2) NW = Non-wearing Course.

(3) The fifth letter indicates the maximum aggregate size:

(3.1) A = ½ in [12.5mm], SP 9.5,
(3.2) B = ¾ in [19.0mm], SP 12.5,
(3.3) C = 1 in [25.0mm], SP 19.0, and
(3.4) D = ⅜ in [9.5mm], SP 4.75.

(4) The sixth digit indicates the Traffic Level (ESAL's × 10^6) in accordance with Table 2360-1, "Traffic Levels."

Table 2360-1
Traffic Levels

Traffic Level	20 Year Design ESALs
2 *	< 1
3 ‖	1 – < 3
4	1 – < 10
5	10 – ≤ 30

NOTE: The requirements for gyratory mixtures in this specification are based on the 20 year design traffic level of the project, expressed in Equivalent Single Axle Loads (ESALs) 1 × 10^6 ESALs
* AADT < 2,300
‖ AADT > 2,300 to < 6,000

(5) The last two digits indicate the air void requirement:

(5.1) 40 = 4.0 percent for SP and SM wear mixtures, and
(5.2) 30 = 3.0 percent for SP non-wear and shoulder.

(6) The letter at the end of the mixture designation identifies the asphalt binder grade in accordance with Table 2360-2, "Asphalt Grades."

Table 2360-2
Asphalt Grades

Letter	Grade
A	PG 52 – 34
B	PG 58 – 28
C	PG 58 – 34
E	PG 64 – 28
F	PG 64 – 34
H	PG 70 – 28
L	PG 64 – 22

2360.2 MATERIALS

A Aggregate

Use aggregate materials in accordance with 3139.2, "Plant Mixed Asphalt Pavement Requirements."

B Asphalt Binder Material 3151

Table 2360-3
Asphalt Binder Selection Criteria for all Mixtures with RAP

Asphalt Binder Selection Criteria for all Mixtures with RAP Specified PG Asphalt Binder Grade	≤ 20 % RAP	> 20 % RAP*
PG XX-28 and PG 52-34	Use specified grade	Use specified grade
PG XX-34	Use specified grade	Use blending chart*

* Use the blending chart on file with the Chemical Laboratory to verify compliance with the specified binder grade when RAP is greater than 20 percent. The Department may take production samples to ensure the the asphalt binder material meets the requirements.

C Additives

The Department defines additives as material added to an asphalt mixture or material that do not have a specific pay item.

Do not incorporate additives into the mixture unless approved by the Engineer. Add anti-foaming agents to asphalt cement at the dosage rate recommended by the manufacturer. The Contractor may add mineral filler in quantities no greater than 5 percent of the total aggregate weight. The Contractor may add hydrated lime in

quantities no greater than 2 percent of the total aggregate weight. Do not add a combination of mineral filler and hydrated lime that exceeds 5 percent of the total aggregate weight. Use methods for adding additives as approved by the Engineer.

C.1 Mineral Filler ..... AASHTO M 17

C.1.a Mineral Filler — Hydrated Lime

Provide hydrated lime for asphalt mixtures with no greater than 8 percent unhydrated oxides (as received basis) and meeting the requirements of AASHTO M 216. Use a method to introduce and mix hydrated lime and aggregate as approved by the Engineer before beginning mixture production.

C.2 Liquid Anti-Stripping Additive (Contractor Added)

If adding a liquid anti-strip additive to the asphalt binder, complete blending before mixing the asphalt binder with the aggregate. Only use liquid anti-strip additives that ensure the asphalt binder meets the Performance Grade (PG) requirements in 3151, "Bituminous Material." The Contractor may use asphalt binder with liquid anti-strip added at the refinery or the Contractor may add liquid anti-strip at the plant site. If using asphalt binder with liquid anti-strip added at the refinery, ensure the supplier tests the binder and additive blend to confirm compliance with the AASHTO M 320. If anti-strip agent is added at the plant, the Department will consider the plant mixed asphalt producer as the supplier and will require the binder to meet the requirements of 3151, "Bituminous Material." Do not pave until the asphalt binder and additive blend testing results meet the criteria in 2360.2.B, "Asphalt Binder Material."

C.2.a Mixture Requirements at Design

Design the mixture with the same asphalt binder supplied to the plant site using mixture option 1, "Laboratory Mixture Design" or mixture option 2, "Modified Mixture Design."

Provide documentation with either design option and include the amount of anti-strip needed to meet the minimum tensile strength requirements. Verify that the binder, with the anti-strip, meets the PG binder requirements for the mixture.

C.2.b Contractor Production Testing Requirements

Sample and test the asphalt binder and anti-strip blend daily. The Contractor may test the blend by viscosity, penetration, or dynamic sheer rheometer (DSR) of the blend. If the contract requires the use of a polymer modified asphalt binder in the mixture, use the DSR as the daily QC test.

Send the Engineer and Chemical Laboratory Director a weekly QC report summarizing the results of the daily testing.

Perform at least one test bi-weekly per project to ensure the binder and anti-strip blend meets the requirements of AASHTO M 320. Send the test results to the Engineer and Chemical Laboratory Director.

Provide asphalt binder and anti-strip blend field verification samples in accordance with 2360.2.G.7, "Production Test."

C.2.c Liquid Anti-Strip Additive Metering System

Include a liquid anti-strip flow meter and an anti-strip pump with the metering system. Connect the flow meter to the liquid anti-strip supply to measure and display only the anti-strip being fed to the asphalt binder.

Position the meter readout so that the inspector can easily read it.

Provide means to compare the flow meter readout with the calculated output of the anti-strip pump.

Provide a system that displays the accumulated anti-strip quantity being delivered to the mixer unit in gallons [liters] to the nearest gallon [liter] or in units of tons [metric tons] to the nearest 0.001 ton [0.001 tonne].

Calibrate and adjust the system to maintain an accuracy of ± 1 percent.

Calibrate each plant set-up before producing the mixture.

"Stick" the anti-strip tank at the end of the day's production to verify anti-strip usage quantities. The Engineer may require "sticking" on a daily basis.

Ensure the system has a spigot for sampling the binder and anti-strip after blending.

Use alternative blending and metering systems only when pre-approved by the Engineer.

E Mixture Design

E.1 Submittal Location

Submit documentation and sample aggregate materials for review to the District Materials Laboratory.

E.2 Aggregate Quality

Provide aggregate in accordance with 3139.2, "Plant Mixed Asphalt Pavement Requirements."

E.3 Restrictions

Do not add aggregates and materials not included n the original mixture submission unless otherwise approved by the Engineer.

E.4 Responsibility

Design a gyratory mixture that meets the requirements of this specification in accordance with the following:

(1) Most current AASHTO T 312, Mn/DOT modified,
(2) The Asphalt Institute's Superpave Mix Design Manual SP-2 (Use a 2 h short term aging period for volumetric), and
(3) The Laboratory Manual.

E.5 Type of Mixture Design Submittal

E.5.a Option 1 — Laboratory Mixture Design

E.5.a(1) Aggregate

Submit the mixture design for option 1, laboratory mixture design, at least 15 working days before beginning production samples for quality testing. At least 30 calendar days before beginning asphalt production, submit samples of aggregates that require the magnesium sulfate soundness test to the District Materials Laboratory. Test the samples for quality of each source, class, type, and size of virgin and non-asphaltic salvage aggregate source used in the mix design. Retain a companion sample of equal size until the Department issues a Mixture Design Report. Provide 24 h notice of intent to sample aggregates to the Engineer. Provide samples in accordance with the following:

Table 2360-4
Aggregate Sample Size

Classification	Sieve	Weight
Virgin	Retained on No. 4 [4.75 mm]	80 lb [35 kg]
Virgin	Passing No. 4 [4.75 mm]	35 lb [15 kg]
Recycled asphalt pavement (RAP)	—	80 lb [35 kg]
Recycled asphalt shingles (RAS)	—	10 lb [5 kg] sample of representative RAS material

E.5.a(2) Mixture Sample

At least 7 working days before the start of asphalt production, submit the proposed Job Mix Formula (JMF) in writing and signed by a Level II Quality Management mix designer for each combination of aggregates to be used in the mixture. Include test data to demonstrate conformance to mixture properties as specified in Table 2360-7, "Mixture Requirements," and 3139.2, "Plant Mixed Asphalt Pavement Requirements." Use forms approved by the Department for the submission.

Submit an uncompacted mixture sample plus briquettes, in conformance with the JMF, compacted at the optimum asphalt content and required compactive effort for laboratory examination and evaluation. Provide a mixture sample size and the number of compacted briquettes and in accordance with the following:

Table 2360-5
Mixture Sample Requirements

Item	Gyratory Design
Uncompacted mixture sample size	75 lb [30 kg]
Number of compacted briquettes	2

E.5.a(3) Tensile Strength Ratio Sample

At least 7 days before actual production, submit sample to the District Materials Laboratory for verification of moisture sensitivity retained tensile strength ratio (TSR). The Engineer may test material submitted for TSR verification for maximum specific gravity G_{mm} compliance in addition to TSR results. The Engineer will reject the submitted mix design if the tested material fails to meet the G_{mm} tolerance. If the Engineer rejects a mix design, submit a new mix design in accordance with 2360.2.E, "Mixture Design." The Contractor may use one of the following options to verify that the TSR meets the requirements in Table 2360-7, "Mixture Requirements."

E.5.a(4) Option A

Batch material at the design proportions including optimum asphalt. Split the sample before curing and allow samples to cool to room temperature, approximately 77 °F [25 °C]. Submit 80 lb [35 kg] of mixture to the District Materials Laboratory for curing and test verification. Use a cure time of 2 h ±15 min at 290 °F [144 °C] cure time for both groups and follow procedures Laboratory Manual Method 1813.

E.5.a(5) Option B

Batch and cure in accordance with Option A. Compact, and submit briquettes and uncompacted mixture in accordance with Table 2360-6, "Option B Mixture Requirements."

Table 2360-6 Option B Mixture Requirements	
Item	**Gyratory Design**
Un-compacted mixture sample size	8,200 g
Number of compacted briquettes*	6
Compacted briquette air void content	6.5 % – 7.5 %
* 6 in [150 mm] specimens.	

For both options, cure for 2 h ±15 min at 290° F [144° C] meeting the requirements of ASTM D 4867-92, Mn/DOT modified as defined in the Laboratory Manual Method 1813.

E.5.a(6) Aggregate Specific Gravity

Determine the specific gravity of aggregate in accordance with Laboratory Manual Method 1204 and 1205.

E.5.b Option 2 — Modified Mixture Design

The Contractor may use the modified mixture design if testing shows that the aggregates meet the requirements of 3139.2, "Plant Mixed Asphalt Pavement Requirements," in the current construction season and if the Level II mix designer submitting the mixture design has at least 2 years experience in mixture design. The Department will not require mixture submittal.

E.5.b(1) Mixture Aggregate Requirements

Size, grade, and combine the aggregate fractions in proportions that are in accordance with 3139.2, "Plant Mixed Asphalt Pavement Requirements."

E.5.b(2) JMF Submittal

At least 2 working days before beginning asphalt production, submit a proposed JMF in writing to the District Materials Laboratory signed by a Level II Quality Management mix designer for each combination of aggregates. For each JMF submitted, include documentation in accordance with 2360.2.E.5.a, "Option1 – Laboratory Mixture Design," to demonstrate conformance to mixture properties as specified in Table 2360-7, "Mixture Requirements," and Table 3139-3, "Mixture Aggregate Requirements." Submit the JMF on forms approved by the Department,

E.5.b(3) Tensile Strength Ratio Sample

Provide a tensile strength ratio sample in accordance with 2360.2.I, "Field Tensile Strength Ratio (TSR)."

E.5.b(4) Initial Production Test Verification

The Department will take a mix verification sample within the first four samples at the start of production for each mix type.

E.6 Mixture Requirements

The Department will base mixture evaluation on the trial mix tests and in accordance with Table 2360-7, "Mixture Requirements."

Table 2360-7
Mixture Requirements

Traffic Level	2	3	4	5
20 year design ESALs	< 1 million	1 – 3 million	3 – 10 million	10 – 30 million
Gyratory mixture requirements:				
Gyrations for N_{design}	40	60	90	100
% Air voids at N_{design}, wear	4.0	4.0	4.0	4.0
% Air voids at N_{design}, Non-wear and all shoulder	3.0	3.0	3.0	3.0
Adjusted Asphalt Film Thickness, minimum µ	8.5	8.5	8.5	8.5
Ratio of Added New Asphalt Binder to Total Binder‖, minimum %	70	70	70	70
TSR*, *minimum %*	75†	75†	80‡	80‡
Fines/effective asphalt	0.6 – 1.2	0.6 – 1.2	0.6 – 1.2	0.6 – 1.2

* Use 6 in [150 mm] specimens in accordance with 2360.2.G.7.i, "Field Tensile Strength Ratio (TSR)."

‖ Ensure the ratio of added new asphalt binder to total asphalt binder is at least 70 percent (added binder/total binder) × 100 ≥ 70) in both mixtures that contain RAP and in mixtures that include shingles as part of the allowable RAP percentage.

† Mn/DOT minimum = 65

‡ Mn/DOT minimum = 70

E.7 Coarse/Fine Mixture Determination

Base the determination of coarse and fine graded mixtures on the percentage of material passing the No. 8 [2.36 mm] sieve in accordance with Table 2360-8, "Coarse/Fine Mixture Determination."

Table 2360-8 Coarse/Fine Mixture Determination		
Gradation	**Fine Mixture,** ***% passing No. 8 [2.36 mm]***	**Coarse Mixture,** ***% passing No. 8 [2.36 mm]***
A	> 47	≤ 47
B	> 39	≤ 39
C	> 35	≤ 35
D	—	—

E.8 Adjusted Asphalt Film Thickness (Adj. AFT)

Ensure the adjusted asphalt film thickness (Adj. AFT) of the mixture at design and during production meets the requirements of Table 2360-7, "Mixture Requirements." Base the Adj. AFT on the calculated aggregate surface area (SA) and the effective asphalt binder content.

Calculate the SA using the following formula:

$$SA = 2 + 0.02a + 0.04b + 0.08c + 0.14d + 0.30e + 0.60f + 1.60g$$

Where:

SA = Aggregate Square Surface Area in sq. ft [sq. m] per lb of dry aggregate,
a = percent of total aggregate passing the No. 4 sieve,
b = percent of total aggregate passing the No. 8 sieve,
c = percent of total aggregate passing the No. 16 sieve,
d = percent of total aggregate passing the No. 30 sieve,
e = percent of total aggregate passing the No. 50 sieve,
f = percent of total aggregate passing the No. 100 sieve, and
g = percent of total aggregate passing the No. 200 sieve.

Round the percent of total aggregate passing the sieves to the nearest 1 percent except for the No. 200 sieve. Round the percent of total aggregate passing the No. 200 sieve to the nearest 0.1 percent.

Using the formula to follow, adjust the calculated SA for mixtures with a combined (-) #4 G_{sb} less than 2.580**,** or greater than 2.700. The SA will increase for mixtures with a combined (-) #4 G_{sb} less than 2.580, and will decrease for mixtures with a combined (-) #4 G_{sb} greater than 2.700.

$$\text{Adjusted } SA = SA \times \left(\frac{2.650}{Mixture(-)No.4G_{sb}} \right)$$

There will be no SA adjustment for mixtures with a combined (-) #4 G_{sb} between 2.580 and 2.700.

Calculate Adj. AFT in accordance with the following:

$$Adj.AFT = AFT + 0.06(SA - 28)$$

Calculate AFT in accordance with the following:

$$AFT = \frac{P_{be} \times 4870}{100 \times P_s \times SA}$$

Where:

AFT = Asphalt Film Thickness in microns,
P_{be} = Effective Asphalt Content as a percent of the total mixture,
4870 = Constant Conversion Factor,
P_s = Percent Aggregate in Mixture /100, or (100-P_b) /100,
P_b = Percent Total Asphalt Cement in Mixture, and
SA = Calculated Aggregate Surface Area in SF/lb.

The Adjusted AFT will be greater than the AFT if the SA is greater than 28.0 sq ft. per lb., and will be less than the AFT if the SA is less than 28.0 sq. ft per lb.

E.9 Documentation

Include the following documentation and test results with each JMF submitted for review:

(1) Names of the individuals responsible for the QC of the mixture during production,
(2) Low project number of the contract on which the mixture will be used,
(3) Traffic level and number of gyrations,
(4) The following temperature ranges as supplied by the asphalt binder supplier:

(4.1) Laboratory mixing,
(4.2) Plant discharge, and
(4.3) Field compaction.

(5) The percentage in units of 1 percent (except the No. 200 sieve [0.075 mm] in units of 0.1 percent) of aggregate passing each of the specified sieves (including the No. 16, No. 30, No. 50, and No. 100) for each aggregate to be incorporated into the mixture. Derive the gradation of the aggregate from the RAP after extracting the residual asphalt.

(6) Source descriptions of the following:

(6.1) Location of material,
(6.2) Description of materials,
(6.3) Aggregate pit or quarry number, and
(6.4) Proportion amount of each material in the mixture in percent of total aggregate.

(7) Composite gradation based on (5) and (6) above. Include virgin composite gradation based on (6) and (7) above for mixtures containing RAP/RAS.
(8) Bulk and apparent specific gravities and water absorption (by % weight of dry aggregate). Both coarse and fine aggregate, for each product used in the mixture (including RAP/RAS). Use Laboratory Manual Method 1204 and 1205. The tolerance allowed between the Contractor's and the Department's specific gravities are G_{sb} (individual) = 0.040 [+4 and -4] and G_{sb} (combined) = 0.020.
(9) FHWA 0.45 power chart represented by the composite gradation plotted on Federal Form PR-1115
(10) Test results from the composite aggregate blend at the proposed JMF proportions showing compliance with Table 3139-3, "Mixture Aggregate Requirements":

(10.1) Coarse Aggregate Angularity,
(10.2) Fine Aggregate Angularity, and
(10.3) Flat and Elongated

(11) Extracted asphalt binder content for mixtures containing RAP/RAS with no retention factor included.
(12) Asphalt binder percentage in units of 0.1 percent based on the total mass of the mixture and the PG grade.
(13) Each trial mixture design includes the following:

(13.1) At least 3 different asphalt binder contents (with at least 0.4 percent between each point), with at least one point at, one point above and one point below the optimum asphalt binder percentage.
(13.2) Maximum specific gravity for each asphalt binder content calculated based on the average of the effective specific gravities measured by using at least two maximum specific gravity tests at the asphalt contents above and below the expected optimum asphalt binder content.
(13.3) Test results on at least two specimens at each asphalt binder content for the individual and average bulk specific gravities, density, and heights.
(13.4) Percent air voids of the mixture at each asphalt binder content.

(13.5) Adj. AFT for each asphalt binder content.
(13.6) Fines to Effective Asphalt (F/A) ratio calculated to the nearest 0.1 percent.
(13.7) TSR at the optimum asphalt binder content.
(13.8) Graphs showing air voids, adjusted AFT, G_{mb}, G_{mm} and unit weight vs. percent asphalt binder content for each of the three asphalt binder contents submitted with trial mix.
(13.9) Evidence that the completed mixture will conform to design air voids (V_a), Adj. AFT, TSR, F/A_e (Fines to effective asphalt ratio).
(13.10) Gyratory densification tables and curves generated from the gyratory compactor for all points used in the mixture submittal.

(14) The Contractor has the option of augmenting the submitted JMF with additional sand or rock. When using this option, provide samples of the aggregate for quality analysis in accordance with 2360.2.E.5, "Type of Mixture Design Submittal." Also provide mix design data for two additional design points per add-material. Provide one point to show a proportional adjustment to the submitted JMF that includes 5 percent, by weight, add-material at the JMF optimum asphalt percent. Provide a second point to show a proportional adjustment to the submitted JMF that includes 10 percent, by weight, add-material at the JMF optimum asphalt percent. Report the following information for each of these two points:

(14.1) The maximum specific gravity determined by averaging two tests,
(14.2) Test results showing the individual and average bulk specific gravity, density, and height of at least two specimens at the optimum asphalt binder content,
(14.3) Percent air voids for the mixture for each point,
(14.4) Fines to Effective Asphalt ratio calculated to the nearest 0.1 of a percent,
(14.5) Crushing of the coarse and fine aggregate,
(14.6) Adj. AFT., and
(14.7) Percent new asphalt binder to total asphalt binder.

F Mixture Design Report

Provide a Mixture Design Report consisting of the JMF. Include the following in the JMF:

(1) Composite gradation,
(2) Aggregate component proportions,
(3) Asphalt binder content of the mixture,
(4) Design air voids,

(5) Adj. asphalt film thickness, and
(6) Aggregate bulk specific gravity values.

Show the JMF limits for gradation control sieves in accordance with aggregate gradation broad bands shown in Table 3139-2, "Aggregate Gradation Broad Bands," percent asphalt binder content, air voids, and Adj. AFT. If the Department issues a Mixture Design Report, this report only confirms that the Department reviewed the mixture and that it meets volumetric properties. The Department makes no expressed or implied guaranty or warranty regarding placement and compaction of the mixture.

Provide materials meeting the requirements of the aggregate and mixture design before issuing a Mixture Design Report. The Department will review two trial mix designs per mix type designated in the plan per contract at no cost to the Contractor. The Department will verify additional mix designs at a cost of $2,000 per design.

Provide a Department-reviewed Mixture Design Report for paving except for small quantities of material in accordance with 2360.3.G, "Small Quantity Paving."

For city, county, and other agency projects, provide the District Materials Laboratory a complete project proposal, including addenda, supplemental agreements, change orders, and plans sheets, including typical sections, affecting the mix design before the Department begins the verification process.

G Mixture Quality Management

G.1 Quality Control (QC)

Provide and maintain a QC program for plant mix asphalt production, including mix design, process control inspection, sampling and testing, and adjustments in the process related to the production of an asphalt pavement.

G.1.a Certification

Provide the following to obtain certification:

(1) Completed and submitted request form application for plant inspection.
(2) Site map showing stockpile locations.
(3) Signed asphalt plant inspection report showing the plant and testing facility passed as documented by Asphalt Plant Inspection Report (TP 02142-02, TP 02143-02). The inspection report must also include documentation showing plant and laboratory equipment has been calibrated and is being maintained to the tolerance shown in the Bituminous Manual and Laboratory Manual, Section 2000.
(4) A Department-signed Mixture Design Report (MDR) before mixture production.

G.1.b Maintaining Certification

Maintain plant certification by documenting the productions and testing of the certified plant asphalt mixtures. Sample and test asphalt mixtures in accordance with this section and meeting the requirements of the Schedule of Materials Control.

G.1.b(1) Annual Certification

Perform annual certification after winter suspension.

G.1.b(2) Sampling Rate

Sample at the rate in accordance with 2360.2.G.6, "Production Testing Rates," and the requirements of the Schedule of Materials Control.

G.1.b(3) Plant Moved

Recertify the plant if the plant moves to a new or previously occupied location.

G.1.c. Plant Certification Revocation

The Engineer may revoke certification for any of the following reasons:

(1) If the mix does not meet the requirements of 2360.2.E.6, "Mixture Requirements," and 3139.2, "Plant Mixed Asphalt Pavement Requirements,"
(2) If there is a failure to meet the testing rates, or
(3) If it is determined records were falsified.

If the Engineer revokes plant certification, the Department may revoke the Technical Certification of the individual or individuals involved. The Department will maintain a list of companies with revoked certifications.

G.2 Quality Assurance (QA)

The Engineer will perform Quality Assurance (QA) on a sample that is a companion to the Contractor's QC sample to accept the work. The Engineer will perform the following:

(1) Conduct QA and verification sampling and testing,
(2) Observe the QC sampling and tests,
(3) Monitor the required QC summary sheets and control charts,
(4) Verify calibration of QC laboratory testing equipment,
(5) Communicate Department test results to the Contractor's personnel on a daily basis, and
(6) Ensure Independent Assurance (IA) sampling and testing requirements are met.

The Engineer will periodically witness the sampling and testing being performed by the Contractor. If the Engineer observes that the Contractor is not performing sampling and quality control tests in accordance with the applicable test procedures, the Engineer may stop production until the Contractor takes corrective action. The Engineer will notify the Contractor of observed deficiencies promptly, both verbally and in writing.

The Engineer may obtain additional samples, at any time and location during production, to determine quality levels in accordance with 2360.2.G.3, "Verification Sample."

The Department will post a chart with the names and telephone numbers for the personnel responsible for QA.

The Engineer will calibrate and correlate laboratory testing equipment in accordance with the Bituminous Manual and Laboratory Manual.

Table 2360-9
Allowable Differences between Contractor and Department Test Results *

Item	Allowable Difference
Mixture bulk specific gravity (G_{mb})	0.030
Mixture maximum specific gravity (G_{mm})	0.019
Adjusted AFT (calculated)	1.2
Fine Aggregate Angularity, uncompacted voids (U) %	1
Coarse Aggregate Angularity, % fractured faces (%P)	15
Aggregate Individual Bulk Specific Gravity (+ No. 4 [+4.75 mm])	0.040
Aggregate Individual Bulk Specific Gravity (- No. 4 [-4.75mm])	0.040
Aggregate combined blend Specific Gravity (G_{sb})	0.020
Tensile strength ratio (TSR), %	Table 2360-7
Asphalt binder content:	
Meter method, %	0.2
Spot check method, %	0.2
Chemical extraction methods, %	0.4
Incinerator oven, %	0.3
Chemical vs. meter, spot check, or incinerator methods	0.4
Incinerator oven vs. spot check	0.4

Table 2360-9 Allowable Differences between Contractor and Department Test Results *	
Item	**Allowable Difference**
Gradation sieve, *% passing:*	
1 in [25.0 mm], ¾ in [19.0 mm], ½ in [12.5 mm], ⅜ in [9.5 mm]	6
No. 4 [4.75 mm]	5
No. 8 [2.36 mm], No. 16 [1.18 mm], No. 30 [0.60 mm]	4
No. 50 [0.30 mm]	3
No. 100 [0.15 mm]	2
No. 200 [0.075 mm]	1.2
* Test tolerances listed are for single test comparisons.	

G.3 Verification Sample

The Department will test a verification sample to assure compliance of the Contractor's QC program. The Department will provide the Contractor a verification companion, which is defined as a companion sample to the verification sample Mn/DOT uses. Test and use this verification companion sample as part of the QC program. Use the verification companion sample to replace the next scheduled QC sample. The Department recommends sampling enough material to accommodate retesting in case the samples fail.

The Department will perform verification testing on at least one set of production tests in accordance with 2360.2.G.6.b, "Production," and 2360.2.G.7, "Production Test," on a daily basis per mix type. Use the verification companion sample to verify the requirements of Table 3139-2, "Aggregate Gradation Broad Bands," Table 3139-3, "Mixture Aggregate Requirements," and Table 2360-7, "Mixture Requirements." Compare the verification companion sample to the verification sample for compliance with allowable tolerances in Table 2360-9, "Allowable Differences between Contractor and Department Test Results." These include the mixture properties of G_{mm} (mixture maximum gravity), G_{mb} (mixture bulk gravity), asphalt binder content, Adjusted AFT (calculated), Coarse and Fine Aggregate crushing, and gradation. Perform one test per week on a verification companion for coarse and fine aggregate crushing meeting the requirements of 2360.2.G.7.g, "Coarse Aggregate Angularity," and 2360.2.G.7.h, "Fine Aggregate Angularity." These do not include the aggregate bulk specific gravity G_{sb}, fines to effective asphalt, or the tensile strength ratio (TSR). Determine the asphalt binder content and gradation in accordance with the extraction method specified in 2360.2.G.7.a, "Asphalt Binder Content," or 23602.G.7.b, "Gyratory Bulk Specific Gravity."

The Contractor may access the Department's verification test results for G_{mm} mixture maximum gravity, G_{mb} mixture bulk gravity, air voids (calculated), asphalt

binder content, Adj. AFT (calculated) within 2 working days from the time the sample is delivered to the District Materials Laboratory. The Department will provide the gradation and crushing results to the Contractor within three working days. The Department will include the verification test results on the test summary sheet. The Department will compare the results with the Contractor's verification companion for the allowable tolerances in Table 2360-9, "Allowable Differences between Contractor and Department Test Results." The Department will consider the verification process complete if the Contractor's verification companion meets the tolerances in Table 2360-9.

If the tolerances between the Contractor's verification companion and the Department's verification sample do not meet the requirements of Table 2360-9, the Department will retest the material. If the retests fail to meet tolerances, the Department will substitute the Department's verification test results for the Contractor's results in the QC program and use those results for acceptance. The Department will only substitute the out-of-tolerance parameters and will recalculate volumetric properties if applicable.

If the Adj. AFT calculation does not meet the tolerance, equalize the Department Adj.AFT result by increasing the original Department value by 0.5 microns. Use the increased Department Adj. AFT for the Individual Adjusted AFT result and to calculate the Moving Average Adj. AFT results. The increased Department Adj. AFT will form the basis for acceptance.

If the verification sample retests do not meet tolerances, the Department will investigate the cause of the difference that will include a review of testing equipment, procedures, worksheets, gyratory specimen height sheets, and personnel to determine the source of the problem. The Engineer may require both the Department and Contractor to perform at least one hot-cold comparison of mixture properties.

To perform a hot-cold comparison, split the sample into three representative portions. The Engineer will observe the Contractor testing. Immediately compact one part while still hot. Apply additional heating to raise the temperature of the sample to compaction temperature if necessary. Allow the second and third part to cool to air temperature. Retain the second part and transport the third part to the District Materials Laboratory. On the same day and at the same time as the District Materials Laboratory, heat samples to compaction temperature and compact. Develop a calibration factor to compare the specific gravity of the hot compacted samples to reheated compacted samples. Use at least two gyratory specimens for each test. The Engineer or the Contractor may request that this test be repeated.

Reheat mix samples to 160 °F [70 °C] to allow splitting of the sample into representative fractions for the various tests. Do not overheat the mixture portions used for testing maximum specific gravity test.

The Department will test the previously collected QA samples until they meet the tolerances or until the Department has tested all of the remaining samples. After testing the samples, the Department will test QA samples subsequent to the verification sample until tolerances are met. The Department will base acceptance on QC data. The Department will base acceptance on QC data with substitution of Department test results for those parameters out of tolerance. Cease mixture production and placement if reestablished test results do not meet tolerances within 48 h. Resume production and placement only after meeting the tolerances.

If the Engineer analyzes the data using methods for determination of bias on file in the Bituminous Office and finds a bias in the test results, the Engineer will specify which results to use. If the Engineer finds bias in the test results after thorough analysis of data, the Engineer will determine which results are appropriate and will govern.

G.4 Contractor Quality Control

G.4.a Personnel

Submit an organizational chart listing the names and phone numbers of individuals and alternates responsible for the following:

(1) Mix design,
(2) Process control administration, and
(3) Inspection.

Provide QC technicians certified as a Level I Bituminous Quality Management (QM) Tester meeting the requirements of the Mn/DOT Technical Certification Program for QC testing and Level II Bituminous QM Mix Designer to make process adjustments. Provide at least one person per paving operation certified as a Level II Bituminous Street Inspector.

Provide a laboratory with equipment and supplies for Contractor quality control testing and maintain with the following:

(1) Up-to-date equipment calibrations and a copy of the calibration records with each piece of equipment,
(2) Telephone,
(3) Fax and copy machine; however, the Engineer may waive the requirement to have a fax machine if internet and email are available,
(4) Internet and Email,

(5) Computer,
(6) Printer, and
(7) Microsoft Excel, version 2007 or newer

Laboratory equipment need to meet the requirements listed in Section 400 of the Bituminous Manual, Laboratory Manual, and these specifications, including having extraction capabilities. Before beginning production, the laboratory equipment needs to be calibrated and operational.

Calibrate and correlate all testing equipment in accordance with the Bituminous Manual and Laboratory Manual. Keep records of calibration for each piece of testing equipment in the same facility as the equipment.

G.4.b Sampling and Testing

Take QC samples at random locations, quartered from a larger sample of mixture, from behind the paver and in accordance with the Schedule of Materials Control. The Engineer may approve alternate sampling locations. When the Engineer approves of an alternate sampling location and used by the Contractor, the daily verification sample must still be taken from behind the paver. The procedure for truck box sampling, an alternate sampling location, is on file in the Bituminous Office. Store mixture bulk and companion samples for 10 calendar days. Label these split companion samples with companion numbers. Determine random numbers and locations using the Bituminous Manual, Section 5-693.7 Table A or ASTM D 3665, Section 5.

G.5 Production Test Requirements

Determine the planned tonnage [metric tons] for each mixture planned for production during the production day. Divide the planned production by 1,000 and round to the next highest whole number. The result is the number of production tests required for the mixture. Table 2360-11, "Production Testing Rates" shows the required production tests.

Split the planned production into even increments and select sample locations as described above. If actual tonnage is greater than the planned tonnage, repeat the calculation above and provide additional tests if the calculation results in a higher number of production tests. During production, the Department will not require mixture volumetric property tests if mix production is no greater than 300 ton [270 tonne]. Provide production tests if the accumulative weight on successive days is greater than 300 ton [270 tonne].

If there is a choice of more than one Mn/DOT approved test procedure, select one method at the beginning of the project with the approval of the Engineer and use that

method for the entire project. The Contractor and Engineer may agree to change test procedures during the construction of the project.

G.5.a Establishing an Ignition Oven Correction Factor..... ..... Laboratory Manual 1852 Appendix

On the first day of production, for each mixture type, establish an ignition oven correction factor from the produced mixture. The Department will also establish an ignition oven correction factor from the produced mixtures. Re-establish correction factors in accordance with the following:

(1) If using aggregate or RAP substitutions, or
(2) If at least three successive tolerance failures on the extracted asphalt content occur between the Department and the Contractor as defined by Table 2360-9, "Allowable Differences between Contractor and Department Test Results."

G.6 Production Testing Rates

G.6.a Start –Up

At the start of production, for the first 2,000 ton [1,800 tonne] of each mix type, perform testing at the following frequencies:

Table 2360-10 Production Start-Up Testing Rates			
Production Test	**Testing Rates**	**Laboratory Manual Method**	**Section**
Bulk Specific Gravity	1 test per 500 ton [450 tonne]	1806	2360.2.G.7.b
Maximum Specific Gravity	1 test per 500 ton [450 tonne]	1807	2360.2.G.7.c
Air Voids (calculated)	1 test per 500 ton [450 tonne]	1808	2360.2.G.7.d
Asphalt Content	1 test per 500 ton [450 tonne]	1853	2360.2.G.7.a
Add AC/Total AC Ratio (calculated)	1 test per 1,000 ton [900 tonne]	1853	2360.2.G.7.a
Adj. AFT (Calculated)	1 test per 500 ton [450 tonne]	1854	2360.2.E.6.b
Gradation	1 test per 500 ton [450 tonne]	1203	2360.2.G.7.f
Coarse Aggregate Angularity	1 test per 1,000 tons [900 tonne]	1214	2360.2.G.7.g
Fine Aggregate Angularity (FAA)	1 test per 1,000 ton [900 tonne]	1213	2360.2.G.7.h
Fines to Effective Asphalt Ratio (calculated)	1 test per 500 ton [450 tonne]	1203 and 1853	2360.2.G.7.f and 2360.2.G.7.a

G.6.b Production

After producing the first 2,000 ton [1,800 tonne] of each mix type test at the following frequencies:

Table 2360-11 Production Testing Rates			
Production Test	**Sampling and Testing Rates**	**Test Reference**	**Section**

Table 2360-11 Production Testing Rates			
Production Test	**Sampling and Testing Rates**	**Test Reference**	**Section**
Bulk Specific Gravity	Divide the planned production by 1,000. Round the number to the next higher whole number	Laboratory Manual 1806	2360.2.G.7.b
Maximum Specific Gravity	Divide the planned production by 1,000. Round the number to the next higher whole number.	Laboratory Manual 1807	2360.2.G.7.c
Air Voids (calculated)	Divide the planned production by 1,000. Round the number to the next higher whole number	Laboratory Manual 1808	2360.2.G.7.d
Asphalt Content	Divide the planned production by 1,000. Round the number to the next higher whole number	Laboratory Manual 1853	2360.2.G.7.a
Add AC/Total AC Ratio (calculated)	Divide the planned production by 2,000. Round the number to the next higher whole number	Laboratory Manual 1853	2360.2.G.7.a
Adj. AFT (Calculated)	Divide the planned production by 1,000. Round the number to the next higher whole number	Laboratory Manual 1854	2360.2.E.7.e
Gradation	1 gradation per 1,000 tons [900 tonne], or portion thereof (at least one per day)	Laboratory Manual 1203	2360.2.G.7.f

Table 2360-11 Production Testing Rates			
Production Test	**Sampling and Testing Rates**	**Test Reference**	**Section**
Coarse Aggregate Angularity	2 tests per day for at least 2 days, then 1 per day if CAA is met. If CAA >8% of requirement, 1 sample per day but test 1 per week.	Laboratory Manual 1214	2360.2.G.7.g
Fine Aggregate Angularity (FAA)	2 tests per day for at least 2 days, then 1 per day if FAA is met. If FAA >5% of requirement, 1 sample per day but test 1 per week.	Laboratory Manual 1213	2360.2.G.7.h
Fines to Effective Asphalt Ratio (calculated)	Divide the planned production by 1,000. Round the number to the next higher whole number.	Laboratory Manual 1203 and 1853	2360.2.G.7.f and 2360.2.G.7.a
TSR	As directed by the Engineer	Laboratory Manual 1213	2360.G.7.i
Aggregate Specific Gravity	As directed by the Engineer	Laboratory Manual 1204, 1205, and 1815	2360.G.7.j
Mixture Moisture Content	Daily unless otherwise required by the Engineer	Laboratory Manual 1805	2360.G.7.k
Asphalt Binder	Sample first load (each grade), then 1 per 250,000 gal sample size 1 qt [1,000,000 L]	Bituminous Manual 5-693.920	2360.G.7.l

G.7 Production Test

G.7.a Asphalt Binder Content

Use spot check for determination of asphalt binder content in virgin mixtures only. See the requirements of the Bituminous Manual.

Perform spotchecks if the Engineer does not require a computerized printout of the plant blending control system in accordance with 2360.2.G.8, "Documentation."

Perform at least one spotcheck per day per mixture blend to determine the new added asphalt binder.

Use an incinerator oven meeting the requirements of the Laboratory Manual Method 1853. Do not use the incinerator oven if the percentage of Class B material is greater than 50 percent within the composite blend, unless the Contractor determines a correction factor approved by the Engineer.

Perform chemical extraction meeting the requirements of Laboratory Manual Method 1851 or 1852.

Use the meter method for determination of asphalt binder content in virgin mixtures only. See the requirements of the Bituminous Manual.

G.7.b Gyratory Bulk Specific Gravity, G_{mb}

Use two specimens to determine gyratory bulk specific gravity meeting the requirements of Laboratory Manual Method 1806. Set gyratory to an internal angle of 1.16° ±0.02°.

G.7.c Maximum Specific Gravity, G_{mm}

Determine maximum specific gravity meeting the requirements of Laboratory Manual Method 1807.

G.7.d Air Voids – Individual and Isolated (Calculation)

Calculate the individual and isolated air voids meeting the requirements of Laboratory Manual Method 1808. Use the maximum mixture specific gravity and corresponding bulk specific gravity from a single test to calculate the isolated air voids. Use the maximum specific gravity moving average and the bulk specific gravity from a single test to calculate the individual air voids.

Compact gyratory design to N_{design} in accordance with Table 2360-7, "Mixture Requirements," for the specified traffic level.

G.7.e Adjusted Asphalt Film Thickness (AFT) (Calculation)

Calculate the Adj. AFT meeting the requirements of the Laboratory Manual Method 1854.

G.7.f Gradation – Blended Aggregate

Determine the gradation of blended aggregate sample, from an extracted bituminous mixture, meeting the requirements of Laboratory Manual Method 1203.

G.7.g Coarse Aggregate Angularity

Test the Coarse Aggregate Angularity (CAA) meeting the requirements of Laboratory Manual Method 1214 to determine the CAA on composite blend from aggregates used in production of hot mix asphalt. Ensure CAA test results meet the requirements in accordance with Table 3139-3, "Mixture Aggregate Requirements."

The Contractor may test mixtures containing virgin aggregates from composite belt samples. Test mixtures containing RAP from extracted aggregates taken from standard production samples. Test the percentage of fractured faces of the composite aggregate blend less than 100 percent twice a day for each mixture blend for at least two days, then one test per day if the test samples meet the CAA requirements. If the CAA crushing test results are greater than 8 percent of the requirements, take one sample per day and perform one test per week.

Report CAA results on the test summary sheet. The Department may reduce payment in accordance with Table 2360-15, "Reduced Payment Schedule for Individual Test Results," for mixture placed and represented by results below the minimum requirement in accordance with Table 3139-3, "Mixture Aggregate Requirements." The Department will calculate tonnage subjected to reduced payment as the tons placed from the sample point of the failing test to the sampling point where the test result meets the specifications.

G.7.h Fine Aggregate Angularity

Use Laboratory Manual Method 1813 to test the composite blend from aggregates used in production of asphalt mixtures for Fine Aggregate Angularity (FAA) meeting the requirements of Table 3139-3, "Mixture Aggregate Requirements." The Contractor may test mixtures that contain virgin aggregates from composite belt samples. Test mixtures that contain RAP from extracted aggregates taken from standard production samples. Perform two tests per day for each mixture blend for at least two days to test the percentage of uncompacted voids from the composite aggregate blend, then one test per day if the samples meet FAA requirements. If FAA test results are greater than 5 percent of the requirement, take one sample per day and one test per week.

Report FAA results on the test summary sheet. The Department may reduce payment in accordance with Table 2360-16, "Reduced Payment Schedule for Individual Test Results," for mixture placed and represented by results below the minimums in accordance with Table 3139-3, "Mixture Aggregate Requirements." The Department will calculate tonnage subjected to reduced payment as the tons placed from the sample point of the failing test to the sampling point where the test result meets the specifications.

G.7.i Field Tensile Strength Ratio (TSR) .....Laboratory Manual Method 1813

If the Engineer requires sampling and testing of the mixture to verify tensile strength ratio (TSR), both the Contractor and the Department will be required to test these samples within 72 h after sampling. The Contractor shall obtain a sample weighing at least 110 lb [50 kg] and split the sample in half to provide a sample for the Department and the Contractor. Label the Department companion of this split with the following information:

Date,
Time,
Project number, and
Cumulative tonnage to date.

After the sample is split and labeled, give the Department's companion sample to the Department Street Inspector or Plant Monitor or to the Materials Engineer within 24 h of sampling as directed by the Engineer. Take mixture samples from behind the paver unless the Engineer approves an alternate sampling location. Provide a 6 in [150 mm] specimen for gyratory design. The Contractor may test the sample at a permanent lab site or a field lab site.

When using Option 2, obtain the sample within the first 5,000 ton [4,500 tonne] of plant mixed asphalt produced or by the second day of production, whichever comes first, to verify tensile strength ratio (TSR).

Refer to Table 2360-12, "Mixture Type, Minimum TSR," for the minimum acceptable TSR values for production. Stop production immediately if the material does not meet minimum TSR requirements. Do not resume production until after adding anti-strip to the asphalt binder. Determine the responsible party for the cost of the anti-strip in accordance with the Department and Contractor TSR values in Table 2360-13, "Anti-Strip Cost Responsibility." If the Department is responsible for the cost of the anti-strip, the Department will only pay for the cost of the anti-strip for mixtures placed on that project. The Department will not pay for delay costs associated with making changes related to this testing.

Table 2360-12
Mixture Type, Minimum TSR

Traffic Level 2 – 3, %		**Traffic Level 4 – 5, %**	
Contractor	**Mn/DOT**	**Contractor**	**Mn/DOT**
75	65	80	70

Table 2360-13 Anti-Strip Cost Responsibility			
Gyratory Level	**Contractor TSR**	**Mn/DOT TSR**	**Responsibility**
2 – 3	≥ 75	≥ 65	No anti-strip required
		< 65	Contractor
	< 75	≥ 65	Department
		< 65	Contractor
4 – 5	≥ 80	≥ 70	No anti-strip required
		< 70	Contractor
	< 80	≥ 70	Department
		< 70	Contractor

Take another sample and test within the first 500 ton [450 tonne] after production resumes. Stop production if the re-test fails to meet the minimum specified value. Discuss a proposal to resolve the problem with the Engineer before resuming production. Do not operate below the specified minimum TSR if at least 2 successive tests fail the TSR requirements.

A new sample and retest is automatically required if a proportion changes by greater than 10 percent from the currently produced mixture for a single stockpile aggregate or the Engineer directs the Contractor to sample and retest.

G.7.j Aggregate Specific Gravity(Gsb) .... Laboratory Manual Methods 1204, 1205, 1815

Sample and test aggregate stockpiles to verify aggregate specific gravity if directed by the Engineer in conjunction with the District Materials Engineer. Provide 90 lb [40 kg] representative stockpile samples for each aggregate component. Split samples in half to provide material for both the Department and the Contractor. Label the Department companion with the following information:

(1) Date,
(2) Time,
(3) Project number, and
(4) Approximate cumulative tonnage to date.

Give the Department companion to the Department Street Inspector or Plant Monitor immediately after splitting or to the Materials Engineer within 24 h of sampling as directed by the Engineer. The Materials Engineer will compare the aggregate specific gravity results to the Contractor's values on the current Mix Design Report. If the results deviate beyond the tolerance in accordance with Table 2360-16, "Allowable Differences between Contractor and Department Test Results," the Materials Engineer will notify the Contractor and issue a new Mix Design Report with

the current specific gravity results. Base new mixture placed after receiving notification of new specific gravity values on the Department results. The Engineer will notify the Contractor regarding new specific gravity values. The dispute resolution procedure for aggregate specific gravity is on file in the Bituminous Office.

G.7.k Moisture Content.....Laboratory Manual Method 1855

Provide a mixture with moisture content no greater than 0.3 percent. Measure moisture content in the mixture behind the paver or with an alternate approved sampling method on file in the Bituminous Office. Sample and test on a daily basis unless otherwise directed by the Engineer. Store the sample in an airtight container. Do not perform microwave testing.

Do not provide plant mixed asphalt with a moisture content greater than 0.3 percent.

G.7.l Asphalt Binder Samples

Sample the first shipment of each type of asphalt binder, then sample at a rate of one per 250,000 gal [1,000,000 L]. Provide a 1 qt [1.0 L] sized sample. Take samples meeting the requirements of the Bituminous Manual, 5-693.920. The Inspector will monitor the sampling the Contractor performs. Record sample information on an Asphalt Sample Identification Card. Submit the sample to the Materials Laboratory. Contact the Department Chemical Laboratory Director for disposition of failing asphalt binder samples.

G.8 Documentation

Maintain documentation, including test summary sheets and control charts, on an ongoing basis. Maintain a file of gyratory specimen heights for gyratory compacted samples and test worksheets. File reports, records, and diaries developed during the work as directed by the Engineer. These documents become the property of the Department.

Number test results in accordance with the MDR and record on forms approved and provided by the Department.

Send production test results on test summary sheets to the District Materials Laboratory and to other sites as directed by the Engineer by 11 AM of the day following production by facsimile, or e-mail when approved by the Engineer.

Include the following production test results and mixture information on the Department approved test summary sheet:

(1) Percent passing on all sieves in accordance with Table 3139-2 (including No. 16, No. 30, No. 50, No. 100),

(2) Coarse and fine aggregate crushing,
(3) Maximum specific gravity ($G_{mm.}$),
(4) Bulk specific gravity (G_{mb}),
(5) Percent total asphalt binder content (P_b),
(6) New added asphalt binder content,
(7) Ratio of percent new added asphalt binder to total asphalt binder,
(8) Calculated production air voids (V_a),
(9) Calculated adjusted AFT (Adj. AFT),
(10) Composite aggregate specific gravity (G_{sb}) reflecting current proportions,
(11) Aggregate proportions in use at the time of sampling,
(12) Tons where sampled,
(13) Tons represented by a test and cumulative tons produced,
(14) Fines to effective asphalt ratio (F/A_e),
(15) Signature Line for Mn/DOT and Contractor Representative,
(16) Mixture Moisture Content, and
(17) Mn/DOT verification sample test result.

Submit copies of failing test results to the Engineer on a daily basis.

Provide the Engineer with asphalt manifests or bill of lading's (BOL) on a daily basis.

Provide a daily plant diary, including a description of QC actions taken. Include changes or adjustments on the test summary sheets.

Provide weekly truck scale spot checks.

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

At the completion of bituminous operations on the project, provide the Engineer with a final hardcopy and electronic copy of QC test summary sheets and control charts, and density worksheets.

Provide an automated weigh scale and computer generated weigh ticket. Ensure the ticket indicates the following information:

(1) Project number,
(2) Mix designation, including binder grade,
(3) Mixture Design Report number,
(4) Truck identification and tare,
(5) Net mass, and
(6) Date and time of loading.

Do not include deviations from the minimum information on the computer generated weigh ticket unless otherwise approved by the Engineer in writing.

Continue test summary sheets, charts, and records for a mixture produced at one plant site from contract to contract. Begin new summary sheets and charts annually for winter carry-over projects. Begin new summary sheets and charts when an asphalt plant is re-setup in the same location after it has moved out.

Provide a computerized printout from an automated plant blending control system within 15 min of sampling the mixture from the roadway. Generate a printout corresponding to each QC/QA sample. The Engineer may waive this requirement if the plant does not have the capability to produce the automated blending control information. If the Engineer waives the requirement, perform daily spotchecks to determine percent new asphalt added. Include the following information on the plant control printout:

(1) Both the virgin and RAP belt feed rates and calibration numbers (SPAN numbers),
(2) Liquid asphalt meter readings, AC% and calibration numbers (SPAN number),
(3) Low project number for the contract,
(4) Mixture designation code,
(5) Date and time stamp, and
(6) Current tons of mixture produced and daily cumulative tons of mixture produced at time of printout.

G.9 Control Charts

Provide control charts and summary sheets computer generated from software approved by the Engineer. The Contractor may use software available at the Bituminous Office. Record the following data on standardized control charts:

(1) Blended aggregate gradation, include sieves in accordance with Table 3139-2, "Aggregate Gradation Broad Bands," for specified mixture;
(2) Percent asphalt binder content (P_b);
(3) Maximum specific gravity (G_{mm});
(4) Production air voids (V_a); and
(5) Adj. AFT.

Unless otherwise directed by the Engineer, plot individual test results for each test point and connect individual points with a solid line. Plot the moving average for each test variable starting with the fourth test and connect with a dashed line. Plot the Department's QA and verification test results with triangles. Plot the specification JMF limits on the control charts using a dotted line.

G.10 JMF Limits

Base the production air voids and Adj. AFT on the minimum specified requirements in accordance with Table 2360-7, "Mixture Requirements." Base gradations and asphalt binder content limits on the current Department reviewed Mixture Design Report. Provide gradation control sieves in accordance with Table 3139-2, "Aggregate Gradation Broad Bands." Refer to the Mixture Design Report for the mixture production targets. JMF limits are the target plus or minus the limits in accordance with Table 2360-14, "JMF Limits (N=4)." Use JMF limits as the criteria for acceptance of materials based on the moving average.

Table 2360-14
JMF Limits (N=4)

Item	JMF Limits
Adj. AFT	- 0.5
Production air voids, *%*	± 1.0
Asphalt binder content, *%*	- 0.4
Sieve, *% passing:*	
1 in [25.0 mm], ¾ in [19.0 mm], ½ in [12.5 mm], ⅜ in [9.5 mm], No. 4 [4.75 mm]	Broad band limits
No. 8 [2.36 mm]	Broad band limits
No. 200 [0.075 mm]	Broad band limits

G.11 Moving Average Calculation

Calculate a moving average as the average of the last four test results. Continue the calculation without interruption, except begin new summary sheets and charts annually for winter carry-over projects and if an asphalt plant is re-setup in the same site after it has been moved out.

G.12 JMF Bands

JMF Bands are the area between the target, as identified on the MDR, and the JMF limits.

G.13 JMF Adjustment

Begin mixture production with materials within 5 percent of the design proportions and other mixture parameters within the JMF limits in accordance with Table 2360-14, "JMF Limits (N=4)" for gradation, asphalt content, and aggregate proportions meeting the requirements of the reviewed MDR. Use all aggregate proportions meeting the requirements of the Mixture Design Report unless the aggregate proportion is 0 percent. The Engineer may waive this requirement if the Contractor provides the District Materials Laboratory with prior documented production data showing how production affects the mixture properties or if the

Contractor provides the District Materials Laboratory with a written justification or explanation of material changes since the original mixture submittal.

G.13.a JMF Request for Adjustment

The Contractor may make a request to the Bituminous Engineer or District Materials Engineer for a JMF adjustment to the mix design if the QC test results indicate a necessary change to achieve the specified properties. Do not use aggregates or materials not part of the original mix design to make adjustments unless otherwise approved by the Engineer, in conjunction with the District Materials Engineer or the Bituminous Engineer.

A Certified Level II Bituminous QM Mix Designer will review the requested change for the Department. If the request meets the design requirements in Table 3139-2, "Aggregate Gradation Broad Bands," Table 313-3, "Mixture Aggregate Requirements," and Table 2360-7, "Mixture Requirements," the Department will issue a revised Mixture Design Report. Each trial mixture design submittal in accordance with 2360.2.E, "Mixture Design," may have three JMF adjustments per mixture per project without charge. The Department will charge the Contractor $500 for each additional JMF adjustment requests.

Perform an interactive process with the Engineer before making JMF adjustments. Make JMF adjustments only within the mixture specification gradation design broad bands in accordance with Table 3139-2, "Aggregate Gradation Broad Bands." Submit a new JMF if redesigning the mixture. Only reduce the JMF asphalt content if at least the last four Adj. AFT production test calculations average at least 8.5 µ or more, and have an Individual Adjusted AFT of at least 7.5 µ.

The Department will not allow consecutive requests for a JMF adjustment without production data. Continue calculation of the moving average after the approval of the JMF.

G.13.b JMF Request for Adjustment for Proportion Change > 10%

If requesting a JMF adjustment for a proportion change greater than 10 percent from the currently produced mixture for a single stockpile aggregate, provide supporting production test data from at least four tests run at an accelerated testing rate of one test per 500 ton [450 tonne] with the adjustment request. The Department will base acceptable verification and approval of the requested JMF on individual and moving average test results in addition to the requirements listed above. Individual test results must be within twice the requested JMF limits for percent asphalt binder, production air voids, and Adj. AFT. Individual gradations must be within the Broad Bands. The moving average values must be within the control limits in accordance

with Table 2360-14. Continue to calculate the moving average after the change in proportions.

If the mixture meets the specified quality indicators, the District Materials Laboratory will sign the request for JMF adjustment effective from the point of the proportion change. If the mixture fails to meet the quality indicators, the Department will either reduce the payment or direct the Contractor to remove and replace. Do not make consecutive requests for JMF adjustments without production data.

G.14 Failing Materials

The Department will base material acceptance on individual and moving average test results. The Department will use isolated test results for acceptance of air voids at the start of mixture production. The Department will consider individual test results greater than two times the JMF bands as failing. The Department will fail moving average test results greater than the JMF limits. Begin new summary sheets annually for winter carry-over projects.

Stop production and make adjustments if the moving average values exceed the JMF limits. Restart production after performing the adjustments and notifying the Engineer. Resume testing at the accelerated rates and for the tests listed in Table 2360-10, "Production Start-Up Testing Rates," for the next 2,000 ton [1,800 tonne] of mixture produced. Continue calculating the moving average after the stop in production.

The Department will consider mixture produced where the moving average of four exceeds the JMF limits as unsatisfactory in accordance with 2360.2.G.14.d, "Moving Average Failure at Mixture Start-Up – Production Air Voids," 2360.2.G.14.e, "Moving Average Failure at Mixture Start-Up — Adjusted AFT," 2360.2.G.14.f, "Moving Average Failure - Production Air Voids," and 2360.2.G.14.g, "Moving Average Failure — Percent Asphalt Binder Content, Gradation, and Adj. AFT."

If the total production of a mixture type for the entire project requires no greater than four tests the Department will accept the material in accordance with 2360.2.G.14.b, "Isolated Failures at Mixture Start-Up — Production Air Voids," and 2360.2.G.14.c, "Individual Failure — Gradation, Percent Asphalt Binder, Production Air Voids, and Adj. AFT."

If the Contractor's testing data fails to meet the tolerances in accordance with Table 2360-9, "Allowable Differences between Contractor and Department Test Results," the Department will substitute QA and verification data to determine the payment factor.

G.14.a Ratio of New Added Asphalt Binder to Total Asphalt Binder — Acceptance Criteria

Add asphalt binder to total asphalt binder to provide a design ratio of at least 70 percent. During production, ensure the ratio meets the individual and moving average requirements in accordance with Table 2360-15,"Ratio of New Added Asphalt Binder to Total Asphalt Binder Acceptance Criteria." If the individual or moving average ratio drops below the minimum requirement, stop production and correct the process. Restart production after notifying the Engineer of the adjustments. Conduct two spot checks within the next 1,000 ton [907 tonne] of mixture produced to verify the ratio. Continue to calculate the moving average after the stop in production.

Table 2360-15
Ratio of New Added Asphalt Binder to Total Asphalt Binder Acceptance Criteria

Individual Ratio	Moving Average Ratio
≥ 66%	≥ 70%

G.14.b Isolated Failures at Mixture Start-Up – Production Air Voids

At the start-up of mixture production, use the first three isolated test results for production air voids before establishing a moving average of four. Calculate isolated production air voids using the maximum mixture specific gravity and the corresponding bulk specific gravity from that single test. After testing four samples and establishing a moving average of four, the Department will base acceptance on individual and moving average production air voids.

The Department will not accept the material if any of the first three isolated test results for production air voids exceeds twice the JMF bands from the target listed on the Mixture Design Report at the start of production. The Department will reduce payment for unacceptable material in accordance with Table 2360-16, "Reduced Payment Schedule for Individual Test Results." The Department will calculate the quantity of unacceptable material on the tonnage placed from the sample point of the failing test to the sample point when the isolated test result is back within twice the JMF bands. If the failure occurs at the first test after the start of production, the Department will calculate the tonnage subject to reduced payment as described above, including the tonnage from the start of production.

If isolated air voids are no greater than 1.0 percent or greater than 7.0 percent, the Engineer will either reduce the payment or order the material removed and replaced at no additional cost to the Department. The Engineer may require the Contractor to test in-place mixture to better define the removal and replacement limits. The Engineer

may require the Contractor to test in-place mixture placed before the failing test result. If the Engineer reduces the payment, the Department will pay for the material at 50 percent of the contract unit price.

G.14.c Individual Failure – Gradation, Percent Asphalt Binder, Production Air Voids, and Adj. AFT

Table 2360-16
Reduced Payment Schedule for Individual Test Results

Item	**Pay Factor, % ***
Gradation	95
Coarse and fine aggregate crushing	90
Asphalt binder content	90
Production air voids, individual ‖ and isolated†	80

* Apply the lowest pay factor applies when using multiple reductions on a single test.

‖ Calculate individual air voids using the moving average maximum specific gravity and the bulk specific gravity from that single test.

† Calculate the isolated air voids from the maximum specific gravity and the bulk specific gravity from that single test. The Engineer will only use isolated void test results for acceptance for the first three tests after mixture production start-up.

The Department will not accept material with individual gradation tests greater than the JMF Broad Bands listed on the Mixture Design Report. The Department will reduce payment for unacceptable material in accordance with Table 2360-16, "Reduced Payment Schedule for Individual Test Results." The Department will reduce payment to all tonnage represented by the individual test.

If the individual test result for adjusted AFT is less than 7.5 μ, the Department may either reduce payment in accordance with Table 2360-17, "Reduced Payment Schedule for Individual Test Results, Adjusted AFT," or order the material removed and replaced represented by the individual test. This tonnage includes all material placed from the sample point of the failing test to the sample point when the test result meets specification requirements. If the failure occurs at the first test after the start of daily production, the Department will include the tonnage from the start of production that day with the tonnage subject to reduced payment or removal and replacement.

Table 2360-17 Reduced Payment Schedule for Individual Test Results, Adjusted AFT	
Individual Adjusted AFT, μ	**Pay Factor, %**
≥ 7.5	100
7.4 – 7.0	90
6.9 – 6.1	75
≤ 6.0	R&R*
* Remove and replace at no additional cost to the Department.	

The Department will not accept material if the individual tests for percent asphalt binder content or production air voids exceeds twice the JMF bands from the target listed on the Mix Design Report. The Department will reduce payment in accordance with Table 2360-16, "Reduced Payment Schedule for Individual Test Results." The Department will calculate the material subject to reduced payment as the material placed from the sample point of the failing test until the sample point when the test result is back within twice the JMF limits. If the failure occurs at the first test after the start of daily production, the Department will include tonnage from the start of production that day with the tonnage subjected to reduced payment.

The Department will not accept material if individual air voids are no greater than 1.0 percent or greater than 7.0 percent, Remove and replace unacceptable material at no additional cost to the Department as directed by the Engineer. Test in-place mixture to better define the area to be removed and replaced as directed by the Engineer. Test mixture placed before the failing test result as directed by the Engineer. The Department may reduce payment for unacceptable material at 50 percent of the relevant contract unit price.

G.14.d Moving Average Failure at Mixture Start-Up — Production Air Voids

If a moving average failure occurs within any of the first three moving average results after mixture start-up (tests 4, 5, 6), the Department will accept the mixture if the individual air void, corresponding to the moving average failure meets the JMF limits. The Department will not accept material if the individual air void fails to meet the JMF limit. The Department will reduce payment for unacceptable material unless the Engineer determines that the isolated air void corresponding to the individual air void meets the JMF limit. The Department will pay for unacceptable material at 70 percent of the relevant contract unit price. The Department will calculate the quantity of material subject to reduce payment as the tons placed from the sample point of the failing moving average result and corresponding individual air void beyond the JMF limit to the sampling point when the individual test result is back within the JMF limit. If the failure occurs at the first test after the start of daily production, the Department will include tonnage from the start of production that day with the tonnage subjected to reduced payment.

G.14.e Moving Average Failure at Mixture Start-Up — Adj. AFT

The Engineer will calculate the Moving Average (n=4) Adj. AFT during the sixth test after the beginning of mixture production of that specific mixture. The Engineer will include the individual results of calculations for tests No. 3, No. 4, No. 5, and No. 6 with this calculation.

G.14.f Moving Average Failure — Production Air Voids

A moving average production air void failure occurs when the individual production air void moving average of four exceeds the JMF limit. The Department will consider the mixture unacceptable and subject to reduced payment. The Department will pay for unacceptable mixture at 70 percent of the contract unit price. The Department will calculate the quantity of mixture subject to reduced payment as the tons placed from the sample point of all individual test results beyond the JMF limits, which contributed to the moving average value that exceeded the JMF limit, to the sampling point where the individual test result meets the JMF limits. If the failure occurs at the first test after the start of daily production, the Department will include the tonnage from the start of production that day with the tonnage subject to reduced payment.

Table 2360-18
Reduced Payment Schedule for Moving Average Test Results

Item	Pay Factor, % *
Gradation	90
Coarse and fine aggregate crushing	NA (individual failures only)
Adjusted AFT	80
Asphalt binder content	80
Production air voids	70

* Lowest Pay Factor applies when there are multiple reductions on a single test.

G.14.g Moving Average Failure - Percent Asphalt Binder Content, Gradation, and Adj. AFT

The Engineer will consider the mixture unacceptable and subject to reduced payment for mixture properties, including asphalt binder content and gradation, where the moving average of four exceeds the JMF limits. The Department may reduce payment for unacceptable mixture properties in accordance with Table 2360-18, "Reduced Payment Schedule for Moving Average Test Results." The Department will calculate the quantity of material subject to replacement or reduced payment as the tons placed from the sample point of all individual test results beyond the JMF limits, which contributed to the moving average value that exceeded the JMF limit, to the sampling point when the individual test result is back within the JMF limits. If the

failure occurs at the first test after the start of daily production, the Department will include the tonnage from the start of production that day with the tonnage subjected to reduced payment.

The Engineer will calculate the Moving Average (n=4) Adjusted AFT during the sixth test after the beginning of mixture production of that specific mixture. The Engineer will include the individual results of calculations for tests No. 3, No. 4, No. 5, and No. 6 with this calculation. The Department will consider material with the Moving Average (n=4) of the Adjusted AFT is less than 8.0 µ as unsatisfactory and will pay for the material at 80 percent of the relevant contract unit price. The Department will calculate the quantity of material subject to replacement or reduced payment as the tons placed from the sample point of all Individual Adjusted AFT results less than 8.0µ, which contributed to the Moving Average value that was less than 8.0µ, to the sample point where the Individual Adjusted AFT is at least 8.0µ. If the failure occurs at the first test after the start of daily production, the Department will include the tonnage from the start of production that day with the tonnage subject to reduced payment.

G.14.h Coarse and Fine Aggregate Crushing Failure

If any CAA or FAA test results do not meet the requirements specified in Table 3139-3, "Mixture Aggregate Requirements," the Department may reduce payment for the placed material in accordance with Table 2360-16, "Reduced Payment Schedule for Individual Test Results." The Department will calculate the quantity of material subject to reduced payment as the tons placed from the sample point of the failing test until the sampling point where the test result meets the specifications. If the failure occurs at the first test after the start of daily production, the Department will include the tonnage from the start of production that day with the tonnage subjected to reduced payment.

2360.3 CONSTRUCTION REQUIREMENTS

A Restrictions

A.1 Asphalt Release Agents

Do not use petroleum distillates to prevent adhesion of asphalt mixtures to surfaces of tools and equipment. Provide an asphalt release meeting the requirements of "Effect on Asphalt" as described in the most recent Asphalt Release Agent on file at the Mn/DOT Office of Environmental Services.

A.2 Edge Drop Off

When construction is under traffic, the requirements of 2221.3.E, "Construction Under Traffic," will apply.

A.3 Surge and Storage Bins

Store the asphalt mixture for no more than 18 h at storage facilities that prevent segregation of the mix and drainage of asphalt from the mix. Maintain the mixture within 9 °F [5 °C] of the temperature when discharged from the silo or mixer, and prevent excessive cooling or overheating.

A.4 Weather Limitations and Paving Date

Do not perform work within the roadway in the spring until removal of seasonal load restrictions on roads in the vicinity unless otherwise approved by the Engineer. Do not place asphalt mixtures when weather or roadbed conditions are unfavorable as determined by the Engineer.

Do not place asphalt pavement wearing course or final wearing course if using multiple wearing courses after October 15 north of an east-west line between Browns Valley and Holyoke, or after November 1 south of an east-west line between Browns Valley and Holyoke. The Engineer may waive these restrictions when:

(1) The Contractor is not placing asphalt mixture on the traveled portion of the roadway,
(2) The roadway involved is closed to traffic during the following winter, or
(3) The Engineer provides written direction to place the mixture.

B Equipment

B.1 Plant

B.1.a Segregation

Provide plant mixed asphalt from a plant capable of producing a uniform mix free of segregation.

B.1.b Scales

Test and calibrate scales in accordance with 1901, "Measurement of Quantities."

B.1.c Mineral Filler

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

B.1.d Storage Tanks

Provide storage tanks equipped to heat and maintain the material at the temperatures recommended by the certified asphalt supplier. Place the discharge end of the circulating line below the surface of the asphalt material. Provide agitation for modified asphalt as recommended by the supplier.

Provide an outage table or chart and measuring stick for each storage or working tank. Equip tanks with provisions to take asphalt binder material samples. After delivery of asphalt binder material to the project, do not heat the material at temperatures greater than 350 °F [175 °C]. Do not store modified asphalt at temperatures greater than the manufacturer's recommendation.

B.1.e Asphalt Binder Control

If proportioning asphalt binder material by volume, equip the plant with either a working tank or a metering system to determine asphalt binder content of the mixture.

Provide a working tank with a capacity from 1,000 gal to 2,000 gal [3,800 L to 7,600 L]. Calibrate and supply the working tank with a calibrated measuring stick. The Contractor may connect the tank to a mixing unit and use it only during spot check operations as long as it is available at all times. Return feedback to the working tank during spot check operations.

Provide a metering system with at least one approved asphalt binder flow meter and a asphalt binder pump. Connect the flow meter to the asphalt binder supply to measure and display only the asphalt binder being fed to the mixer unit. Position the meter readout for convenient observation. Provide a means to compare the flow meter readout with the calculated output of the asphalt binder pump. Provide a system to display that shows the accumulated asphalt binder quantity being delivered to the mixer in gallons [liters] or to the nearest 0.001 ton [0.001 tonne]. Calibrate and adjust the system to maintain an accuracy of ±1 percent error for each plant set-up before producing the mixture.

Provide an outage table or chart and measuring stick for each storage or working tank. Equip tanks with provisions to take asphalt binder material samples. After delivery of asphalt binder material to the project, do not heat the material at temperatures greater than 350 °F [175 °C]. Do not store modified asphalt at temperatures greater than the manufacturer's recommendation.

B.1.f Dryer

The Department will not allow unburned fuel in the mix.

B.1.g Temperature Control

Equip the plant with enough temperature sensors to ensure temperature control of the aggregate and asphalt binder.

B.2 Street Equipment

B.2.a Paver

Provide a paver capable of spreading and finishing to widths as shown on the plans and with an operational vibratory screed and automatic screed control to place mix without segregation.

Use an asphalt paver to place the mixture. When necessary, the Contractor may use a motor grader, as approved by the Engineer, to spread mixtures in areas that are inaccessible to a paver or when the quantity of mixture makes it impractical to place with a paver.

Use a shouldering machine to spread the mixture on shoulder surfacing and uniform width widening, when the placement width is too narrow for a paver.

Using a screed or strike-off assembly, produce a finished surface of the required evenness and texture without tearing, shoving, or gouging. For mainline paving, if the paving width is greater than the basic screed, auger and mainframe extensions, which meet manufacturer's recommendations for the paving width, are required unless otherwise directed by the Engineer. The Department will not allow strike-off only extension assemblies for mainline wearing course paving, unless the Engineer directs otherwise.

Equip all pavers with an approved automatic screed control. Sensor-operated devices need to include automatic controls that follow reference lines, or surfaces on one or both sides of the paver as required. Adjust the speed of the paver to produce the best results. A string line is only required if stated in the contract.

Spread all mixtures without segregation to the cross sections shown on the plans. The objective on the leveling layer is to secure a smooth base of uniform grade and cross section so that subsequent courses will be uniform in thickness. The Contractor may spread the leveling layer with a properly equipped paver or, when approved by the Engineer, a motor grader equipped with a leveling device or with other means for controlling the surface elevation of the leveling layer.

Place each course over the full width of the section under construction on each day's run, unless the Engineer directs otherwise.

B.2.b Trucks

Provide trucks with tight, clean, and smooth truck haul beds. Do not allow mixture to adhere to the truck beds. When directed by the Engineer, provide a cover that extends at least 1 ft [300 mm] over the truck bed sides and attach to tie-downs, if the truck is not equipped with a mechanical or automated covering system.

B.2.c Motor Graders

Use a motor grader with the following characteristics:

(1) Self-propelled,
(2) Equipped with pneumatic tires with a tread depth of no greater than ½ in [13 mm],
(3) Equipped with a moldboard blade that is at least 10 ft [3 m], and
(4) With a wheelbase of at least 15 ft [4.5 m].

B.2.d Distributor

Provide a distributor capable of uniformly applying material up to 15 ft [4.6 m] wide and equipped with the following:

(1) An accurate volume measuring device with tachometer,
(2) Pressure gauges,
(3) Thermometer for measuring temperatures of tank contents,
(4) Power-operated pump, and
(5) Full circulation spray bars with lateral and vertical adjustments.

B.2.e Rollers

Provide rollers capable of compacting each lift of asphalt to the density required in 2360.3.D, "Compaction."

B.2.e(1) Steel-Wheeled Rollers

Provide self-propelled steel wheeled compacting equipment weighing at least 8 ton [7.3 tonne]. If using vibratory rollers, provide rollers that produce 3,085 lbf per ft [45 kN per m] of width and a vibratory frequency of at least 2,400 vpm using the low amplitude setting. Provide a roller capable of reversing without backlash and equipped with spray attachments for moistening rollers on both sets of wheels.

B.2.e(2) Pneumatic Tired Rollers

Provide a roller with a compacting width of at least 5 ft [1.5 m] and a gross wheel load force of at least 3,000 lb [13 kN] per wheel for traffic level 2 and level 3 mixtures, 5,000 lb [22 kN] per wheel for traffic level 4 and level 5 mixtures, and, if using vibratory, at least 8 ton [7.3 tonne] total mass. Provide a roller with a tire arrangement that obtains full compaction over the full width with each pass of the roller.

B.2.e(3) Trench Rollers

Provide self-propelled trench rollers weighing at least 2,960 lb per foot [4,400 kg per meter] of width.

B.3 Tack Coat

Apply an asphalt tack coat to the existing asphalt or concrete surfaces, and to the surface of each course or lift constructed, except for the final course or lift, in accordance with 2357, "Bituminous Tack Coat." Allow emulsified asphalt tack coats to break, as indicated by a color change from brown to black, before placing subsequent lifts.

Apply the tack coat to contact surfaces of all fixed structures and the edge of the in-place mixture in all courses at transverse joints and longitudinal joints.

C Joints

C.1 Construction Joints

Compact joints to produce a neat, tightly bonded joint that meets surface tolerances in accordance with 2360.3.E, "Surface Requirements." Transverse and longitudinal joints are subject to the density requirement in accordance with 2360.3.D, "Compaction."

C.2 Transverse Joints

Construct a transverse joint, the full width of the paver, at right angles to the centerline when mixture placement operations are suspended. When work resumes, cut the end vertically for the full depth of the layer unless constructing a formed edge as approved by the Engineer.

C.3 Longitudinal Joint

Construct the longitudinal joint between strips and parallel to the pavement centerline. In multiple lift construction, construct the longitudinal joints between strips in each lift at least 6 in [150 mm] measured transversely from the longitudinal joints in the previously placed lift. If constructing a wearing course in an even number of strips, place one longitudinal joint on the centerline of the road. When constructing a wearing course in an odd number of strips, locate the centerline of one strip on the centerline of the road, provided that no joint is located in the wheel path area of a traffic lane. Align longitudinal joints in multiple lift construction over portland cement concrete pavements directly over the concrete pavement longitudinal joints as approved by the Engineer.

At longitudinal joints formed by placing multiple strips, ensure the adjoining surface is higher but does not exceed ⅛ in [3 mm], after final compaction of the previously placed strip. When constructing a strip adjoining a previously placed strip or a concrete pavement, remove to the longitudinal joint line, any fresh mixture that overlaps a previously placed strip or pavement before rolling.

D Compaction

After spreading each course, compact in accordance with the maximum density method in accordance with 2360.3.D.1, "Maximum Density," unless the ordinary compaction method is called for in the special provisions or as described in 2360.3.D.2, "Ordinary Compaction." Do not allow rollers to stand on the uncompacted mixture or newly rolled pavement with a surface temperature greater than 140 °F [60 °C]. Do not roll with steel-wheeled rollers if rolling produces aggregate that is crushed, cracked, or pulverized or causes displacement of the mixture.

To maintain a true surface, correct the following by removing and replacing the material in the defective areas as directed by the Engineer at no additional cost to the Department:

(1) Variations such as depressions or high areas, which may develop during rolling operations; and
(2) Lean, fat, or segregated areas.

When spreading mixtures with a motor grader, compact the mixture with pneumatic tired rollers simultaneously with the spreading operation.

D.1 Maximum Density

Compact the pavement to at least the minimum required maximum density values in accordance with Table 2360-19, "Required Minimum Lot Density (Mat)," and Table 2360-20, "Longitudinal Joint Density Requirement." Density evaluation will include compacted mat density and compacted longitudinal joint density. Density evaluation will not include longitudinal joint density on lifts with a 1 percent reduced density requirement.

Table 2360-19 Required Minimum Lot Density (Mat)				
			SP Shoulders* ‖	
	SP Wear Mixtures* ‖	SP Non-Wear Mixtures* ‖	Designed at 3% Voids	Designed at 4% voids
% Gmm	92	93	93	92

* Reduce the minimum by 1 percent on the first lift constructed over PCC pavements.

‖ Reduce the minimum by 1 percent for the first lift constructed on aggregate base (mainline and shoulder), reclaimed or cold in place recycled base courses and first lift of an overlay on roadway with a spring load restriction no greater than 7 ton [6.35 tonne], including shoulders.

Table 2360-20 Longitudinal Joint Density Requirement		
Location	Confined Edge of Mat *	Unconfined Edge of Mat ‖
Long joint wear and shoulder (4% air voids)	89	86.5
Long joint non-wear and shoulder (3% air voids)	90	87.5

* The Department defines "confined" as the edges of the placed mat abutting another mat, pavement surface, or curb and gutter.

‖ The Department defines "unconfined" or "unsupported" as no abutment on the side of the mat being placed with another mat or pavement surface.

D.1.a Shoulders Greater Than 6 ft [1.8 m]

Unless otherwise shown on the plans or required by the special provisions, compact shoulders wider than 6 ft [1.8 m] paved using the maximum density method. When shoulders are compacted by the maximum density method and are paved separately from the driving lane, or have a different required minimum density than the driving lane, delineate the lot tonnage placed on the shoulder in separate lots from the driving lanes for the day paving was conducted.

D.1.b Shoulders Equal to or Less Than 6 ft [1.8 m]

Unless otherwise shown on the plans or required by the special provisions, use the ordinary compaction method in accordance with 2360.3.D.2, "Ordinary Compaction," to compact a narrow shoulder no wider than 6 ft [1.8 m] paved in the same pass as a driving lane or paved separately. The Department will exclude mixture compacted

under ordinary compaction from lot density requirements and from incentive or disincentive payment.

When compacting a narrow shoulder using the maximum density method, compact to densities in accordance with Table 2360-19. If the minimum required density of the shoulder is different than the driving lane, delineate the tonnage placed on the shoulder in separate lots from the driving lane.

D.1.c Echelon Paving

The Department considers echelon paving, two pavers running next to each other in adjacent lanes, as separate operations.

D.1.d Determination

Calculate each individual lot's maximum density by averaging the results of the cores within the lot expressed as the percentage of the maximum specific gravity. Test fine graded mix in accordance with Laboratory Manual Method 1810. Test coarse graded mix in accordance with Laboratory Manual Method 1816 as directed by the Engineer. Determination of coarse or fine graded mixtures is based on the percentage of material passing the No. 8 [2.36 mm] sieve as defined in Table 2360-8.

Obtain the maximum specific gravity value for calculating the percentage density for the lot from the maximum gravity values taken from production tests during that day's paving. If the production tests during that day's paving result in only one or two maximum specific gravity values, use the moving average value at that test point. If production tests during that day's paving result in three or more maximum specific gravity values, use the average of those tests alone as indicated above.

D.1.e Timeline

Complete compaction within 8 h of mixture placement and before obtaining core samples. Only use pneumatic tired or static steel rollers for compaction performed 6 h and 8 h after mixture placement. Do not reroll compacted mixtures with deficient densities.

D.1.f Stop Production

If all of the lots produced in a day or greater than 50 percent of the lots produced in multiple days fail to meet the minimum density requirement, stop production, determine the source of the problem, and take corrective action to bring the work into compliance with specified minimum required density.

D.1.g Lot Determination

Table 2360-21
Lot Determination

Daily Production, *ton [tonne]*	Lots
300* – 600 [270* – 545]	1
601 – 1,000 [546 – 910]	2
1,001 – 1,600 [911 – 1,455]	3
1,601 – 2,600 [1,456 – 2,360]	4
2,601 – 4,600 [2,361 – 4,175]	5
> 4,600 [4,175]	‖

* If producing no greater than 300 ton [270 tonne] of mix, establish the first lot when the total weight is greater than 300 ton [270 tonne].

‖ Add one lot for each additional 900 ton [820 tonne] or part of.

D.1.h Mat Density Cores

Obtain four cores in each lot. Take two cores from random locations as directed by the Engineer. Take the third and fourth cores, the companion cores, within 1 ft [0.3 m] longitudinally from the first two cores. Submit the companion cores to the Engineer immediately after coring and sawing. If the random core location falls on a longitudinal joint, cut the core with the outer edge of the core barrel 1 ft [0.3 m] away laterally from the edge of the top of the mat. Do not take cores for compacted mat density within 1 ft [300 mm] of any longitudinal joint. The Contractor is responsible for maintaining traffic, coring, patching the core holes, and sawing the cores to the paved lift thickness before density testing.

The Engineer may require additional density lots to isolate areas affected by equipment malfunction, heavy rain, or other factors affecting normal compaction operations.

D.1.i Contractor Core Testing

Take and test cores at least 4 in [100 mm] in diameter at locations determined and marked by the Engineer.

Mark samples with the lot number and core number or letter. Transport the cores to the laboratory daily to prevent damage. Schedule the approximate time of testing during normal project work hours to allow the Engineer to observe the test and to record the saturated surface dry and immersed weight of the cores.

Determine the density by the end of the next working day after compaction. Measure each core three times for thickness before saw cutting. Report the average lift thickness on the core sheet. If placing multiple layers in a single day, saw and separate cores for each layer, test, and report by the end of the next working day. Place and compact mix into the coring hole to restore the surface within 24 h after coring or the Department will fine the Contractor $100 per working day per lot until restored.

D.1.j Companion Core Testing

The Department will select at least one of the two companion cores per lot to test for verification. For lots designated as longitudinal joint density lots, the Department will test at least one of the mat density companion cores and at least one of the longitudinal joint density companion cores.

D.1.k Tolerance Comparison

D.1.k(1) Tolerance Comparison – Individual

Compare the individual core bulk specific gravities obtained by the Contractor and by the Department. If the bulk specific gravities differ by greater than 0.030, use the Department's bulk specific gravity.

D.1.k(2) Tolerance Comparison – Day's Shrinking Tolerance

For a second comparison of the cores that pass the individual tolerance criteria, compare the average of the Contractor's bulk specific gravities with the average of the Department's bulk specific gravities. Determine the tolerance by dividing 0.030 by the square root of the number of samples compared. Use all the Department's results for the day's paving if the cores do not fall within the determined tolerance.

D.1.l Re-coring

The Engineer may allow the Contractor to re-core a sample if the sample was damaged in the coring process or damaged in transit to the laboratory through no fault of the Contractor.

D.1.m One Percent Reduced Density

The Department will exclude incentive payments for reduced minimum density in accordance with Table 2360-19, "Required Minimum Lot Density (Mat)." The Contractor may request the Engineer to waive the reduced density requirement and reevaluate the density in accordance with Table 2360-19, "Required Minimum Lot Density (Mat)," including incentives, for all cases except the first lift constructed over concrete pavement. Make the request and obtain approval from the Engineer after the first day's paving and before beginning the third day of paving. If the Engineer

approves the request, the normal maximum density will remain in effect for the duration of mixture placement on that lift. The Contractor shall comply with any construction requirements on subsequent lifts.

D.1.n Longitudinal Joint Density

Evaluate longitudinal joint density in one lot per day unless the total daily weight is greater than 5,000 ton [5,000 tonne]. If the total daily weight is greater than 5,000 ton [5,000 tonne], evaluate two lots per day. Randomly select the location to take cores for longitudinal joint density from the mat density core locations. Take six cores at this location. Take cores for longitudinal joint density with the outer edge of the core barrel within 6 in [150 mm] from the edge of the top of the mat for both sides of the mat. Take a companion core 1 ft [0.3 m] longitudinally from each core. Take two cores for mat density at either 2 ft [0.61 m] right or 2 ft [0.61 m] left of the center of the mat the Contractor is paving, regardless of random number generation.

D.1.o Imaginary Joint

An actual longitudinal joint will not exist if pulling the shoulder and driving lane in the same paving pass. Do not cut a core on the imaginary line where a joint would have existed had the shoulder and the drive lane been paved separately.

D.1.p Shoulders

D.1.p(1) Shoulder – Ordinary Compaction

If compacting the shoulder under the ordinary density specification, do not take longitudinal joint cores in shoulders. Core at the centerline longitudinal edge cores (6 in [150 mm] from the joint) and at the mat density cores (2 ft [0.61 m] right or left of the center of the paving pass).

D.1.p(2) Shoulder-Maximum Density Specification

Core at the following locations:

(1) Centerline longitudinal edge cores (6 in [150 mm] from the joint),
(2) Mat density cores (2 ft [0.61 m] right or left of the center of the paving pass), and
(3) Edge of the shoulder (6 in [150 mm] from the outside edge).

Do not cut cores on the imaginary line at the edge of the shoulder adjacent to the driving lane. Move coring locations on imaginary lines to 6 in [150 mm] inside the edge of the shoulder.

D.1.q Payment Schedule

Table 2360-22
Payment Schedule for Maximum Mat Density

SP Wear and SP Shield (4% Void) Density, %*	SP Non-Wear and SP Shoulders (3% Void), Density, %*	Mat Density Pay Factor A	
		Traffic Level 2 & 3	Traffic Level 4 & 5
≥ 93.6	≥ 94.6	1.03 ‖	1.05 ‖
93.1 – 93.5	94.1 – 94.5	1.02 ‖	1.04 ‖
92.0 – 93.0	93.0 – 94.0	1.00	1.00
91.0 – 91.9	92.0 – 92.9	0.98	0.98
90.5 – 90.9	91.5 – 91.9	0.95	0.95
90.0 – 90.4	91.0 – 91.4	0.91	0.91
89.5 – 89.9	90.5 – 90.9	0.85	0.85
89.0 – 89.4	90.0 – 90.4	0.70	0.70
< 89.0	< 90.0	†	†

* Calculate the percent of maximum specific gravity to the nearest tenth.

‖ Payment will only apply if the day's weighted average individual production air voids fall within - ½ percent of the target air void value. Base the weighted average air voids on all the mixture production tests in accordance with 2360.2.G.7, "Production Tests" for the corresponding day and weight by the tons the corresponding test represents.

† The Department will pay for the HMA material represented by the lot at 70 percent of the relevant contract unit price, unless a single core density is less than 87.0 percent of the maximum specific gravity (G_{mm}). If a single core density is less than 87.0 percent of Gmm, the Engineer will decide if the mixture is subject to removal and replacement or reduced payment at 50 percent of the relevant contract unit price. If the Engineer decides the material needs to be removed and replace, the Contractor will remove and replace the material at no additional cost to the Department. Use additional core samples to determine the limits of the removal and replacement area. Take additional core samples at the same offset from centerline as the original core. If the original low density core was taken within 1½ ft [0.45 m] of an edge of the paver pass, take additional cores at 1½ ft [0.45 m from the edge of the paver pass. Determine the densities at 50 ft [15 m] intervals both ahead and behind the point of unacceptable core density until finding a point of acceptable core density. If the incremental core density testing extends into a previously accepted lot, remove the unacceptable material. Do not use to the test results to recalculate the previously accepted lot density. Perform additional coring and testing for unacceptable core density at no additional cost to the Department. The Department will calculate the area of unacceptable pavement as the product of the longitudinal limits as determined by the 50 ft [15 m] cores and the full width of the paver pass, laying in the traffic

Table 2360-22 Payment Schedule for Maximum Mat Density			
SP Wear and SP Shield (4% Void) Density, %*	SP Non-Wear and SP Shoulders (3% Void), Density, %*	Mat Density Pay Factor A	
		Traffic Level 2 & 3	Traffic Level 4 & 5

lane or lanes. The Department will exempt shoulders from this calculation unless density failure occurred in the shoulder area.

After removing and replacing the unacceptable material, determine the density of the replacement material by averaging the two cores. The Department will pay for the replacement material in accordance with Table 2360-22 or Table 2360-23. The Department will not pay for material removed. The Department will pay for the remainder of the original lot at 70 percent of the relevant contract unit price.

Table 2360-23* 1 Percent Reduced Table		
SP Wear and SP Shield (4% Void) Maximum Specific Gravity, %‖	SP Non-Wear, and SP Shield (3% Void), Maximum Specific Gravity, %‖	Payment, %
≥ 91.0	≥ 92.0	100
90.0 – 90.9	91.0 – 91.9	98
89.7 – 89.9	90.5 – 90.9	95
89.4 – 89.6	90.0 – 90.4	91
89.2 – 89.3	89.5 – 89.9	85
89.0 – 89.1	89.0 – 89.4	70
< 89.0†	< 89.0	†

* Reduce the minimum by 1 percent for the first lift constructed on aggregate base (mainline and shoulder), reclaimed or cold inplace recycled base courses and first lift of an overlay on a roadway with a spring load restriction (including shoulders) no greater than 7 ton [6.35 tonne]. Reduce the minimum reduced by 1 percent on the first lift constructed on PCC pavements. The Engineer will not waive the reduced density requirement.

‖ Calculate the percent of maximum specific gravity to the nearest tenth.

† The Department will pay for the HMA material represented by the lot at 70 percent of the relevant contract unit price, unless a single core density is less than 87.0 percent of the maximum specific gravity (G_{mm}). If a single core density is less than 87.0 percent of Gmm, the Engineer will decide if the mixture is subject to removal and replacement or reduced payment at 50 percent of the relevant contract unit price. If the Engineer decides the material needs to be removed and replace, the Contractor will remove and replace the material at no additional cost to the Department. Use additional core samples to determine the limits of the removal and replacement area. Take additional core samples at the

Table 2360-23* 1 Percent Reduced Table		
SP Wear and SP Shield (4% Void) Maximum Specific Gravity, %	**SP Non-Wear, and SP Shield (3% Void), Maximum Specific Gravity, %**	**Payment, %**
same offset from centerline as the original core. If the original low density core was taken within 1½ ft [0.45 m] of an edge of the paver pass, take additional cores at 1½ ft [0.45 m from the edge of the paver pass. Determine the densities at 50 ft [15 m] intervals both ahead and behind the point of unacceptable core density until finding a point of acceptable core density. If the incremental core density testing extends into a previously accepted lot, remove the unacceptable material. Do not use to the test results to recalculate the previously accepted lot density. Perform additional coring and testing for unacceptable core density at no additional cost to the Department. The Department will calculate the area of unacceptable pavement as the product of the longitudinal limits as determined by the 50 ft [15 m] cores and the full width of the paver pass, laying in the traffic lane or lanes. The Department will exempt shoulders from this calculation unless density failure occurred in the shoulder area. After removing and replacing the unacceptable material, determine the density of the replacement material by averaging the two cores. The Department will pay for the replacement material in accordance with Table 2360-21 or Table 2360-22. The Department will not pay for material removed. The Department will pay for the remainder of the original lot at 70 percent of the relevant contract unit price.		

Table 2360-24*
Payment Schedule for Longitudinal Joint Density
(SP Non-wear and SP Shoulders, 4% Void)

	Pay Factor B Longitudinal (Confined Edge)			Pay Factor C (Unsupported Edge)	
Longitudinal Joint (Confined Edge) Density, %‖	**Traffic Level 2 & 3**	**Traffic Level 4 & 5**	**Longitudinal Joint (Unsupported Edge) Density, %‖**	**Traffic Level 2 & 3**	**Traffic Level 4 & 5**
≥ 92.1	1.02†	1.03†	≥ 91.0	1.02†	1.03†
91.6 – 92.0	1.01†	1.02†	90.1 – 90.9	1.01†	1.02†
89.5 – 91.5	1.00	1.00	88.1 – 90.0	1.00	1.00
88.5 – 89.4	0.98	0.98	87.0 – 88.0	0.98	0.98
87.7 – 88.4	0.95	0.95	86.0 – 86.9	0.95	0.95
87.0 – 87.6	0.91	0.91	85.0 – 85.9	0.91	0.91
< 87.0	0.85	0.85	< 85.0	0.85	0.85

* The Department will limit incentive payment for longitudinal joint density to lots with evaluated longitudinal joint densities.

‖ Calculate the percent of maximum specific gravity to the nearest tenth.

† Payment will only apply if the day's weighted average individual production air voids fall within - ½ percent of the target air void value. Base the weighted average air voids on all the mixture production tests in accordance with 2360.2.G.7, "Production Tests," for the corresponding day and weight by the tons the corresponding test represents.

Table 2360-25*
Payment Schedule for Longitudinal Joint Density
(SP Non-wear and SP Shoulders, 3% Void)

	Pay Factor B Longitudinal (Confined Edge)			Pay Factor C (Unsupported Edge)	
Longitudinal Joint (Confined Edge) Density, % ‖	**Traffic Level 2 & 3**	**Traffic Level 4 & 5**	**Longitudinal Joint (Unsupported Edge) Density, % ‖**	**Traffic Level 2 & 3**	**Traffic Level 4 & 5**
≥ 93.1	1.02†	1.03†	≥ 92.0	1.02†	1.03†
92.6 – 93.0	1.01†	1.02†	91.1 – 91.9	1.01†	1.02†
90.5 – 92.5	1.00	1.00	89.1 – 91.0	1.00	1.00
89.5 – 90.4	0.98	0.98	88.0 – 89.0	0.98	0.98
88.7 – 89.4	0.95	0.95	87.0 – 87.9	0.95	0.95
88.0 – 88.6	0.91	0.91	86.0 – 86.9	0.91	0.91
< 88.5	0.85	0.85	< 86.0	0.70	0.85

* The Department will limit incentive payment for longitudinal joint density to lots with evaluated longitudinal joint densities.

‖ Calculate the percent of maximum specific gravity to the nearest tenth.

† Payment will only apply if the day's weighted average individual production air voids fall within ½ percent of the target air void value. Base the weighted average air voids on all the mixture production tests in accordance with 2360.2.G.7, "Production Test," for the corresponding day and weight by the tons the corresponding test represents.

D.1.r Pay Factor Determination

Determine the pay factor in accordance with the following:

(1) Case 1: Total Pay Factor = (Pay Factor A) × (Pay Factor B) × (Pay Factor C)
(2) Case 2: Total Pay Factor = (Pay Factor A) × (Pay Factor B) × (Pay Factor B)
(3) Case 3: Total Pay Factor = (Pay Factor A) × (Pay Factor C) × (Pay Factor C)

Where:

Pay Factor A = Mat density,
Pay Factor B = Confined edge density,
Pay Factor C = Unsupported edge density.

Use a pay factor of 1.00 for Pay Factor B, Pay Factor C, or both in lots where no cores are taken at the longitudinal joint.

D.2 Ordinary Compaction

Perform ordinary compaction for the following:

(1) Layers identified in the typical sections with a minimum planned thickness less than 1½ in [40 mm],
(2) Thin lift leveling,
(3) Wedging layers,
(4) Patching layers,
(5) Driveways, and
(6) Areas the Contractor cannot compact with standard highway construction equipment.

If using the ordinary compaction method to evaluate density, use a control strip to establish a rolling pattern. Use the rolling pattern to compact the asphalt mixture for the layer on which the control strip is constructed or until constructing a new control strip. The Engineer may waive the control strip requirement in small localized areas or other areas not conducive to its establishment.

D.2.a Control Strip

Construct a control strip at least 395 sq. yd [330 sq. m] and of the same thickness as the lift the control strip represents at the beginning of the work on each lift of each course. Begin compacting immediately after spreading the mixture. Continue compacting until additional roller coverage does not produce appreciable increase in density. Determine densities by means of a portable nuclear testing device or approved alternate and create a growth curve to determine the optimum rolling pattern. Provide documentation of the growth curve to the Engineer. Roll the remainder of that course in accordance with the pattern developed in the test strip for that roller. Provide a new control strip in accordance with the following:

(1) If using a new JMF with a proportion change greater than 10 percent when compared to the currently produced mixture for a single stockpile aggregate,
(2) If changing the source of either aggregate or binder, or
(3) After 10 days of production.

D.2.b Equipment

Use rollers that meet the requirements in 2360.3.B.2.e, "Rollers." Use the same equipment type and weight on the remainder of the pavement course that was used to construct the control strip. Provide at least two rollers. Provide a tandem steel wheeled roller for final rolling. The Contractor may use trench rollers or mechanical tampers to compact areas inaccessible to the conventional type rolling equipment.

D.2.c Mixture Temperature

Refer to Table 2360-26, "Mixture Temperature Control" for the minimum laydown temperatures in all courses of the asphalt mixture as measured behind the paver or spreading machine. Do not pave when the air temperature is less than 32 °F [0 °C] unless otherwise directed by the Engineer in writing.

Table 2360-26*
Mixture Temperature Control

Air Temperature, *°F [°C]*	**Compacted Mat Thickness, †**			
	1 in [25 mm]	**1½ in [40 mm]**	**2 in [50 mm]**	**≥3 in [75 mm]**
32 – 40 [0 – 5]	—	265[129] ‖	255 [124]	250 [121]
41 – 50 [6 – 10]	270 [130] ‖	260 [127]	250 [121]	245 [118]
51 – 60 [11 – 15]	260 [127] ‖	255 [124]	245 [118]	240 [115]
61 – 70 [16 – 21]	250 [121] ‖	245 [118]	240 [115]	235 [113]
71 – 80 [22 – 27]	245 [118]	240 [115]	235 [113]	235 [113]
81 – 90 [28 – 32]	235 [113]	230 [110]	230 [110]	230 [110]
≥ 91 [33]	230 [110]	230 [110]	230 [110]	225 [107]

* Not applicable if using a Warm Mix Asphalt (WMA) additive or process.
‖ Use at least one pneumatic-tire roller for intermediate rolling unless otherwise directed by the Engineer. The Engineer may specify or modify the minimum laydown temperature in writing.
† Based on the lift thicknesses shown on the plans.

E Surface Requirements

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

Table 2360-27 Surface Requirements		
Course/Location	**Description**	**Tolerance**
Leveling/1st lift using automatics	Tolerance also applies to 1st lift placed other than leveling when automatics are used.	½ in [15 mm]
Wear	Tolerance of final 2 lifts from the edge of a 10 ft [3 m] straightedge laid parallel to or at right angles to the centerline.	¼ in [6 mm]
Shoulder Wear, Temporary Wear and bypasses	Tolerance from the edge of a 10 ft [3 m] straightedge laid parallel to or at right angles to the centerline.	¼ in [6 mm]
Transverse joints/construction joints	Tolerance from the edge of a 10 ft [3 m] straightedge centered longitudinally across the transverse joint. Correction by diamond grinding required when directed by the Engineer.	¼ in [6 mm]
Transverse Slope	Tolerance for surface of each lift exclusive of final shoulder wear.	Not to vary by more than 0.4% from plans.
Distance from edge of each lift and established centerline.	No less than the plan distance or more than 3 in [75 mm] greater than the plan distance. The edge alignment of the wearing lift on tangent sections and on curve sections of no greater than 3° cannot deviate from the established alignment by more than 1 in [25 mm] in any 2 ft [7.5 m] section.	See Description
Final wear adjacent to concrete pavements.	After compaction the final lift wear adjacent to concrete pavements must be slightly higher but not to exceed ¼ in [6mm] than the concrete surface.	See Description

Table 2360-27 Surface Requirements		
Course/Location	**Description**	**Tolerance**
Final wear adjacent to fixed structures.	After compaction the final lift wear adjacent to gutters, manholes, pavement headers, or other fixed structures must be slightly higher but no greater than ¼ in [6mm] than the surface of the structure.	See Description
Finished surface of each lift.	Must be free of segregated and open and torn sections and deleterious material.	See Description

Cut or saw and then remove and replace material placed outside the described limitations at no additional cost to the Department. If the Engineer determines the material can remain in place outside the limits, the Department will pay for the material at a reduced cost of $10 per sq. yd [$12 per sq. m]. The Department will consider any single occurrence of material outside the limitations to have a minimum dimension of at least 1 sq. yd [1 sq. m] in any dimension.

Ensure the pavement surface also meets the requirements of 2399, "Pavement Surface Smoothness."

E.1 Lift Thickness

After compaction, the thickness of each lift shall be within a tolerance of ¼ in [6 mm] of the thickness shown on the plans, except that, if automatic grade controls are used, this thickness requirement will not apply to the first lift placed. This thickness requirement will not apply to a leveling lift whether or not automatic grade controls are required. Remove and replace any part of any lift that is constructed to less than the minimum required thickness as directed by the Engineer and at no additional cost to the Department.

Measure cores taken for density determination for thickness also. Measure each core three times for thickness before sawing. Report the average of these three measurements. Document each lot's average core thickness and submit to the Engineer. If the average of the two Contractor cores exceeds the specified tolerance, an additional two cores may be taken in the lot in question. The Engineer will use the average of all core thickness measurements per day per lift to determine daily compliance with thickness specifications.

On that portion of any lift constructed to more than the maximum permissible thickness, the materials used in the excess mixture above that required to construct that portion of the lift to the plan thickness plus ¼ in [6 mm] may be excluded from

the pay quantities and at the discretion of the Engineer and at the Contractor's expense may be required to be removed and replaced.

F Asphalt Mixture Production (FOB Department Trucks)

Produce asphalt mixture for the Department. Load the mixture being produced onto 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 required not less than 2 weeks prior to completion of the final wearing course. The Engineer will not accept the asphalt mixture if it is unsuitable for the intended use.

G Small Quantity Paving

The Department will not require an MDR for planned project quantities less than 9,000 sq. yd per in of thickness [191,200 sq. m per mm] or 500 ton [450 tonne]. Verify in writing that the asphalt mixture delivered to the project meets the requirements of Table 3139-3 and Table 2360-7, "Mixture Requirements." The Department will obtain samples, as determined by the Engineer, to verify mixture requirements and to perform material acceptance in accordance with 2360.2.G14.b, "Isolated Failures at Mixture Start-Up — Production Air Voids," 2360.2.G.14.c, "Individual Failure — Gradation, Percent Asphalt Binder, Production Air Voids, and Adj. AFT," and 2360.2.G.14.h, "Coarse and Fine Aggregate Crushing Failure."

2360.4 METHOD OF MEASUREMENT

When paying for material by weight, the Engineer will measure separately asphalt mixture of each type by weight based on the total quantity of material hauled from the mixing plant. The Engineer will not make deductions for the asphalt materials.

When paying for material by area, the Engineer will separately measure asphalt mixture of each type and for each specific lift by area and by thickness on the basis of actual final dimensions placed.

2360.5 BASIS OF PAYMENT

The contract unit price for asphalt mixture used in each course includes the cost of constructing the asphalt surfacing and providing and incorporating asphalt binder, mineral filler, hydrated lime. The contract unit price for asphalt mixture used in each course may also include the cost of anti-stripping additives as permitted or required in accordance with 2360.2.C, "Additives."

The Department will pay for additives required by the contract at the relevant contract unit price for the mixture. The Department will pay for additives

incorporated as directed by the Engineer as extra work in accordance with 1402, "Contract Revisions."

The Department will apply reduced payment if the mixture includes steel slag as one of the aggregate proportions and the production lab density at the design gyrations at the recommended or established asphalt content is greater than 160 lb per cu. ft [2,565 kg per cu. m]. The Department will pay for the mixture at the contract unit price, calculated as follows:

$$\%Payment = \frac{100 - (100 \times (production\_density\_at\_design\_gyrations - 160)}{160}$$

$$\left[\%Payment = \frac{100 - (100 \times (production\_density\_at\_design\_gyrations - 2{,}565)}{2{,}565}\right]$$

If the plans do not show a contract pay item for shoulder surfacing and other special construction, the Department will include payment for the quantities of material used for these purposes in the payment for the wearing course materials.

Complete yield checks and monitor thickness determinations to construct the work as shown on the plans. Use the tolerances for lift thickness in accordance with 2360.3.E, "Surface Requirements" and surface smoothness requirements in accordance with 2399, "Pavement Surface Smoothness," for occasional variations and not for continuous over-running or under-running, unless otherwise required by the Engineer.

The contract unit price for asphalt mixture production includes the cost of the material and loading onto Department-provided trucks at the mixing plant.

The Department will pay for plant mixed asphalt pavement on the basis of the following schedule:

Item No.:	Item:	Unit:
2360.501	Type SP* Wearing Course Mixture †‡	ton [metric ton]
2360.502	Type SP* Non-Wearing Course Mixture †‡	ton [metric ton]
2360.503	Type SP*‖ Course Mixture †‡# in [mm] thick,	square yard [square meter]
2360.504	Type SP*‖ Course Mixture †‡	square yard [square meter]
2360.505	Type SP * Bituminous Mixture for Specified Purpose	ton [metric ton]
2360.506	Type SP * Bituminous Mixture Production	ton [metric ton]

* Aggregate size Designation, 9.5, 12.5 or 19 as appropriate, see item (3) in 2360.1.A, "Mixture Designations."
‖ "Wearing" or "Non Wearing" as appropriate.
† Traffic level in accordance with Table 2360-1, "Traffic Levels."
‡ AC binder grade designation (Table 2360-2).
# Lift thickness shown on the plans.

2399 PAVEMENT SURFACE SMOOTHNESS

2399.1 DESCRIPTION

This work consists of measuring the smoothness of the final concrete or bituminous surface.

A Definitions

The Department defines "smoothness" as the composite International Roughness Index (IRI) value per 0.1 mi [0.1609 km] segment. The Department defines "areas of localized roughness" (ALR) as areas greater than or equal to the limiting criteria for a continuous IRI calculation with a 25 ft [7.62 m] interval, as calculated using the FHWA's Profile Viewing and Analysis (ProVAL) software.

2399.2 MATERIAL REQUIREMENTS

A Inertial Profiler (IP)

Provide a Department certified, calibrated, and documented IP meeting the requirements of ASTM E 950, Class 1 and procedures maintained by the Mn/DOT Pavement Engineering Section. Refer to the procedures maintained by the Mn/DOT Pavement Engineering Section or to the Mn/DOT Smoothness website for the required settings for individual certified profilers.

Provide an IP capable of producing a profilogram and exporting raw profile data in an unfiltered electronic Engineering Research Division (ERD) file format. Produce

ERD filenames in the YYMMDD-T-N-D-L-W-S.ERD standardized format in accordance with Table 2399-1:

Table 2399-1
Electronic ERD File Standardized Naming Convention

Abbreviation	Definition
YY	Two-digit year
MM	Month (include leading zeros)
DD	Day of month (include leading zeros)
T	Route type (I, MN, US, CSAH, etc.)
N	Route number (no leading zeros) and auxiliary ID (if applicable, for example E, W, etc.)
D	Primary route direction (I or D)
L	Lane number (1 for driving lane, increasing by one for each lane to the left)
W	Wheel path (L, R, or B, indicating Left, Right, or Both)
S	Beginning station

B Profile Analysis Software

Use ProVAL software to conduct a profile analysis to determine smoothness and areas of localized roughness. Report IRI values in units of in per mi to one digit right of the decimal [m per km to two digits right of the decimal] in accordance with conventional rounding procedures.

C Operator Certification

Provide an operator, trained in the operation of the particular IP in accordance with 2399.2.A, "Inertial Profiler", and knowledgeable in the use of the required profile analysis software in accordance with 2399.2.B, "Profile Analysis Software." Ensure profiler operators pass a proficiency test and possess a current certification issued by the Department. The Contractor may access a list of certified operators on the Mn/DOT Smoothness website. Provide documentation of operator certification to the Engineer.

D Submittals

D.1 Before Profiling

Provide the Engineer with current, valid documentation, issued by the Department, indicating the inertial profiling equipment certification and the operator's certification.

D.2 Day of Profiling

Submit a printout containing the inertial profiler's settings, each segment's IRI values, and the signature of the operator to the Engineer on the same day of the profiling.

Submit electronic files in ERD format representing the raw data from each pass on the same day of the profiling.

If the Contractor fails to submit actual data to the Engineer on the day of profiling, the Department will require the Contractor to reprofile the measured segments.

D.3 Upon Completion of Pavement Placement

Within 5 calendar days after all pavement placement and before beginning corrective work, submit a paper ProVAL summary report for each lane, indicating the results of the "Ride Quality" and "Smoothness Assurance" analyses. Use the ERD filenames in accordance with 2399.2.A, "Inertial Profiler" to create ProVAL summary reports.

If the summary reports indicate no areas of localized roughness, submit a final spreadsheet summary in accordance with 2399.2.D.5, "After Corrective Work."

D.4 Before Corrective Work

If the summary reports indicate any areas of localized roughness, submit a written corrective work plan to the Engineer in accordance with 2399.3.E, "Corrective Work." Include the beginning and ending points of locations planned for correction in the corrective work plan. Do not begin corrective work before the Engineer approves the plan.

If the Engineer elects to assess a monetary deduction for areas of localized roughness in accordance with Table 2399-7 instead of requiring corrective work, submit a final spreadsheet summary in accordance with 2399.2.D.5, "After Corrective Work."

D.5 After Corrective Work

After reprofiling, submit a paper summary ProVAL report for each lane, indicating the results of updated "Ride Quality" and "Smoothness Assurance" analyses to the Engineer. Submit a spreadsheet summary in tabular form, with each 0.1 mi [0.1609 km] segment occupying a row to the Engineer. The Contractor may access an acceptable spreadsheet summary template in electronic form on the Mn/DOT Smoothness website.

2399.3 CONSTRUCTION REQUIREMENTS

Using an IP, measure the final mainline and other pavement surfaces for IRI in areas with a posted vehicle speed of 30 mph [48 km/hr] or greater unless otherwise excluded in Table 2399-3.

Unless otherwise approved by the Engineer, perform all smoothness testing in the presence of the Engineer. Mutually agree on a schedule for smoothness testing with the Engineer. Rerun tests performed in the absence of the Engineer as directed by the Engineer at no additional cost the Department.

The Engineer will use a 10 ft [3.05 m] straightedge to evaluate areas excluded from surface testing with the IP in accordance with Table 2399-3.

A Pavement Surface Testing

Remove objects and foreign material from the pavement surface before performing the pavement surface evaluation. Provide traffic control required for testing and performing corrective work on the final pavement surface.

Run the IP in the direction of traffic. Measure profiles in the left and right wheel paths of each lane.

Test and evaluate each lane separately. The Engineer will determine the length in miles [kilometers] of each mainline traffic lane. Operate the IP at the optimum speed as recommended by the manufacturer.

Separate each lane into segments 0.1 mi [0.1609 km] in length. Evaluate the remainder segment less than 0.1 mi [0.1609 km] in each lane as an independent segment. The Engineer will prorate pay adjustments for length.

Make each pass continuously, regardless of length, and end passes before exclusions in accordance with Table 2399-3, "Areas Excluded from Smoothness and ALR Evaluation." Begin each subsequent pass 50 ft [15.24 m] before and including, construction headers and end-of-day work joints. In concrete pavements, evaluate terminal headers tying into existing portland cement concrete pavement.

For percent improvement projects, measure the smoothness before the beginning of construction and after the completion of construction. Use the same stationing for the final smoothness measurement as the stationing used for the initial smoothness measurement, to allow for a direct comparison when calculating the percent improvement. Measure the initial IRI and the final IRI with the same IP.

The Engineer will use a 10 ft [3.05 m] straightedge to measure for surface deviations greater than ¼ in [6 mm] in 10 ft [3.05 m]. The Engineer will evaluate

transverse joints by centering the straightedge longitudinally across the transverse joint.

B Exclusions

Table 2399-2 indicates areas that are excluded from smoothness evaluation, but still require measurement with an IP, and are subject to evaluation for areas of localized roughness and the 10 ft [3.05 m] straightedge. Table 2399-3 indicates areas that are excluded from surface testing with the IP, but are subject to evaluation with the 10 ft [3.05 m] straightedge

Table 2399-2 **Areas Excluded from Smoothness Evaluation**
For All Pavements
Paving in areas with a posted vehicle speed less than or equal to 45 mph [73 km/hr]
Ramps, loops, acceleration and deceleration lanes less than or equal to 1,000 ft [304.8 m] in length
Projects less than 1,000 ft [304.8 m] in length
For Bituminous Pavements
Single lift overlays over concrete

Table 2399-3 **Areas Excluded from Smoothness and ALR Evaluation**
For All Pavements
Turn lanes, crossovers
10 ft [3.05 m] on either side of obstructions in lane that obstruction is located
Intersections where mainline profiles are merged or blended into the cross street profile – begin and end exclusion 100 ft [30.48 m] from the intersection radius
Side streets, side connections
Junctions between pavement and bridge approach panels, junctions between pavement and bridges
For Bituminous Pavements
Paved shoulders
For Concrete Pavements
Undoweled shoulders less than 10 ft [3.05 m] in width
Headers adjacent to colored concrete

C Calculations

C.1 Smoothness

Obtain the IRI for the left and right wheel paths in an individual lane using the ProVAL "Ride Quality" analysis with the 250 mm filter. Calculate pavement smoothness for each lane by averaging the IRI for the left and right wheel paths in the lane. The Engineer will use the averaged results to determine pay adjustments.

For percent improvement projects, use the initial IRI and final IRI to calculate the percent ride improvement.

C.2 Areas of Localized Roughness

Identify ALR using the ProVAL "Smoothness Assurance" analysis, calculating IRI with a continuous short interval of 25 ft [7.62 m] with the 250 mm filter. Only use the right wheel path to determine ALR.

D Pay Adjustments

D.1 Smoothness

Evaluate smoothness requirements using the equations and criteria in accordance with the following tables:

(1) Table 2399-4 for bituminous pavements,
(2) Table 2399-5 for concrete pavements, and
(3) Table 2399-6 for percent improvement projects.

The Engineer will base pay adjustments on the segment IRI value (or percent improvement value, for percent improvement projects) measured at the completion of surface pavement, unless corrective work is required by the summary report results. If a segment is less than 100 ft [30.5 m] long and if Table 2399-4, Table 2399-5, or Table 2399-6 requires corrective work, the Engineer will waive the corrective work requirement for the segment and instead assess a prorated maximum disincentive. The Department will still subject the segment to ALR analysis in accordance with Table 2399-7

For segments requiring corrective work, reprofile the entire 0.1 mi [0.1609 km]segment after performing corrective work as directed by the Engineer and enter the reprofiled left and right wheel path IRI values into the final spreadsheet summary. Calculate the segment IRI value by averaging the IRI values calculated from the left and the right wheel path passes.

D.1.a Bituminous Pavements

The Engineer will use IRI Equation HMA-A for pavements with at least 3 layers, IRI Equation HMA-B for pavements with 2 layers, and IRI Equation HMA-C for single pavement layers.

Table 2399-4
Pay Adjustments for Bituminous Pavements

Equation	Composite IRI in/mi [m/km]	Pay Adjustment $/0.1 mi [0.1609 km]
HMA-A	< 30.0 [0.47]	400.00 [400.00]
	30.0 – 75.0 [0.47 – 1.18]	850.00 − 15.000 × IRI [850.00 − 957.450 × IRI]
	> 75.0 [1.18]	Corrective Work to ≤ 56.7 in/mi [0.89 m/km]
HMA-B	< 33.0 [0.52]	270.00 [270.00]
	33.0 – 85.0 [0.52 – 1.34]	600.00 − 10.000 × IRI [600.00 − 638.950 × IRI]
	> 85.0 [1.34]	Corrective Work to ≤ 60.0 in/mi [0.94 m/km]
HMA-C	< 36.0 [0.57]	180.00
	36.0 – 95.0 [0.57 – 1.50]	414.00 − 6.500 x IRI [414.00 − 410.500 x IRI]
	> 95.0 [1.50]	Corrective Work to ≤ 63.7 in/mi [1.01 m/km]

For bituminous projects, the Engineer will not pay a net incentive payment for smoothness if greater than 25 percent of all mainline density lots for the project fail to meet the minimum density requirements in accordance with 2360, "Plant-Mixed Asphalt Pavement."

D.1.b Concrete Pavements

For concrete pavements, the Engineer will use equation PCC-A. For concrete pavement rehabilitation projects or concrete grinding, the Engineer will use equation PCC-B if the contract requires pay adjustments for concrete grinding.

Table 2399-5 Pay Adjustments for Concrete Pavements		
Equation	**Composite IRI in/mi [m/km]**	**Pay Adjustment $/0.1 mi [0.1609 km]**
PCC-A	< 50.0 [0.79]	890.00 [890.00]
	50.0 – 90.0 [0.79 – 1.42]	2940.00 − 41.000 × IRI [2940.00 − 2597.800 × IRI]
	> 90.0 [1.42]	Corrective Work to ≤ 71.7 in/mi [1.13 m/km]
PCC-B	< 50.0 [0.79]	450.00 [450.00]
	50.0 – 71.2 [0.79 – 1.12]	1511.30 − 21.226 × IRI [1511.30 − 1344.900 × IRI]
	71.3 – 90.0 [1.13 – 1.42]	0.00
	> 90.0 [1.42]	Corrective Work to ≤ 71.3 in/mi [1.13 m/km]

D.1.c Percent Improvement Projects

The Engineer will base pay adjustments on the number of segments and the percent improvement values. The Engineer will not require corrective work and will not assess a negative pay adjustment if the initial segment IRI value is less than 60.0 in per mi [0.95 m per km] and the percent improvement is greater than zero. The Engineer will calculate the percent improvement in accordance with the following equation:

$$\%I = \left(\frac{InitialSegmentIRI - FinalSegmentIRI}{InitialSegmentIRI} \right) \times 100$$

Determine the Initial Segment IRI before patching or other repair. Determine the Final Segment IRI after the completion of paving.

Table 2399-6 Pay Adjustments for Percent Improvement Projects		
Equation	**Percent Improvement (%I)**	**Pay Adjustment, per $/0.1 mi [$/0.1609 km] segment**
PI-A	> 64.0	180.00
	15.0 to 64.0	−236.00 + 6.500 × (%I)
	< 15.0	Corrective work to %I of at least 36.3

For bituminous percent improvement projects, the Engineer will not pay a net incentive payment for smoothness if greater than 25.0 percent of all mainline density lots for the project fail to meet minimum density requirements in accordance with 2360, "Plant-Mixed Asphalt Pavement."

Correct segments with a percentage improvement of less than 15 percent at no additional cost to the Department as required by the Engineer.

D.2 Areas of Localized Roughness

The Engineer will evaluate areas of localized roughness (ALR) in accordance with Table 2399-7, "ALR Monetary Deductions and Corrective Work Requirements."

Table 2399-7
ALR Monetary Deductions and Corrective Work Requirements

Equation	25 ft [7.62 m] Continuous IRI, in/mi [m/km]	Corrective Work or Monetary Deduction, per linear 1.0 ft [0.3048 m]
HMA-A or HMA-B, and a posted vehicle speed > 45 mph [73 km/hr]	< 125.0 [1.97]	Acceptable
	≥ 125.0 [1.97] to < 175.0 [2.76]	Corrective work or $10.00, as directed by the Engineer
	≥ 175.0 [2.76] to < 250.0 [3.94]	Corrective work or $25.00, as directed by the Engineer
	≥ 250.0 [3.94]	Corrective work or $50.00, as directed by the Engineer
PCC-A or PCC-B, and a posted vehicle speed > 45 mph [73 km/hr]	< 125.0 [1.97]	Acceptable
	≥ 125.0 [1.97] to < 175.0 [2.76]	Corrective work or $10.00, as directed by the Engineer
	≥ 175.0 [2.76] to < 250.0 [3.94]	Corrective work or $25.00, as directed by the Engineer
	≥ 250.0 [3.94]	Corrective work as directed by Engineer
HMA-C, PI, ramps. loops, or any paving with a posted vehicle speed ≤ 45 mph [73 km/hr]	< 175.0 [2.76]	Acceptable
	≥ 175.0 [2.76] to < 250.0 [3.94]	$10.00
	≥ 250.0 [3.94]	$25.00

The Engineer will consider areas of localized roughness acceptable if the retested segment contains no areas of localized roughness. The Department will reduce payment for areas of localized roughness remaining after retesting as determined by the Engineer and in accordance with Table 2399-7, "ALR Monetary Deductions and Corrective Work Requirements."

D.3 Straightedge Evaluation

The Engineer will allow variations less than or equal to ¼ in [6 mm] within the span of the straightedge in the longitudinal or transverse direction to remain in place without correction or penalty.

The Engineer will require corrective work on surface deviations greater than ¼ in [6 mm] within the span of the straightedge in any direction. For corrected variations, the Engineer will accept deviations less than or equal to ¼ in [6 mm] within the span of a 10 ft [3.05 m] straightedge in any direction.

E Corrective Work

Notify the Engineer at least 24 hr before beginning corrective work. Do not begin corrective work before the Engineer approves the methods and procedures in writing.

Perform corrective work using a surface diamond grinding device consisting of multiple diamond blades, unless otherwise approved by the Engineer. Fog-seal diamond ground bituminous surfaces as required by the Engineer and at no additional cost to the Department. Repair and replace joint sealant damaged by diamond grinding on concrete pavement as directed by the Engineer and at no additional cost to the Department.

The Contractor may correct bituminous pavements by overlaying the area or replacing the area by milling and inlaying as approved by the Engineer. If milling and inlaying or overlaying, perform work in accordance with 2399, "Pavement Surface Smoothness," over the entire length of the correction. If milling and inlaying or overlaying, use a transverse saw cut to begin and end the surface correction.

Perform smoothness corrective work for ALR across the entire lane width. Maintain the pavement cross slope through corrective areas.

Perform coring to determine if diamond grinding corrective work results in thin pavements, as directed by the Engineer. Provide additional coring for thickness verification at no additional cost to the Department. The Department may reduce the payment for thin pavement sections after diamond grinding. Handle residue and excess water resulting from diamond grinding in accordance with 1717, "Air, Land, and Water Pollution."

Perform surface corrections before placing permanent pavement markings. Replace permanent pavement marking damaged or destroyed by corrective work at no additional cost to the Department.

Reprofile segments containing corrected areas with the same certified IP in accordance with 2399.2.A, "Inertial Profiler" within 5 calendar days after the completion of corrective work required by the Engineer.

F Retesting

Perform retesting as directed by the Engineer and within 30 days of the original profiling.

If the retested IRI values differ from the original IRI values by greater than 10 percent, the Engineer will use the retested values as the basis for acceptance and pay adjustments. If the retested values differ from the original values by greater than 10 percent, the Department will not pay for the cost of retesting.

If the retested IRI values differ by less than or equal to 10 percent of the original IRI values, the Engineer will use the original values. If the Engineer verifies the accuracy of the original results, the Department will pay for retesting as directed by the Engineer, except for retesting required after corrective work, at $100.00 per lane mi [$62.14 per lane km] retested or $500.00, whichever provides the greater amount.

2399.4 METHOD OF MEASUREMENT — (BLANK)

2399.5 BASIS OF PAYMENT

The Department will include the cost of the IP, testing, and traffic control in the relevant contract unit price for wearing course mixture for bituminous pavements, concrete pavement for concrete pavements, or for concrete grinding.